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PRESTON S. ARKWRIGHT

Preston S. Arkwright, forty-second president of the National Electric Light Association and president of the Georgia Power Company, is a native Georgian. He was born in Savannah, February 24, 1871. He prepared for college in the Savannah schools and was graduated from the University of Georgia in 1890 and from the law school of that University in 1891.

Soon after his graduation he began the practice of law in Atlanta. He entered public utility work in 1901, when he became vice-president of the Georgia Electric Light Company. In 1902, he was elected president of the Georgia Railway and Electric Company, and when the Georgia Railway and Power Company was formed in 1912, acquiring control of the Georgia Railway and Electric Company and other utility companies, Mr. Arkwright was elected president of the new company. This position he held until the Georgia Railway and Power Company consolidated with about twenty other public utility companies in Georgia to form the Georgia Power Company in 1927, Mr. Arkwright becoming president of the consolidated company. Formation of the new company followed the acquisition of control of the Georgia Railway and Power Company and a number of other Georgia utilities by the Southeastern Power and Light Company. These various Georgia companies were consolidated in the new company or are operated as subsidiaries, and together they supply electric service to approximately 235 cities and towns in Georgia. Street railway service is supplied to the larger cities.

Mr. Arkwright is chairman of the Public Policy Committee of the National Electric Light Association. He is also vice-president of the Association of Edison Illuminating Companies, and former president of the Southern Gas Association.

NATIONAL ELECTRIC LIGHT ASSOCIATION

PROCEEDINGS

VOLUME 86

52nd Convention

Atlantic City Auditorium and Convention Hall,
Atlantic City, New Jersey
June 3 to 7, 1929

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GENERAL SESSIONS

PROCEEDINGS

of the

Fifty-second Convention

NATIONAL ELECTRIC LIGHT ASSOCIATION

FIRST GENERAL SESSION

TUESDAY, JUNE 4, 1929

[The fifty-second Convention of the National Electric Light Association convened in the ballroom of the Atlantic City Auditorium and Convention Hall, Atlantic City, N. J., at 10.10 a.m., President P. S. Arkwright presiding.]

PRESIDENT ARKWRIGHT: The Convention will please come to order. The time of the meeting is limited. It begins later than usual, and I am anxious that it should start on time hereafter.

The representative of the Mayor is here. We have been to Atlantic City often and enjoyed the hospitality of the city, but we have never been welcomed into the city's own home before, as well as the city itself. We have the distinction of being the first guest in the city's house and home.

I present to you Bertram E. Whitman, the representative of the Mayor of Atlantic City, who will tell us how very welcome we are. Mr. Whitman! (Applause).

ADDRESS OF WELCOME

BY BERTRAM E. WHITMAN, *City Clerk*

His Honor, the Mayor of Atlantic City, because of another business engagement which took him from the city, found it impossible to be with you on this occasion, and he has requested me to come in his stead and to express his regrets.

As his representative I assure you that it is with no small amount of mingled pride and pleasure that I appear before you at this time in order to extend to you a sincere welcome to our city. I feel, however, that this is not at all necessary, due to the fact that on so many previous occasions you have been holding your annual gatherings in this city. And you know, without any words from me, that you are sincerely welcome, and how glad we are to have you in our midst.

However, it does seem a very pleasing coincidence that for the first time this great auditorium has been used for a purpose such as you are now using it that that distinction has fallen to your body. Just at this time, as you well know, we have completed the dedication of this wonderful auditorium. We are at the present time celebrating the seventy-fifth anniversary of the incorporation of our city, and at the same time there is being celebrated the fiftieth anniversary of the perfection of the incandescent light.

And so I say to you that it is a very happy situation to have you assembled in this great building and at this particular time, because it is to you men that the world owes the great advancement in the matter of the perfection of the electric light that we are now enjoying throughout the land.

I am reminded of a couple who came into our city not long ago to spend their honeymoon. They went to one of our large hotels, and the waiter seemed to be over-zealous in looking after their needs. Every once in a while he would go up to them and ask them if there was anything further he could do for them. The young man said, "No" repeatedly, and after a while he became a little annoyed at the waiter's persistence, and he said, "Yes, bring us an order of honeymoon salad."

The waiter goes back to the kitchen and gives the order. The chef is somewhat perplexed. Finally he calls the waiter and says, "Do you mind finding out what that honeymoon salad is?"

The waiter goes back to the young man, and he says, "Boss, pardon me, but will you kindly tell me what that honeymoon salad is?"

The young man said, "Yes, just let us alone." (Laughter).

And so, my friends, having performed the very pleasant duty for which I have come here this morning, it gives me great pleasure at this time to turn over to your President the key to our city, the queen of seashore resorts, the world's playground, and to assure you that it is our desire that your stay among us may be a most pleasant one, and that we will have the opportunity of welcoming you here to our city many, many more times.

And having concluded the duties for which I have come before you this morning, it gives me pleasure to turn over this key to the President of your organization, with the hope that you will make use of it. And if there is anything that the Mayor of the city or the officials can do to make your stay more pleasant, we sincerely hope that you will call upon us. And now I will let you alone in order that you may conduct the business for which you have assembled. I thank you.

[Tenders key of the city to President P. S. Arkwright (Applause).]

PRESIDENT ARKWRIGHT: I know we appreciate the very gracious words of welcome from Mr. Whitman. We are inclined to feel at home here; he has made us feel completely so. We will not abuse his hospitality, and we are very, very thankful to him for his kind words.

[Vice-Chairman J. F. Owens assumed the chair.]

ADDRESS OF PRESIDENT P. S. ARKWRIGHT

This convention can't help being good. It has the distinction of being the first convention of any kind to meet in the largest and best equipped auditorium in the world, just completed by the municipality of Atlantic City. This not only adds interest but provides conveniences, facilities and comforts never possessed before.

The exhibition hall, in commodiousness, arrangement, protection, accessibility, lighting, ventilation facilities and appointments, approaches perfection. The auditorium, while a credit to Atlantic City, will prove a joy to us.

The exhibition is in keeping with the electrical industry and the auditorium. The manufacturers and the Exhibition Committee have excelled themselves. It is the largest, most complete and most attractively displayed exhibition we have ever enjoyed. It excels any previous exhibition of any industry. Its value in education and interest to our membership is more than sufficient recompense for the entire cost in time and money devoted to holding and attending the convention.

The program has been arranged so as to provide adequate time for a close inspection and study of the exhibits. If, however, any of you should find that you cannot inspect the exhibits and attend the General Business Sessions, too, I recommend, nevertheless, that you do not fail to see the exhibits.

A Nation-Wide Tribute

This convention occurs in the year of the fiftieth anniversary of the electric incandescent lamp, and marks the beginning of the great nation-wide tribute to Thomas A. Edison and the observance of Light's Golden Jubilee. So useful a need did the electric incandescent lamp fill, that two and one-half billion of its fellows are in use today. But vastly improved are they—in appearance, in ruggedness, in longevity, in economy, in efficiency, in quality of light, and in adaptability for varied uses.

The improvements in the lamp, combined with the wonderful development of the electric industry following in its wake, have brought such great reduction in its price that its enjoyment is now within the reach of any pocket book. It is the cheapest light the world has ever had. Wherever available—and that means almost everywhere—electric light is now the universal artificial illuminant. If the only accomplishment of the electrical industry were the electric light alone, it would have more than justified itself. The value to the world and the customers of the industry of the lighting service by itself exceeds the total cost of all the electric service of all kinds and for all purposes.

But out of the lamp came the electrical industry, serving at first a limited area in the most congested section of our largest city, and through the ingenuity, initiative, courage and effort of men, growing by leaps and bounds through the short years, until we now have electric central stations with long distance transmission and interconnected systems and their distribution networks, supplying house-to-house electric service for lighting, heating and power purposes to over 23 million customers in the United States, in practically every city, town and hamlet. Within a few years of the very recent past electric service has been made available to approximately 500,000 farms and is now spreading to the others at an accelerating pace.

Almost every day brings new applications of the service, new devices to take the place of human drudgery, to lighten and brighten the work of living, to multiply the output of the factory and the earnings of the workman, and to take away the tasks of the home.

No wonder that all over the world the fiftieth anniversary of the birth of the electric incandescent lamp is celebrated!

To this association at this convention has come the privilege of inaugurating Light's Golden Jubilee. A day of the sessions has been set aside especially for appropriate recognition of the event. But the spirit of the occasion will be over all the sessions, stimulating and inspiring us to continued and greater effort to carry electric service over expanding areas to more and more people and to their even greater advantage, and to accept Mr. Edison's example of patience, persistence and whole-hearted devotion to an idea as the ideal of what the industry should strive for in its dealings with the public.

An Association of Independent Units

You have honored me to serve you during the year as President of the National Electric Light Association. I have had opportunity to more fully evaluate the work of the Association and to measure the contributions it makes to advancement in electrical progress. In spite of the apparent needlessness of saying it, I would like to emphasize that the National Electric Light Association is a voluntary association of separate, independent units. It does not operate, control, manage, construct, finance or share in the ownership of any electric light or power company. Nor has it any power or authority of direction, control, censorship or veto over the acts, conduct or utterances of any member of the Association. Its function is to accelerate, stimulate and coordinate effort in electrical progress. The objective of the Association is "to advance the art and science of the production, distribution and use of electrical energy for public service." This objective is followed with vigor and certainty of purpose. Through the Association the most advanced ideas, drawn from the practical field of experience of member companies in engineering, accounting, business methods and all the various aspects making up the business, are discovered and diffused.

The company members are not in direct competition with each other in the same field. Therefore, there cannot be and there is not any effort to fix prices of the product or to curtail production. There are no trade secrets between the utilities. On the contrary, the originator of a new idea or improvement finds recognition for his contribution by making it known to his co-workers through the Association.

The Result of Cooperation

The sum total of best abilities and best minds within the utilities is made available to member companies, large and small, in all sections of the country. Without the Association improvements found by one company would be isolated there; through the Association they find acceptance and prompt application throughout the entire country. Each company thus benefits from the progress of the others, and the public generally obtains the benefits of a progressive, improved electric service.

Of the recent forces in the economic structure of the nation, none has been more fundamental in advancing the living standards than mass production. Mass production of electric power is outstanding among these. We call it interconnection. I refer to the creation of the great interconnected electrical systems concentrating major power production in large, efficient power houses, then diffusing and subdividing this power as required for smallest or largest user, in city or hamlet, in the home, the factory, or on the farm. Our engineers, through the medium of the Association, years ago formulated and secured wide acceptance of standard voltages, frequencies and operating practices, thereby laying the essential background which made possible the interconnection of adjacent power systems. The Association rightfully deserves much credit for the rapidity and soundness with which the benefits of this far-reaching advance in power development have been brought to the American people.

Service Everywhere

There is today available in practically every quarter of the United States abundant and reliable supply of central station electric power at prices competing so successfully with the cost of power from other sources that the public often assumes that the utility companies have a complete monopoly of power supply. The total increase in power capacity in the nation's factories, mines and quarries since 1919, amounting to 9½ million horsepower, has been in electric motors. These industries had available to them alternative power sources, which they could themselves locally install. This growing reliance of the country's manufacture and mining upon electric utilities for their added power supplies is convincing evidence of the remarkable performance of these companies in provision of low cost, reliable power deliverable at almost any point in any quantity desired.

Advances in Power Production

The accomplishment of the almost revolutionary changes in the engineering, operating and economic characteristics of electric power supply, concurrently with need for large expansion in facilities, has thrown an enormous burden of work on our engineers. The best engineering policy and experience within the industry is engaged in interchanging ideas, compiling authoritative information and making this available to every company. Each company benefits from the judgment and experience of engineering talent which in the aggregate but few, singly, could afford to engage.

The major advances in the art of power production from the beginning of the electrical industry have come through that industry. Without these inventions and improvements, there could have been no large scale substitution of mechanical for hand labor. Let me briefly summarize these advances: The reciprocating engine was developed to its maximum size and efficiency; the steam turbine, known to Nero in 100 B.C., remained impractical until its combination with the high-speed electric generator, and is the major development in steam utilization in the last half century and now the world's principal prime-mover; hydro turbines and the whole conception of hydroelectric development have reached their furthest advance in the utilities. Running through all this path of progress may be found the work of the National Electric Light Association and its members in constant stimulation and diffusion of information on best practice.

Economical Generation and Transmission

The trend is toward larger and more efficient units for power production. Size of turbine and generating units has increased in ten years from 40,000 kw. to 208,000 kw. Single power houses are under construction to house 1,000,000 h.p. These huge power stations—the hearts of the electrical systems—are outstanding marvels of engineering accomplishment. Average quantity of fuel burned per kilowatt-hour in 1919 was 3.2 lb. Continued improvement in power house design and operation pushed this average consumption per kilowatt-hour to 1.76 lb. in 1928. The aggregate saving due to gains in efficiencies since 1919 amounts to 180 million tons.

The Association is directing aggressive attention to transmission and distribution, design, construction methods, operating and maintenance practice and safety rules, in both overhead and underground systems. High-voltage cables are under experimental research. Ways are being sought to more economically transmit the increased quantities of power in both overhead wires and underground cables, in spite of conditions increasingly difficult due to congestion. Marking and lighting of power structures within airways, power line crossings over railroads, coordination of the operation of our service with telephone, telegraph, train control and radio—all involving important relations with other public service—are enlisting your Association's consideration.

Our engineers have focused particular attention toward sound, advance planning of whole electrical systems, anticipating future requirements of the communities served and visualizing the step-by-step placement of power houses and transmission structures to adequately meet the power requirements of each locality at minimum cost. Because of this system planning, electric power facilities, taking the country as a whole, are located and constructed for maximum utilization, most economic operation and without wasteful duplication.

Research

Your Association, in behalf of its members, at the convention last year announced its participation along with other industries in the plans of the Pure Science Research Fund for a program in pure science research in the colleges and universities during the next ten years. Provision for our participation was made through increased dues, and the Association is now prepared to take its part in this movement as soon as plans are finally formulated by the National Research Council and the National Academy of Sciences.

Cooperation

There has been fuller cooperation between the various branches of the electrical industry in meeting common problems of electrical development. There has been decided progress in better understanding between the manufacturer, the contractor-dealer and all merchandisers of electrical equipment. Our visualization of the contributing factors in electrical development is expanding to properly embrace the whole group of some 700,000 men and women engaged in research, design, manufacture, construction, installation, management, operation and financing of this great development. The fine work of the National Electrical Manufacturers Association, the Association of Electragists, International, and the Society for Electrical Development, and their cooperation with the National Electric Light Association, have been contributing factors to this enlarged mutual understanding and direction of common effort toward fuller electrical development.

Accident Prevention

The association from its beginnings has continuously prepared and diffused information on safe methods of operation, improvements in design for safety, instruction in methods of resuscitation from shock—all designed to safeguard both life and property. As a result of the association's stimulus, thousands of executives and employees of the companies each year receive instruction. Savings in property loss and from reduction of time loss resulting from accidents are extremely large. A direct measure of the great human value of this useful endeavor is the award in seven years of Insull Medals to 264 persons for saving life.

Standardization

Most of us do not realize the enormous volume of work carried on by the association in connection with standardization, simplification, and codification. It is a decided factor in lowering cost and increasing facility in use of electric service. There is scarcely a piece of equipment apparatus or material used in rendering the service which is not involved; it likewise relates directly to our customers. This work could not be accomplished by any company acting individually; it requires expression of industry viewpoint at over 200 points of contact with national and international standardizing groups. The savings attained to the companies in reduced costs of equipment, reduction of inventories and facility in repairs amounts to millions of dollars annually. Practical uniformity in character of electric supply for voltage and frequency has been attained; attachments for lamps and appliances are the same throughout the nation effecting large reductions in cost of electrical equipment purchased by the consumer, and adding enormously to convenience. Particular attention has been given this year to increased participation in this work and to strengthening industry representation.

Community Development

The electric utility company prospers only as the individual community prospers. Our investments in facilities are an integral part of the thousands of communities we serve. If business is better elsewhere, we cannot pick up and move. Recognizing this, the association is assisting and urging its member companies to more actively participate in local community and State development. It develops information of value particularly to the small town in furthering industrial development.

Rural Service

Decided progress has been made in extension of electric service to farms, an increase of 30 per cent being credited to this year, which brings the total served to 500,000. It is perhaps the most significant accomplishment of the year. It is only well started. The National Electric Light Association has sponsored and stimulated this endeavor. In 1923 it initiated through the Committee on Relation of Electricity to Agriculture a nation-wide research program participated in by the farmers, agricultural engineers, agricultural colleges, electrical manufacturers, and utility companies, along with other agencies. Research in rural electrification continues in a number of State experimental projects, and a National Rural Research project is being established in Maryland. A vast body of practical information on adaptations of electricity to farm work has been developed and diffused. It aids the farmer in visualization of benefits of electric service to him; it stimulates us to greater effort in overcoming problems of extension of our service to him. The same intensive effort which successfully accomplished electrification of manufacturing industries is now being turned to the most important of all our industries—agriculture. The association has this year sponsored important regional conferences on rural electrification, and has provided information of assistance to companies in establishing rural service departments.

Railroad Electrification

Increased volume of freight and passenger traffic, arising from growing population and advancing prosperity, has stimulated further attention by railroads to main line and terminal electrification. Electrification programs have been announced this year by the Pennsylvania, the Philadelphia and Reading, and the Lackawanna railroads. Other railroads have electrification plans under study. It is certain that our railroads will make that use of electricity consonant with sound transportation development. We wish to assist them.

Accounting

The accountants of the industry have a great responsibility. The volume and complexity of accounts have grown to enormous proportions. They have been confronted with the task of handling current accounts, as represented by gross earnings, which increased from 281.9 million dollars in 1912 to 1,900 million dollars in 1928. The number of customer records involving monthly billings has grown from 4 million to 23 million. The investment in facilities to be accounted for has grown from 2.1 to 10 billion dollars.

In this field of accounting, the association has been constantly on the alert, keeping pace with ever-changing conditions and problems and in step with industry progress. Every phase of accounting principles and interpretation has been made the subject of thorough research.

The Accounting Section is giving special attention to accounting for interconnection, merchandise accounting, budgeting, and the latest questions in the field of investment trusts.

Continued study has been applied to simplification of procedure in forms and records, particularly in simplification of customer records and bills. Savings attained in reducing cost of handling these accounts represent thousands of dollars. The care and attention given by our accountants to methods of maintaining customers' accounts and billings have been a most important factor in improved customer relations for the only point of contact with many of our customers is through the monthly bill. The Accounting Section of the association is to be particularly commended for the excellent results attained in this direction and for their fine concept of the customer viewpoint in handling accounts.

With the growing proportions and complexity of the business the accountant will increasingly be called upon to furnish the records of the past and to visualize problems of the future as a base upon which our executives may make forward plans.

Public Relations

From the standpoint of morale, as well as of material things, I believe no twelve-month period ever has been better for the electrical industry than the one just passed. This is equally true of your association.

During the year the industry, largely through the association, has borne the brunt of the assault of those who would nationalize the country's industries, businesses and professions. Much of this attack has been directed toward the so-called public relations work of the association—a work miscalled "propaganda." Despite this, the Public Relations National Section has carried on its constructive work of aiding and directing the industry in its duty of fully informing the public regarding past and present performance and future possibilities and obligations.

Among the many committee activities, all of which have consistently and persistently moved ahead under the able leadership of Vice-president J. F. Owens, chairman of the Public Relations National Section, are two outstanding developments. One is the study made of industrial relations, by a committee of that name, which includes Health and Medical and Employee Contact practices and instruction, serial reports having been issued and others being in preparation. The other is a study of the Migration of Industry, made by the Metropolitan Life Insurance Company at the request of the Association and in cooperation with the Civic Development Committee.

Widespread as are the activities of this Section, they constitute but a minor part of the overall activities of the Association although a most important part, since future progress of the industry depends in no small degree upon the confidence the public has in the industry and its integrity and honesty of purpose. We feel that we are successfully doing our job—furnishing the best electric service in the world to our customers at fair rates, safeguarding the interests of our investors in our securities, and doing our part in helping to make this the happiest and most prosperous country in the world, and it is a part of that job to keep the public informed.

Commercial

Problems of marketing are confronting our industry no less than other industries producing products for distribution. We recognize an immediate need for concentration on our commercial possibilities. Potentially they are amazing, and the selling departments of our power companies are meeting the challenge with vigorous effort.

Surveys reveal our accomplishments of the past and unfold almost limitless opportunity for commercial expansion. Whether we vision the future all-electric home or the vast sales possibilities in the application of electricity in commerce and industry and in the industrializing of the farm, our conclusion is the same. "Serving the public" unfolds unlimited opportunity for business development.

Our commercial progress, of course, is affected by numerous agencies making the marketing of our service unlike that of other commodities. We cannot store our product; we cannot change our prices at will; we cannot transport and deliver always in the most economic methods; we have a limitation of territory in which we can market. In fact, we must build a market by building the community. And yet, we realize as never before how keen our competition is in the selling field.

Important problems of market analysis, the construction of industry-selling programs, the development of salesmen and methods to cope with modern requirements of highly specialized selling, are all being examined and promoted by our National Commercial Section. It is organized to meet the demand upon it for intensified activity and is rendering a highly valued service to the industry.

Geographic Divisions

The Geographic Divisions are recognized as the basis backbone of the whole Association. I have been enormously impressed as I have gone from one Geographic Division to another with the intensiveness, practicalness and thoroughness with which the respective Geographic Divisions and their committees are dealing with and mastering the problems relating to their respective areas, this not only through the Geographic Convention, but in the conferences and committee meetings taking place during the year. Also, I have been impressed by the contributions coming from the several Geographic Divisions which, through the agencies of the National organization, are diffused throughout the entire country, to the benefit of the entire industry.

An electric light and power company, in itself, can make no enemies, can gain no friends, can do no wrong. Such friends as it has, those engaged in the industry must gain for it. Such enemies as it gets, those in the industry make for it. It has only such character as the men and women who are operating and managing these companies give to it.

So in going around the country and meeting the men and women from all sections, above all, I have been impressed with the outstanding character, the exceptionally high ideals of business conduct and integrity possessed by the men and women engaged in the electric light and power industry. They are seeking to operate the properties at a profit, of course, because a business service must earn its way if the business service is to continue, but there is a striking absence of greed among them. They are endeavoring to furnish a useful service at a reasonable rate of pay, and if you will notice the rates charged by this industry for its service, you will see that they almost stand alone as a record of constantly descending prices year by year from its beginning to the present day. And I believe it is true that almost every company in the entire United States during the last 18 to 24 months has revised some of its rates downward so that average rates are each year less than they were the year before.

But everywhere, in addition to rendering useful service at a fair rate, these companies and the men and women engaged in them are taking a leading part in the development of their communities and their companies are generally regarded in their localities as the most constructive force in the upbuilding and progress of the territories they serve. Locally they deserve and enjoy almost universal respect and esteem.

The story of the industry, its accomplishments, opportunities, purposes and policies will unfold as the program of the convention proceeds. It is an inspiring story with new things happening year by year which give zest to the telling.

Another matter I have been particularly impressed with in your association is the type of the headquarters organization. I found it completely organized, well equipped, a selected personnel, well trained and experienced, and in my judgment there is no better business organization or headquarters organization of any industrial association in the whole country.

Anybody can be president of the National Electric Light Association, if you show him sufficient partiality. He can't go far wrong with such an organization behind him to do the work for him and give to him the credit.

I extend to you my very great thanks and appreciation for your partiality and kindness in conferring upon me the distinction of being president of the National Electric Light Association for this year. I shall cherish the memory of it always. (Applause).

CHAIRMAN OWENS: President Arkwright, with his characteristic modesty, has requested that no Committees on the President's Address be named. We who have followed him during the year will, of course, accede to that request, but I am sure you would not like to have this moment pass without having some of us who have followed under his leadership during the past year give an expression of what I am certain is in your mind, of the marvelous contribution that this great man, with his great mind, has made to the industry during the past year. (Applause).

These have been trying times, but it seems as though Providence itself had looked down and had picked the very man who could lead the industry, with credit to the industry and with glory to himself, during this period of trial. And I assure you, and I believe you will agree, that leadership just such as that, perhaps not so outstanding, but certainly leadership, is to be found in every branch of this industry, in every section of the country. And Mr. Arkwright in his great contribution, not only to the industry but to the nation during the past year, is typical of the contributions that men and women in this industry are making every hour and every day to the advancement of social order and to the benefit of society.

And I congratulate you on having had the privilege of having, as the leader of this great industry during the past year, such an outstanding man as our President, Mr. Arkwright. (Applause).

[President Arkwright resumed the Chair.]

President Arkwright: I am overwhelmed, but I nevertheless find it very pleasing to have people say nice things, even if I do feel that I have put something over on them.

The next item of business is the report of the Treasurer, Mr. P. S. Young.

REPORT OF TREASURER P. S. YOUNG

I might summarize this report by saying that the finances of the Association are in excellent condition. As you know the operations of the Association are conducted under a budget system, thus all the expenditures come under complete control of the officers of the Association. The fiscal year of the Association ends on June 30, and therefore it is only possible to give you at this time the income and expenditures for ten months of this fiscal year.

A very considerable part of the Association's funds are now set aside for the purpose of a contribution to the Pure Science Research Fund. The Committee in charge so far has not called for any contributions from us. We have set aside, however, the funds which we have contracted to contribute.

Perhaps a few salient figures which will tell you of the financial occurrences for the past ten months may be interesting to you. There will be incorporated in the proceedings the report for the full fiscal year. That report will include a balance sheet as of June 30, 1929, a statement of income and expenditures for the fiscal year, and a summary of the surplus account.

At the beginning of the fiscal year, July 1, 1928, there was $407,172.08 cash on hand. Receipts for the first ten months of the year included $1,472,577.68 from dues; $66,225.73 from publications; $32,953.29 interest on deposits and income from securities; $400,000 redemption of Third Liberty Loan Bonds, those bonds having been purchased in order that we might get a larger rate of interest temporarily; $58,800 from contributions of subscribers to the Pure Science Research Fund—those were advance contributions; $50,505 from contributions to the 1929 Joint Research Fund; and $81,537.22, miscellaneous income and other credits; making the total receipts for the ten-month period $2,162,598.92. Adding the cash on hand previously mentioned, makes the total cash to be accounted for $2,569,771.

The expenditures during the same period have been as follows: Those applicable to preceding administrative year, $81,448.34; those applicable to budget appropriations of present administrative year, $1,000,903.15; cost of securities purchased, $202,425; for the 1929 Joint Research Fund, $25,443.41; and miscellaneous expenditures of $66,538.92; making total disbursements of $1,376,758.82, and leaving a cash balance as of April 30 of $1,193,012.18. I want to remind you, however, that this balance is subject to be drawn against for the remainder of the calendar year, as the 1930 dues are not collectible until Jan. 1, 1930.

The market value of the stocks and bonds owned by the Association as of May 31 was $487,839, as against a book value of $456,474 on that date. The market value of the securities owned on the same date a year ago was $232,000. A list of the securities owned will be published in the 1929 Proceedings.

The Association has had periodical audits of the accounts made by certified public accountants, and the accounts have been audited to April 30, 1929.

In closing, I again wish to express my appreciation of the highly satisfactory, faithful and efficient work of the members of the Headquarters Staff, whose duties have come under my observation. (Applause).

President Arkwright: The finances are in good condition and in good hands. The direction of the business and affairs of the Association is in the hands of the Managing Director, the leader of the Headquarters Staff, the real director not only of the Association's activities, but a director who sees to it that the volunteers do some work also themselves.

I take pleasure in presenting to you Mr. Paul S. Clapp, Managing Director. (Applause).

REPORT OF MANAGING DIRECTOR PAUL S. CLAPP

It is fitting at the outset of this convention that we briefly take note of certain outstanding marks of progress made during the year in electrical development.

Increased Use of Electricity in the Home

The increase of 1.1 billion kw-hr., or 15 per cent, of electricity used in homes during the year portrays accurately and vividly an unparalleled advance in American living standards. Again this year, over one million homes commenced to use electricity. They are in largest city, in smallest village and on the farms. This rate of growth has been maintained for the past seven years, and in this short span the benefits from utilization of electricity have been opened to nine million homes—the hearthstones of well over one-quarter of the nation's people. No more positive measure can be found of the part this industry has in furthering national well-being.

Homes are using more and more power. The average family used 459 kw-hr. during 1928, an increase of 7 per cent over the preceding year. The average paid by these families for their year's electricity was $30.10, an increase of only 3 per cent, clearly reflecting the lowering price and expanding use of electric service in homes. The average cost this year reached a level 25 per cent under pre-war, while costs of living generally persist at levels 70 per cent above pre-war.

Electricity and Industry

Again during this year electricity continued to assert itself as the essential source of power for industries. The year 1919 marked the beginning of a new industrial era—the era of electrification. It is as profound as the great economic transformation ushered in by England, which marked the shift from hand labor to machines. Government reports show that the tremendous increase of 9,800,000 h.p. put behind factory workers since 1919 has all been in electric motors. Beyond its use for prime-movers, electricity is finding added applications for heating, welding and processing. The widespread interconnected electric systems operated by the electric utility companies have become the source of reliable, adequate and low-cost power upon which this country's marvelous industrial performance depends.

Results of Factory Electrification

Electrification of factories is exerting vital and fundamental economic forces. This electrification of factories has released manufacturers from investments in boilers and engines amounting to nearly one billion dollars in the last ten years, thereby greatly facilitating industrial expansion. It has decreased coal required for factory production. Widespread availability of electric power is an important factor in the new industrial development which in increasing degree is taking place in small towns.

Increase in Power Capacity

During the year the public utilities increased the power capacity dedicated to public service by 1,890,000 kw. The capacity of the Pearl Street plant built by Mr. Edison, although its ratings were in number of lamps that could be lighted, was not over 559 kw. It represented virtually the whole electric power capacity of the nation. The grand total of the electric power generating capacity operated by the electrical industry has now reached 27 million kw., an amount four and a half times greater than that of any other nation.

Construction of added facilities last year required the expenditure of 753 million dollars, 60 per cent of which was spent for transmission and distribution facilities.

Over 14,000 additional miles of transmission lines above 11,000 volts were put into service, completing a network of 150,000 miles engaged in diffusion of power over the areas served. The investment in physical property of the utilities passed 10 billion dollars. Lowering charges for service have slowed down the rate of capital turnover from once in four and three-quarter years for 1922 to once in five and a half years for 1928.

The urgent need is for more aggressive business development. In the electric utilities, as in business generally throughout the country, the major advance since the war has been in the field of production. A remarkable job has been done in the provision of facilities for service, and enormous investments have been made in them. We now need larger utilization of electricity. The National Electric Light Association is strengthening its facilities to aid in commercial expansion. Intensive studies are being made of restrictions to enlarged electrical use, and plans are being evolved to overcome them. Intensive training courses have been held this year in electrical advertising, industrial heat applications, commercial cooking and rural electrification. General informational material of benefit to electrical salesmen has been and is being prepared. A national food preservation activity, to enlist further attention to food preservation in homes and to public health, has been sponsored, bringing together in coordinated effort all those interested in preservation of foods. I bespeak your local cooperation for its success.

The use which is made of electricity does not depend alone upon the cost of the kilowatt-hour. It depends upon the cost of wiring and installation, and it depends upon the cost of the current-consuming equipment. All these factors are interrelated. But of far greater importance, increased utilization of electric service depends upon enlarged public understanding and public acceptance of the electrical idea. We have a vast territory opened to us in more thoroughly informing our customers and prospective customers of the electrical equipment and appliances now available, and what they can do in the way of saving in time, effort and money. This larger field is a common responsibility of all those in any way connected with the electrical business.

Directing Common Effort

Accomplishment of full opportunity does not rest alone with the utility company. There are many groups concerned. Analysis discloses over 700,000 men and women directly engaged in electrical development—in research, design, manufacture, merchandising, wiring, construction, jobbing, financing and operation. Comprehension of possibilities, better mutual understanding and direction of common effort on the part of this great body will make it an enormous unconquerable driving force in electrical development. To this end your Association is bending every effort.

I can confidently say that this year will be characterized by increased understanding and common appreciation of possibilities between manufacturer, contractor-dealer, wholesaler, merchandiser, electric utilities and all those responsible for electrical progress.

The electrical industry involves every conceivable element growing out of the development and maintenance of an enormous public service. The National Electric Light Association not only must keep apace with this development; it must be a dynamic force projecting it forward.

You may be assured that every phase of the business is under constant study by the Association and its Committees. The budgets are carefully considered and supervised. There is ceaseless search for advanced ideas and improvements. These are promptly diffused to all member companies, and each participates in the general forward march. Without the Association, an idea originating within a particular company would largely be isolated there. With the Association, there is a constant interfusion and interchange of ideas between the thousands of men and women engaged in the industry.

Railroad Electrification

Under the auspices of its Committee on Railroad Electrification, the Association this year sent a special commission of experts to Europe to study railroad electrification practices of these countries. There has been developed information which, it is expected, will be helpful both to the utilities and railroads of this country. The findings will be reported to the convention tomorrow morning by Mr. Britton I. Budd.

Industrial Development Studied

Another fundamental research participated in by the Association this year deserves your particular attention. Our Civic Development Committee, in cooperation with the Metropolitan Life Insurance Company, has made a broad study of industrial development in the United States for the last two-year period. Over 14,000 factory owners were canvassed to determine where new factories are locating, and the factors affecting location. Mr. Madden, Vice-president of the Metropolitan company, will tell you of this on Friday morning.

Decentralization of Association's Work

With the growing complexity and magnitude of electrical development, it is clearly evident that decentralization of our work insofar as practicable is desirable. The work of the Geographic Divisions of the Association is increasingly important. To this end every positive assistance is being given to them from Headquarters.

Convention Uses New Instrument

The introduction of the talking-moving picture has provided us with a new instrument rich in possibilities. We are undertaking something this year which has never been tried by any national convention. We are making a talking-movie film of the whole convention and exhibit. A staff of expert talking-moving picture operators is here under the direction of a leading moving picture director. This film will be finished next week. Within ten days after the close of the convention it will be shown at Breezy Point, Minn. (North Central Division Convention), then in succession at Del Monte, Cal. (Pacific Coast Division Convention) and Seattle, Wash. (Northwest Division Convention). Thus we hope to translate to the thousands back home something of the inspiration and benefits of this great convention which you are privileged personally to enjoy.

Federal Investigation

During the year the National Electric Light Association has been under intensive Federal investigation. In accordance with the policy indicated by the officers of the Association, our attitude has been one of complete cooperation with the Government. Various representatives of the Federal Trade Commission have made repeated visits of varying lengths to our Headquarters offices. All accounts reaching back ten years have been scrutinized in detail several times; each voucher has been critically reviewed. Indexes of the complete files were furnished, and investigators were given prompt and complete access to every file requested. Requests for specific information and voluminous copies of material were complied with. Members of the staff, including myself, have testified in Washington frankly, completely and often. There has not been an expenditure, an action, a single phase of activity of the Association which has not been exposed to the searchlight of closest analysis. The investigation has been thoroughly, painstakingly and carefully done.

Only Facts Are Made Available

The Association assumes full responsibility for the accuracy and truthfulness of information it makes available. We fully realize the high obligation for real facts and correct interpretation. Mistakes and errors do occur, but every effort is made to prevent and correct them. Your statistical research organization has been developed until it is among the best maintained by any basic industry. The statements and publicity of the Association are made from this background of factual information, widely gathered, critically available, and competently interpreted. Our objective is to make facts available, confident that they will speak for themselves in securing for this industry a fuller public understanding of its problems, accomplishments and services.

You rightfully take pride in the men and women associated with you in your respective organizations. I wish you to share the great pride and confidence which I have in my co-workers at Headquarters. Not one of you is surrounded by more loyal, enthusiastic and untiring aids. We derive happiness from service to you, and our real rewards come through contributions to your success.

The Industry's Main Asset

We expect the registration of the convention to be between 10,000 and 11,000. As I have watched this great crowd gathering, as I have observed the hail greetings and comradery on the Boardwalk, as I stand before you this morning, one thought persists—that the industry's main asset is not its power plants, not its transmissions and distributions, not its investments in physical equipment. The greatest asset the industry has is the enthusiasm, character, loyalty and ability of the 270,000 men and women who are engaged in it. I would that we appreciate more than ever these rich human values, realizing that from them has come all the progress that has been attained, and in them lies all our hopes for the future.

PRESIDENT ARKWRIGHT: An indication of the good job that Managing Director Clapp always does.

There is no subject of greater consequence and importance to us than proper rate structures and correct principles of rate making and rate regulation. We are fortunate to have on the program a gentleman who has had a great deal of experience in rate regulation, rate schedule making. He is an authority on the subject. It is a privilege to have him present, and it is an honor to present to you Hon. William L. Ransom of Whitman, Ransom, Coulson & Goetz, who will talk to us on the subject of The Public Right as to Electric Rates. Judge Ransom!

THE PUBLIC RIGHT AS TO ELECTRIC RATES

By WILLIAM L. RANSOM

Of the New York Bar;
Member Whitman, Ransom, Coulson & Goetz

I have been honored by your invitation to take part in the program of this impressive convention, marshalled under your leadership, Mr. President, and that of the other officers and the staff of this association. You, sir, have been a tower of strength to this industry, during what has seemed at times a transitional and troubled year. The members of the industry have come increasingly to respect your counsels and love you as a friend. Perchance that respect and affection will persist, in spite of your suggestion of electric rates as the topic for my remarks.

I think you will all agree with me that this subject of electric rates does not lend itself well to discussion within a fifteen-minute period, before so large a General Session. With other speakers with less technical subjects about to follow, as well as a talking movie, I shall avail myself of the opportunity of referring to the subject only in a rather sketchy way, and in preparing my remarks for later publication I may refer to some angles of the subject in greater detail than is possible here this morning. [Judge Ransom's complete paper follows.]

Discussion of Electric Rates Is Growing

There are signs of a growing discussion of the subject of electric rates. So far this has been largely technical although enlightening in character, has been carried on chiefly by company representatives, and has proceeded for the most part from the point of view of the electric companies, their operators and their investors, and what the companies have a right to expect from the rates which they charge the public.

Now there are multiplying indications that this discussion will soon reach a further phase. There are manifestations of a growing public interest and consciousness as to electric rates, their forms, and their economic effects as limitations on the service which electrical energy may perform. The emphasis may soon shift to vital questions of what the public has a right to expect as to the rates which customers pay. Needless to say, I am not at all referring to the occasional agitations conducted by demagogues, who dangle before voters the illusion of cheapness for its own sake. Except, perhaps, for one or two conspicuous instances, there is less of this kind of discussion now than for several years past. Such outbursts rarely have had any practical relationship to the rate reductions which have steadily taken place, throughout the electric industry; more often, these unreasoned agitations and consequent litigations have actually delayed reductions which would otherwise have taken place and have seriously obstructed normal improvements, of public benefit, in the rate structures of the utilities affected.

Consciousness of Rates

But I believe that there is an increasing volume of reasoned and beneficial consideration of the subject of electric rates, by customers and by representatives of the public interest. By this, I do not at all suggest that present discussion lacks vigor or that it proceeds from any undue friendliness to the companies. Although reasoned, it is aggressive and often based on misinformation and false hypotheses. Nevertheless, it exists, is increasing, and must be reckoned with, as a reasoned discussion from a public point of view. Perhaps, naturally, this consideration has been most manifest in the public service commissions of the various States and in their expert staffs, but there are evidences that customers also are becoming conscious of electric rates and their relationship to home life and to industry and commerce. Rates and forms of rates are no longer taken wholly for granted, in all communities; and what we may call this consciousness of the rates and of the effect of rate forms is leading to an inevitable questioning whether electric rate-making has so far kept fully apace with the tremendous progress in electrical engineering and corporate organization. You need not be reminded that the dependence on electric service has become such that your electric rates, their forms and amounts, vitally and continuously affect the daily home life of this country and determine its industrial development, to a far greater extent than do tariff schedules or tax bills or the prices charged for the products of any other industry. Tasks of statesmanship in rate-making are undoubtedly ahead. The electric industry will soon be subject to increased pressure and insistence from the State commissions, for needed changes in rates and rate structures.

For my own part, I believe that the electric industry does and will welcome most cordially the challenge of any fair scrutiny of its rate structures from the point of view of the public interest. It will prepare to meet and deal with any kind or extent of public discussion and criticism, whether fair or not. In the long run and the last analysis, the public right and the real public interest has been, and should and will remain, paramount as to anything pertaining to the electric industry. This inheres in the very nature of the essential service which you furnish and the far-reaching economic consequences of your rate schedules. You have always to take these elements into account in making and changing rates. This great industry could not, if it would, assume a merely passive attitude, a rôle of non-resistance, and compel that the leadership and initiative in these vital matters shall come from the pressure of public authorities. To whatever extent the public now or hereafter has a right to expect progress in the matter of electric rates, the responsibility for the prompt proposal and explanation of adequate changes rests inescapably with the utilities. Therefore it may be fitting that in this most representative Association, an effort shall be made to perceive and point out the elements of public interest and concern.

Analyzing the Discussion

I have lately been trying to make some analysis and appraisal of what is being said by way of fair and serious-minded comment, criticism, and suggestion, as to electric rates. Before presenting any of the results of such study, I think I ought to say two things, because they express a point of view which undoubtedly affects my analysis:

1. It is very dangerous, and it may be altogether too early, to try to generalize as to electric rates throughout this country. The rates and rate practices in one locality vary sharply from those in many others, and there is a wide diversity of experience and reasoned opinion. Any analyst is in the utmost peril of giving undue weight and emphasis to what has been done and said in the localities with which he is most familiar. Almost any present generalization that may be undertaken as to electric rates, beyond their steady decrease as consumption has increased, is likely to be no more than partially true, if true at all, and there will be numerous and impressive variants and exceptions. As some of you know, the vicissitudes of the law have led me to see a good deal of public utility problems, from several angles of relationship and responsibility—in municipal government, in the legal work of a public service commission, and as counsel for companies. My work has brought me into contact with practically all types of public service companies, in a good many cities and States—electric, gas, water, communication, and various types of transportation. If this diversified experience has helped me to see public utility matters from a point of view which is at all broader than that of one locality or branch of the industry, probably another result has been to deprive me of power to dogmatize and declare ready formulas for the convenient solution of the problems which beset you. So I shall refer to these rate questions rather tentatively, and not at all dogmatically. My purpose is, frankly, to present them anew as questions for consideration and discussion, and I have neither pride of opinion nor finality of opinion concerning them.
2. I am not one of those who believe that the operations or rates of this industry should or can be forced into any strait-jacket of uniformity. The electric utilities of this country have grown up as local institutions, each meeting its own community needs according to the divergent conditions and the best judgment of its local managers in conjunction with the public supervisory authorities. The essence of the situation has been friendly, cooperative relations between the utility and its locality, with the State power in the background, likewise exercised in such a manner as to take account of local conditions, moods, and needs. Continuance of this wholesome local responsiveness, so far as may be, is of great benefit to the industry and those whom it serves. For my own part, I am keenly cognizant of practical difficulties and dangers which would inhere in regulatory pressure, or even pressure from central holding-company management, for too much uniformity or standardization.

Nevertheless, many changes have come about; the earlier conditions of the industry have been sharply altered; and it may be that the public interest will sooner or later point out to you the avenues of some needed progress in your rate-making. These may here be explored without in any way accepting the view that all of them should immediately and uniformly be adopted by the utilities.

Elements of Question and Challenge

Some of the elements of question and challenge which are coming to the electric industry may be briefly outlined:

(a) There is sometimes a serious and fair-minded assertion that existing electric rates must be too high. This is said in the face of the fact that electric rates, per unit of service, have been steadily and generally reduced from year to year, despite sharp increases in wages and material costs, and the fact that the net earnings of the electric utilities are and have been kept substantially less than an adequate return upon either the present value of the properties or the actual investment therein, taken on any basis of valuation or return that could reasonably be defended. Among the seven general classes of living expenses listed and analyzed by the National Industrial Conference Board, electricity is the only one which shows a unit price below that of 1914. The decrease has been about 14 per cent, without giving effect to the lessened purchasing power of money, which would make the percentage of actual reduction still larger. The figures which have been carefully compiled from all available sources, many of them governmental in origin, confirm the fact that existing electric rates yield an annual return of less than seven and one-half per cent on the investment, and, of course, a substantially smaller percentage of return upon the present value of the useful property. Despite these facts, there is oftentimes a manifest feeling that electric rates, or at least the cost of electric service, are too high.

(b) On analysis, any assertion that electric rates are too high is usually found to be unsupported by any demonstration or conclusion that the net earnings as a whole are excessive. Oftentimes the assertion finds its pretext and pretended justification only in wholly extraneous and irrelevant considerations, unrelated to the operating companies, their properties, their costs, or their net earnings. In many instances, however, the feeling that electric rates are too high is a feeling that the cost of electric service has become too high in the sense that the increased quantity of current now used by many customers costs too much and has not been reduced sufficiently as the quantity has increased. There is also an impression that the existing rates or their forms tend strongly to prevent the use of electrical energy for many purposes in homes and industries which would gladly make full use of electricity, for various additional functions, if the rates or rate structure permitted it, within the limits of a reasonable total cost for the total electrical service rendered.

(c) On further analysis, in most or many of these instances, it appears that the utilities could well afford to supply electrical energy to these homes and industries, for all purposes (including these added uses), at unit rates producing a total cost which they could well afford to pay, and that the managers of the utilities would, in fact, very much like to obtain the additional volume of sales which these full-use customers would ensure.

(d) In some localities, there is also a somewhat vague feeling, increasing but not yet very militant, that rates and rate schedules are adversely affected by the fact that some electric companies furnish large quantities for resale at unregulated rates by unregulated middlemen, depriving the regulated utilities of their normal diversity of retail and wholesale business and compelling higher wholesale and retail rates.

(e) Over and beyond these questionings as to rates and their forms, there is oftentimes a public feeling that electric rate structures and rate schedules are needlessly complicated and prolix, beyond the comprehension of the customer, and lending themselves to misunderstanding and misrepresentation. There seems to be an increasing amount of questioning based on comparative rates, in different localities and within the same general area and system—a resentment against unexplained local variances in amount and form, a feeling that rate-making has not yet caught up with the larger operating and corporate units which have become characteristic of the utility systems.

Reviewing Questions of Public Right

Within the available limits of time, I can here comment only very briefly upon these elements of criticism and questioning, advanced from the point of view of the public right and interest. In part for the same reason of time, I shall refer to these several questions in which may seem to you, as to me, the reverse order of their importance, placing first for brief statement the more superficial public criticisms of present rates and schedules.

It is suggested that the public right reasonably calls for:

1. *Greater simplicity of rates and rate schedules:*

There seems likely to be an increasing amount of regulatory pressure, backed by considerable customer opinion, to the end that electric rates and rate schedules shall become more simple and understandable. The public has a right to expect that your rate structures shall not be needlessly complicated or prolix, and that the terms and conditions on which your essential service to the public will be furnished, shall be stated as clearly, explicitly, and simply as possible, so as to be comprehended by customers as well as by rate technicians. Too many rate structures and rate schedules are still an evolutionary growth, made and amended from time to time to deal with changing conditions, and in a makeshift way. The result too often is more or less a patchwork, needlessly intricate, and lending itself to public misunderstanding and customer irritation. In other business fields, under the leadership of the Department of Commerce, there has been great simplification of forms, standards, and types, which has enabled salesmanship to make effective concentration upon those best suited. May not the electric utilities gain added public commendation through similar steps as to their rate schedules and rate structures?

2. *Uniformity of rate forms, and even of rates, over larger territorial areas:*

From some of the regulatory commissions, there has come recently the demand for greater uniformity as well as simplification, at least as to the forms of rates. Beyond a doubt, this suggestion presents serious practical difficulties, in view of the diversified conditions and the general prevalence of customer satisfaction under the varied forms of rates now in use. Uniformity, if pressed too far for its own sake, might lead to disturbances and irritations more serious than have ever arisen from lack of it.

But the question is squarely propounded whether your rate-making has kept pace with the growth of your corporate systems and the widening of the areas served from a central station? We all know that comparisons of rates, in different and distant communities, have been used as bases for unfounded inferences and attacks. Marked differences in rates or rate forms in nearby areas served by the same utility system, perhaps even from the same central station, have sometimes lent themselves to criticisms which are not as readily refuted. In putting together larger units of operation and management, the electric utilities have generally been quick to give to the public the economies and advantages which flow from such larger units in engineering and management; but has the same thing yet been done to an equal or appropriate extent as to rate-making? Too often, as to rate-making, the anachronisms which arose in the days of local ownership and management have been perpetuated despite the consolidations. The suggestion is made that the outlying locality may well be averaged in with the more congested areas, and the rates made alike for each. This is deemed to follow logically from your own creation of the larger units. You may need soon to consider whether the growth of this industry has not reached the point where greater uniformity in the forms of rates may advisably be sought and promoted, over larger territorial areas? Instead of sharply differing rates and rate forms for each locality and local condition within the territory served, does not the great growth of the electric business entitle the public soon to look for progress toward a greater uniformity in form, and even in amount, over larger territorial areas, particularly including those which are partly suburban or rural in character?

3. *Rates based on service direct to the ultimate user of electric service:*

Here is an issue you may soon have to face squarely. Many rates and rate schedules in the electric industry remain seriously affected by the fact that a large part of the energy supplied thereunder by the public utility is for purposes of resale, within its franchise territory, by unregulated middlemen, who, in turn, resell the energy to those who would otherwise be customers of the utility and would help give to the latter the normal diversification of its business, as between wholesale and retail classifications and in other respects. This issue is already before various commissions and courts, and the decisions so far have, I think, been uniformly adverse to the practice of the supplying of electricity by non-utilities, at rates and under conditions of service not controlled by law. Beyond a doubt, this practice, where it exists, throws the rates and rate structures of the utilities out of balance, and keeps both retail and wholesale rates higher than would otherwise be necessary. I submit for consideration that the public will be better served by the utilities themselves, in direct relationship and responsibility to each user of electric energy, and that within their franchise territories the utilities ought not to make their rate schedules and rate forms such as to permit resale of their energy by non-utilities, at prices not subject to public regulation and control. There is no need or room for a middleman, in the selling of electric energy generated by a public utility. The rates charged to the public should not be burdened with his profits, and the public should and will benefit from his elimination, in the communities where commercial, industrial or residential sub-metering has obtained vogue. In my judgment, the utilities have only themselves to blame for permitting the establishment of a rate practice which first disadvantaged the public but now threatens serious consequences to the utilities themselves.

4. *Rates reasonable in amount and in such form as to enable electrical energy to perform all of the labor-saving and comfort-giving functions for which it is economically suited:*

This phase of the public right is basic and clearly the most important of all. It is axiomatic that an electric utility is entitled to charge rates which will yield net earnings amounting to an adequate annual return upon the present value of the property which it devotes to the public service. That is the constitutional right of the utility, which may, nevertheless, in the exercise of its own business judgment and discretion, put and keep in effect rates which yield net earnings amounting to less than a fair return. That is commonly done by the electric and gas utilities, and is a right and function of sound management. There seems little or no danger of losing sight of this principle of constitutional protection, declared and enforced by the State and Federal Courts; and the public itself has commonly come to realize that in the electric industry, the rates must be kept such as to yield revenues enabling the continuance of the best possible service and the making of extensions and improvements as fast as necessary to that end. The public has not often made the mistake of destroying ability to serve and grow, through any desire to seek rates which are merely low and cheap. Adequacy of net revenues, as essential to the best possible service, the integrity of investments, and a liberal policy of extensions into outlying areas, is the right alike of the utilities and of the public which they serve.

But the electric industry cannot expect to grow and hold public confidence as to its rate policies merely by demonstrating periodically, before some commission or court, that the total amount of net earnings of this or that company, or system, or the industry as a whole, does not exceed the constitutional assurance of a fair return. Truly enough, the rate structure and the return from it should be envisaged as a whole, but the right to make competitive rates in the exercise of sound business judgment and the right to compel classes of customers to pay their own way may alike be insisted upon. There are signs of public questioning of ancient forms of rates still in effect.

It is the right of the utilities that rates shall be kept such as to yield an adequate return, and such an adequacy of utility revenues as a whole is also in the public interest, no less than the prevention of excessive charges. But there is no public right of any class of utility customers to be served at a loss, and no right of any class of customers to insist that a substantial part of the cost of serving them shall be assessed against and paid by other classes of customers. It is the economic necessity that the rates shall defray the costs of the service and yield a substantial annual return. Utilities may, and often do, secure for themselves some illusion of popular or political favor, by cutting the rates for the more numerous classes of their customers so low that the deficiency in bare operating costs, as well as return, has to be made good in large part by less numerous groups of customers and in part by utility investors. I do not hesitate to state my personal belief that any such practice in rate-making violates the public right.

The Most Important Rate Problem

As I see it, the most important rate problem confronting the electric business today may be denoted, in barest outline, by the following factors:

(a) The existing rates do not yield excessive revenues or returns. On any basis of valuation or return, the net earnings of the electric operating companies are at a lower rate of return than is the constitutional right of the companies. The amount of investment required, per kilowatt of generating capacity, is increasing; and the rate of return yielded upon even the investment is decreasing. The averaged rate, per kilowatt-hour of electrical energy sold to the public, is steadily decreasing. These tendencies would create a serious problem for any industry.

(b) There are many uses for which electricity is well adapted, in the homes of America and in its commerce and industry, from which electricity is to a large extent excluded by its present rates and rate forms. How many of us have occasionally an opportunity to contrast the conditions of home life, in homes to which electricity has not yet been made available, with those in which electrical energy has come to perform many of the functions for which it is suited? There are so many things which electricity can do, for comfort, convenience and good cheer, in lightening the drudgery of household tasks and making new comforts and conveniences available in even the humblest homes. The aid of electricity has become a vital part of the American standard of living; its economic availability for full use is a part of the public right. There are millions of persons who would like to make full use of electricity, particularly in the homes, but who find themselves unable to do so, economically or at all, under the present rate schedules. This presents at once the duty, and a large part of the opportunity, of the electric industry.

(c) This situation seems the more surprising and lamentable when analysis discloses that the electric companies could, in fact, well afford to supply to these full-use customers all of the electrical service they desire at a total annual cost which they recognize they could well afford to pay. If these full-use customers were called on to pay only the cost of serving them, the rates for such use could be made low enough to remove the economic barrier to the taking on of this business. The electric companies could do this without decreasing their present net revenues. They, in fact, greatly need this additional volume of business. They are not fulfilling the whole of their public function if they do not render the service which would call for it.

(d) From the above it clearly appears that the present barrier to electricity's full service in the home and in industry lies in the *forms* of the rates rather than in the total net revenues which they yield. The essential thing is that the utility shall not compel their full-use customers, in the homes and in industry, to continue to pay also the losses incurred in keeping electrical service available, at less than cost, to those who choose to make only a limited and occasional use of electricity, regardless of the price. If the present rate structure makes a home-owner pay an average of, let us say, six or seven cents a kilowatt-hour for a relatively small quantity of energy, whereas he would be glad to use a much larger quantity for a variety of labor-saving uses, for which he could afford to pay an average of three cents, the rate schedule must be seriously at fault, provided the company could well afford to supply him the larger quantity of energy at the price he could afford to pay.

(e) Perhaps the most potent factor in excluding from the American home the full service of that most efficient aid to comfort, leisure and convenience has been and is the form of rate under which all of these full-use customers, regular and substantial users of electricity in the home and factory, have to make good the heavy deficiency incurred in serving many casual, convenience or limited users, who wish electric service kept continuously available to them, but do not wish to use it in regular or substantial quantities throughout the year. This anomaly has readily produced the condition under which a rate structure yielding less revenue than the company is entitled to, produces kilowatt-hour rates nevertheless so high as to penalize the regular and substantial users and bar the way to full use of electricity in the American homes and in American industry.

Violating a Public Right

I am not asking you to take my word as to whether a public right is here involved. The United States Court has passed upon that question in a case* involving gas rates but presenting the same question. A utility customer, which wished to become a substantial and regular user of gas, brought suit against the gas company. The plaintiff customer was being charged a flat or straight-meter rate, paid by all customers alike for each 1000 cu. ft. of gas consumed. Those to whom gas service was kept available paid nothing at all unless they consumed some gas, and if they used gas only occasionally and in slight quantities, they paid only the same flat unit rate as did the regular and substantial users, in the homes and in industry. The plaintiff customer claimed and proved that such a rate structure violated the actualities of the relative costs of service; that the flat rate compelled the regular and substantial users to pay excessive sums for gas service; and that *the property rights of the customer* were violated by a form of rates which prevented it from making regular and substantial use of gas in the quantities which he could economically utilize.

The Federal Court held, in an opinion by Judge Hazel, that the customer's complaint was sound in law; that the right of the customers to service at a reasonable rate, without advantage or disadvantage as compared with other customers, is in the nature of "a property right which entitled the parties to equal protection and treatment"; that this right of the public was violated by a flat rate which failed to take into account the actual costs of serving different classes of customers; and that a statute which compelled the continuance of such a flat rate and prevented a service charge violated the constitutional rights of the customers. The Court said:

> "No essential difference is perceived between one who actually uses the gas, paying an inordinate rate, and one who in good faith desires to become a customer but is estopped by an excessive exaction."

Here, then, is an economic maladjustment, a serious infringement of the public right as to electric rates. It may not be necessary here to go as far as the Court did in holding that an unsound rate structure violates a *property* right, but you cannot escape the fact that it violates a *public* right. Until this condition is changed, all of your sales campaigns and educational efforts under the auspices of this Association will encounter an inexplicable resistance. I have heard utility executives say that they did not care about the *forms* of their rates, because they could not earn more than a fixed return upon their useful property. Hence they concluded that the forms of their rates and their economic and social effects upon American life were "somebody else's business"—the concern of the commissions and other public representatives.

I do not believe that any such attitude of indifference can long be taken in this industry. Beyond question, the public, your customers, have a right to expect you to take the lead in making the rate readjustments which will remove these unnatural economic barriers to the full use of electricity. This will require leadership and action, courage and patience. You are as aware as anyone else of this condition and this need. You have been talking a good deal as to doing something about it, and some companies and groups have made real progress. It remains to be seen whether the industry generally will translate its convictions into action, or will wait for compulsion in the public interest.

Changes in the *Forms* of Rates Essential

In my remarks this morning, Mr. President, I have said no word to counsel any utility to embark upon any program of reduction in its rates, much less in its net revenues. The matters discussed do not relate to the amount of the net earnings or the rate of return at all. Beyond question any utility should resist to the uttermost any effort of public authorities to compel it to forego the adequate revenues which are essential to good service and are the right of its investors. My plea here is only for such changes in the *forms* of rates as will enable this servant of mankind to do those things which are the public right.

This is more easily said than done, as many of us have found. It generally means the giving up, for a while, of those spectacular and popular reductions in the "top" rate. These have been responsible for many of the mal-adjustments in present rate schedules. To cope with the present situation means frank recognition of our debt to that little group of serious thinkers—men like Henry L. Doherty in the gas industry and Samuel Ferguson in the electric—who have pioneered with their studies of utility rates and allocated costs. A great deal remains to be done along these lines, and the national leadership of this Association will be appropriate. The situation calls for an infinite amount of patient effort to explain to customers the significance of the changes and the betterments for which they clear the way. This is no inconsiderable task, in an industry which has placed its emphasis so strongly upon other things; but I believe that it can and will be done.

PRESIDENT ARKWRIGHT: We are most grateful and most appreciative to Judge Ransom for his fine analysis and address on this subject.

The next feature on our program is a novel one at conventions. We owe our having it to two particular individuals and interests. It wouldn't have been possible to have obtained it without the generosity and cooperation of placing at our disposal the facilities and the organization of the Western Electric Co., nor could we have obtained this without the effort, the interest and the work of Mr. W. H. Onken, the senior editor of *Electrical World*. I will not attempt to tell you what this feature is. It can best be told by Mr. Onken himself who went to Europe for this purpose. He did better than that. He had arranged to get certain particular people to participate in the features, but through unforeseen circumstances he couldn't get a single one of them. Instead of coming back empty-handed, he went out and got better ones. Mr. Onken will present this feature.

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* *U. S. Light and Heat Corpn.* v. *Niagara Falls Gas and Electric Corporation*, 23 Fed. (2nd) 719.

INTRODUCTION OF FOREIGN SPEAKERS VIA "TALKING MOVIES"

By W. H. Onken, Jr.

Senior Editor, Electrical World

This year marks the fiftieth anniversary of the invention of the electric incandescent lamp by Mr. Edison, and inasmuch as the electric lamp was but the forerunner of a system of electric generation and distribution of low tension, also invented by Edison, it is but natural that the electric light and power industry of this country should celebrate the event.

Now, a prophet is not without honor save in his own country, and President Arkwright, President of the National Electric Light Association, conceived the idea that possibly some foreigners of note might be induced to pay a tribute to the beneficent work of Mr. Edison, and to tell of what electricity has done for civilization. The question then, was who to invite and how to secure them. It would have been pleasant and entertaining to have some outstanding foreigners appear in person on this platform, but that was too much to expect. To have them express their sentiments in writing would be to have robbed their thoughts somewhat of their personal charm and magnetism.

Then the idea of a talking movie suggested itself. Here was something electrical that might measure up to the occasion, a moving picture surcharged with action and personality, and animated by a living, human voice. The idea, to be sure, was novel and dramatic. The Movietone had never been used before for such a purpose, and it is only natural that a progressive and enterprising organization like the National Electric Light Association should be the first to employ it for this Golden Jubilee Celebration.

Through the courtesy of Mr. McGraw, I was loaned to the National Electric Light Association and sent to Europe to secure speakers and Movietone records, and I was fortunate in getting in touch with people possessing a vaster vision of the world, and to whom the youth, confidence, energy and vigor of the United States were not unknown. These men graciously consented to make movietone records for this celebration.

They include Sir Kengo Mori, head of the Japanese Debt Commission now in session in Paris, Dr. Alberto Pirelli, Milan, Italy, President of the International Chamber of Commerce, and Sir Ernest Benn, economist and publisher, of London. In addition we have been very fortunate in securing a Movietone record of Mr. Edison himself. One of these records will be shown at each of the morning sessions during the Convention.

THE SUPERIORITY OF PRIVATE ENTERPRISE*

By Sir Ernest Benn

Economist and Publisher, London, England

The property problem—the question as to whether wealth or property should belong to the individual or to the community has been discussed and debated ever since the days when public affairs first became the subject of thought and conversation. Plato advocated the public ownership of property and for twenty centuries people who were not so well off as they would like to be have argued that there was something wrong with private ownership.

The argument still goes on today, and yet the vast bulk of all the property in the world is still in private hands. We are asked to believe that the whole world has been wrong through all the ages, and that there is a better way—the way of public ownership. It wants some courage in face of the accumulated experience of mankind to carry on this old argument, but Socialists and Revolutionaries make up in courage what they lack in brains.

When property consisted almost entirely of land and cattle and natural products there was a suspicion of a case for public ownership, but today when property and wealth are 95 per cent brains and 5 per cent nature, public ownership is the road to the end of our civilization.

Before wealth or property can be OWNED it has to be MADE, and nobody will suggest that Society can make anything. The making of wealth is beyond any question the exclusive function of the individual. The best society or community or state from the economic point of view is the one which has amongst it the greatest amount of wealth.

The best public policy, therefore, is that which will encourage the making of the maximum of wealth.

If, for instance, six people can live in comfort in one house, a community of 60,000,000 people will require 10,000,000 houses. If only 8,000,000 houses exist a discussion as to their ownership is apt to obscure the real problem—how to get another 2,000,000 houses built.

Public authority can *own,* but it cannot *make.* It only owns what it can extract by force from the individual who does the making. Public ownership, therefore, acts as a discouragement to those invaluable citizens who are by nature makers of wealth, and encourages the incompetents, the parasites, the passengers, the incapables and the pauper-minded.

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* Presented as a "Talking-Movie."

I have said that before you can own wealth or property it must be made, but there is a third consideration—it must be cared for, preserved, maintained and guarded from depreciation.

A public authority, which has confiscated—for all taxation is confiscation — which has confiscated wealth, values it so lightly and cares so little for it, that it will throw it away on the slightest provocation. The world is littered with the ruins of public works that have been discarded.

The civilization of each generation through the whole of history has rested upon the private property made, owned and cared for by the previous generation. There is no exception to this universal and age-long experience.

On the other hand, each generation has been handicapped with the debts of its forefathers, represented only by the blunders of public ownership.

The private individual tends always to acquire wealth—real wealth—which remains in the community for its comfort. No community has ever acquired anything worth mentioning but debts—the opposite of wealth.

Marshall, in the "Principles of Economics," says:

> "The tendency of careful economic study is to base the rights of private property not on any abstract principle, but on the observation that in the past they have been inseparable from solid progress, and that, therefore, it is the part of responsible men to proceed cautiously and tentatively in abrogating or modifying even such rights as may seem to be inappropriate to the ideal conditions of social life."

The property in the hands of public authorities of the world today is not worth more than 5 per cent of the amount of the debts of the same authorities.

That, after all, is quite natural, when we remember that it is nobody's business to look after public property.

The argument, therefore, boils down to this. The economically perfect society wants the maximum of wealth—houses, railways, electricity plants, steamships, machines and numbers of other things. All experience shows that the private individual through private ownership is the only agent that can be trusted with these things. He makes them, he cares for them, and he passes them on, free of debt, to the next generation.

Can there, then, be a shred of doubt in the mind of any reasonable man that the public good, the well-being of society, the advancement of civilization, the raising of the standard of life of the people, and all the highest and the best of economic aims can only be secured by a firm adherence to the principle of PRIVATE OWNERSHIP.

PRESIDENT ARKWRIGHT: I leave it to you if it isn't worth while. I think to praise it would be to detract from it. It is beyond praise. Again there can't be any possibility of a suspicion that Sir Ernest Benn's sentiments are not his own.

The next feature of the program is an address by Mr. J. F. Owens, the Chairman of the Public Relations National Section. Mr. Owens is also a Vice-President of your Association, and not like I was when I was a Vice-President; he is a working member of your organization. He has given a great deal of his time and talent to this Association and for the benefit of this industry, not only through the past year but for many years preceding that. I take great pleasure in presenting to you Mr. J. F. Owens, Vice-President of this Association and Chairman of the Public Relations National Section. Mr. Owens is also of the Oklahoma Gas & Electric Co., of Oklahoma City, Okla. Mr. Owens! (Applause).

REPORT ON PUBLIC RELATIONS NATIONAL SECTION

By J. F. OWENS, *Chairman*

It has been said many times, but will bear repetition, that, unlike most other businesses having an intimate bearing on the public well-being, the electric light and power business has grown up within the remarkably short space of forty years and in that length of time has assumed staggering proportions and a relatively vital importance in the financial, social, industrial and educational life of the country. It might almost be said that it is the warp of our modern social fabric.

No small part of the progress made has been linked with the activities of the National Electric Light Association, of which the Public Relations National Section is a major division.

Purposes of This Section

The Public Relations National Section is organized for and devoted to the purpose of encouraging member companies to disseminate information that will give their employees and the public an understanding of the problems involved in the financing of electric light and power companies, and the furnishing, at fair rates, of continuous, dependable electric service. Its major purposes are:

To encourage member companies in so developing and training members of their organizations that employees will be able to interpret the industry to its customers and the public;

To act as a clearing house through which such ideas and practices as are found helpful in one company or section of the country may be made available to all;

To bring about and maintain a ready acceptance by the public of sound securities issued by the industry;

To be prepared, through study and research, to furnish accurate information on national problems mutually affecting the industry and the public;

To foster and develop cooperative work with legitimate agencies for the dissemination of such information, to the end that friction born of misunderstanding or misrepresentation, shall be eliminated and the stability of the electrical industry be maintained.

The Section's Work

In the main, the work of the section throughout the past year has consisted of the carrying forward of plans and policies evolved and partially developed during the preceding year.

As in the past, it has operated mainly through the eight major committees. These committees are:

Cooperation with Educational Institutions
Customer Ownership
Industrial Relations
Information Bureaus
Manufacturers' Advertising
Public Speaking
Relations with Financial Institutions
Women's

Through the investigation still under way by the Federal Trade Commission, the activities of some of these committees have been the subject of discussion and editorial comment in the public press, and for that reason it is felt that in presenting this report a review of their purposes and functions deserves special attention.

The Cooperation with Educational Institutions Committee and the Committee on Information Bureaus have been, during the past year, the focal point of attack from certain sections of the press.

The Committee on Cooperation with Educational Institutions was established in 1923. Its purpose, as set forth in the Organization Personnel, is "to bring about a closer understanding and better methods of education with reference to public utilities in the higher institutions of learning."

At the beginning, it proceeded carefully and somewhat slowly in mapping out its functions and establishing a concrete program. This is justified as a matter of policy in any new undertaking along an unmapped course, and is entirely appropriate, first, in connection with an organization voluntary in its nature, and, second, in connection with any program which ultimately must be determined and approved by educational authorities of the nation.

Coordinated Organization Planned

In respect to the work of this committee in the past, it may be said that there never has been and is not even now a coordinated organization representing both the National Association and its geographic and State divisions. This is not due, at least primarily, to any lack of appreciation of the importance of the matter itself, but, as pointed out in the National Committee meeting in 1926, it is primarily due to the lack of establishment of a national program and correct guiding principles of cooperation in the public interest on the one hand, and meeting the approbation of educational authorities on the other. At the 1926 meeting of the committee, it appeared very clearly that two things were necessary:

First—the mapping out of a cooperative program, useful in itself, and meeting the approbation of educational authorities.

Second—the establishment of such machinery within our own organization, always recognizing its voluntary nature, as would be best calculated to carry out the program that was finally established.

It was with the thought of ascertaining the extent to which this cooperation had existed and with mapping out a program through which it might be promoted that it was finally determined by the committee, which had already made recommendations as to cooperation, that the definitive program should be based upon an actual survey of the situation in respect to cooperation in the various parts of the country, and this led to the securing of the services of Dean C. O. Ruggles, then with the Ohio State University, for the purpose of making such a survey. This survey has been carried out, and a report, made by the educators of the committee, will be forthcoming in the near future.

During the last year there has not been a meeting of the full committee. The educational members have been in conference with Dean Ruggles in connection with the survey. The matter of organization within our own ranks seemed to be one which should primarily be given study by our own representatives, and the utility representatives on the committee met on March 4 and 5 of this year. They made a report and recommendation for consideration by the Executive Committee of the Public Relations National Section. This report and recommendation is as follows:

The Committee's Report

"This committee has considered the general situation in respect to cooperation by the industry with higher educational institutions. In our opinion it has been clearly demonstrated that this cooperation is not only of mutual benefit but that it serves the public interest and should be continued and further developed.

"There are, however, certain essential facts which we believe worthy of the most serious consideration. During the last year, this industry has been subjected to criticism in relation to some of the cooperative activities, and there exist in some quarters a misinterpretation of our motives and the opinion that there has not always been shown a complete appreciation of the high ethical standards which must at all times prevail in such activities. This committee is convinced that modification of our present organization would reasonably provide in the future against any occasion for adverse criticism of cooperative relationships and further strengthen the field of useful cooperation.

"The actual functions of cooperation have been generally exercised by organizations neither directly related to, nor cooperating with, this committee. The committee has lacked such contacts with State or local cooperative agencies as are essential for the formation and promulgation of national policies.

"We recognize the fact that cooperation cannot be exercised efficiently or in the public interest merely through a centralized committee out of touch and inadequately acquainted with local conditions, demands or sentiments. Our organization rests upon a basis of voluntary cooperation as its mainspring. The major responsibility must remain local and any attempt at centralized control would be ineffective. A survey of the entire situation leads us to the following conclusions:

"First: That it is desirable that there should be established in an authoritative way guiding principles to control future cooperative activities, such principles being in general those which should prevail between educational institutions on the one hand and electric light and power companies on the other hand. It is our belief that such principles can be best declared in an authoritative way by educational administrators of national standing and experience. We recommend to our Association the furtherance and encouragement of such measures as may be best fitted to secure such declaration of principles.

"Secondly: We recommend more efficient cooperation within our organization to assure sound development of relations with educational institutions, free from legitimate criticism, and such as to sustain with the educators that confidence in our activities and purposes that must at all times prevail if the best interests of the public and all concerned are to be served. We believe that the following plan will lead to this result without trespassing on the full measure of local responsibility in such activities and we recommend that steps be taken to put the plan in effect in the immediate future.

"We recommend that each geographic representative of this committee take up with leading executives in each State within his division the initiation of such steps by the utility executives in connection with administrative heads of educational institutions as will bring about in each State the selection of an industry representative satisfactory to the educational institutions to whom in each State there shall be referred for approval all proposed cooperative activities.

"We further recommend that such representatives be requested to act as the State representatives on the geographic division committee of this committee."

These recommendations have been endorsed by the Public Relations National Section Executive Committee and by the Executive Committee of the National Electric Light Association.

Educators' Attention Deserved

Certainly, our industry occupying such an important place in the scheme of things deserves the careful attention of educators. So rapidly has it grown and so rapidly is it developing that it is almost beyond the power of those in intimate contact with its development, those who are wont to call themselves a part of this development, those whose brains and minds and hearts are given to it, to keep abreast of its progress in all of its phases.

If this business of ours is destined to play in the future even a more important part than it has in the past in the social, economic and industrial life of the nation, it is important enough to have brought to bear upon its development the best thought of the best trained minds in the nation. It is important enough that the youth of the land, who are being poured out annually from the colleges and universities of the country into this whirlpool of the present social order, are allowed to drink from the running stream of current facts, rather than from the stagnant pool of worn out ideas, pools poisoned as they frequently are by the sophistries of discredited theorists. That the youth of the land going forth from our great universities, to be the moulders of public opinion in the future, should have the benefit of facts relative to the evolution and operation of our business goes without saying.

If the students of the universities and colleges are to drink from the pure stream of current facts, they must have free access to the only reliable source of information: the great operating utilities of the electric light and power industry.

It is through these companies that the product of the minds of thousands of men and women, who have been and are engaged in research and study into nature's laws; that the product of manufacturers, who have taken these laws and fabricated out of them instruments through which the laws might be applied for the comforts and conveniences of mankind, have found practical application to the every day needs of modern life of the mechanical genius of the one, and the discoveries of the other.

Companies the Logical Source for Information

What better than the operating companies can be found to serve as a basis for authoritative information of electricity to modern day needs? Where is the educator to go, if not to the electric light and power companies, for the information that he needs in fitting the young minds in his charge to cope with the problems which the introduction of this new force is bringing to the social order?

It was with the full realization of the duty that the electric light and power industry owes to those whom it serves, that they should be able to secure from authoritative sources accurate information on our business, that the Cooperation with Educational Institutions Committee was established. For, let it be said here, that our obligation to the public does not end with the furnishing of an ample supply of electric energy at the entrance switch to the house or factory, but we owe the public the duty of seeing to it that the information given to the youth of our land is accurate, current and in keeping with the facts.

Be it said in passing, that most of the cooperation that had hitherto existed between educational institutions on the one hand and electric light and power companies on the other had its inception in the eagerness of educators to gather from electric light and power companies the facts needed by them for proper presentation of the industry's place in the modern scheme of things.

Be it said further that in too many instances electric light and power companies are yet unmindful of their obligation, not only to those of our own time, but to those who shall follow, and are indifferent to the justice of the request of the educator and to the importance to the industry and to the public of complying with his request. I believe it to be the duty of those engaged in the electric light and power industry, when they realize that institutions of higher learning are not being adequately supplied with facts relative to our business, to take the initiative in seeing that such contacts are made as will warrant educators in believing that they can secure accurate information about the financing and operation of electric light and power companies.

Work of the Information Bureaus

Mention was made earlier in this report of the activities of the various Information Bureau organizations.

In keeping with the feeling on the part of many leaders of the industry that the public should be kept fully informed by operating companies, using for that purpose the recognized channels of information, and to set up for companies unable to maintain such equipment for themselves a vehicle through which this information could readily be conveyed, Information Bureaus were established in most of the States of the Union.

In the main, these bureaus have served a very useful purpose, and through their operation has been set up a source of information which the recognized media for the dissemination of facts have found to be authoritative and helpful. Newspapers have, in the past, come to lean on these bureaus for news that to them appeared timely relative to the progress and growth of the companies in their State. Speakers and writers have found the information furnished by these bureaus timely and accurate.

Since the establishment of the Information Bureaus, however, mergers and consolidations have eliminated many of the smaller companies, making it possible for the units so formed to maintain, as a part of their personnel, experts in the matter of assembling and distributing information relative to the operation or financing of the companies. For this reason, there has grown up in the minds of some a feeling that the usefulness of the Information Bureaus has passed, and that their functions can well, and perhaps better, be taken over by the operating companies themselves, who, after all, are charged with the responsibility of seeing to it that full and accurate information is obtainable by and given to their customers.

The question of the continuance of these Information Bureaus is food for thought, but it is felt that the solution lies with the individual companies within the States maintaining bureaus.

Gaining Public Confidence

Any business, if built on a lasting foundation, must have the confidence of those whom it essays to serve. To gain this confidence and hold it, the organization must deserve it. A business can deserve it only by adopting as a policy in the transaction of its business the old-fashioned virtues of honesty, fair dealing, straightforwardness, and a willingness at all times to give fully and freely information of any kind and character pertaining to its business.

Particularly, in the utility business is confidence the basis of any sound and lasting prosperity.

As one studies the progress of the human race and the development of society, he is convinced that no movement that has made for social progress has long lasted, unless it had as its motivating force a conscious purpose to make of the movement something beneficial to those whom it would serve.

Business is but one branch of our social order. But lasting business, like any other function of society, must have as its objective a beneficial influence on the race.

Measured by this test, our business has within it an inherent contribution to the advancement of the social order.

Through the use of electrical energy, men and women are relieved of back-breaking drudgery and hours of endless toil. Their God-given minds are free to reach out toward higher development. We are no longer content to do with manpower the hard work that can be accomplished with electricity and steam.

New Uses for Electrical Energy

Each month, in fact, almost every day, new applications are being found for electrical energy. New machines are being perfected to relieve man of still another form of labor. The American farmer, through the application of the products of American inventive genius, soon will find the drudgery, which constituted the greatest obstacle to the retention of keen business minds on the farm, a thing of the past. Already the isolation, characteristic of the farm a few years ago, is but a memory. Electricity has done all this, and we have been a part of it.

It is interesting to contrast the present day mode of life with what obtained ages ago, when human lives were held cheaper than the products of the quarry, and thousands of men were worn out in the erection of the great structures that stand as perpetual protests and reminders of the sacrifices of human energy that went into their making. Contrast our present age with the days when men were chained as slaves to the galleys, pushing vessels of war and commerce across the seas; and, even in later years, the days when not only men but women and children toiled out their lives in the mines, factories and workshops of industry. American genius, American enterprise, fostered by American individualism, aided by American business, is fast bringing us to the time when, in America, electrically driven machinery will do our every task.

Through the efforts of the men of this industry, in cooperation with manufacturers and scientists, electric power plants are taking from the earth its stored energy in the form of coal, oil and natural gas, and converting it into the most mobile form of energy—electricity—and transmitting it to the home and the factory, and, with it, performing the labor of 350,000,000 men.

Think of it, every man, woman and child in America, has at his beck and call an average of three, willing, tireless servants, never complaining, ever ready to do his bidding. Is it any wonder that America is prosperous? You men and women of the electrical world have seen your genius, your industry, your enterprise, remake a world. I say, therefore, and I say it with pride, that our industry has within itself inherently those qualities which, if honestly applied to the service of mankind, should and will insure its stability and its lasting prosperity.

Our task is made the more difficult because we are, by the very nature of our industry, a monopoly. The lengths to which men have gone to free themselves of monopolistic power have demonstrated the fact that men do not readily give up the right to pick and choose of their own free will, those upon whom they would bestow their patronage. We, therefore, have a handicap in obtaining and retaining public goodwill not encountered by those engaged in competitive businesses.

The industry has been successful in applying the laws of nature and the products of inventive genius to our problems. We have won the confidence of the leaders of the financial world. This is much, but it is not enough. Our future depends upon the degree to which we can obtain and retain the confidence of those, who, in the last analysis, are the makers or unmakers of business and government, "the folks back home."

"The Proper Study of Mankind—"

Years ago, the immortal Pope said, "The proper study of mankind is man." What a world of philosophy, what a treatise on all human relationship is bound up in this short, terse sentence.

After all, it is not enough that we conduct our business with honesty of purpose, with an unselfish desire first of all to give to our customers the full measure of service, beaten down and running over, but that our customers must know and feel within their inner-being that we are honest. In short, they must believe in us. This is my reason for saying that, in the end, public relations begin and end within our own organization.

Our business has grown up through an era of great mechanical development. The best minds of the world have been directed toward drawing from the mines of the hidden recesses of nature her jealously guarded secrets. They have patiently, by day and by night, woven these secrets into recognizable laws. Other men, through employment of their inventive genius, have made it possible, through the development of mechanical processes, to apply these laws. We have taken up the gauge at this point and are carrying it forward for the benefit of the home, the farm, and the factory.

We have been very careful in the selection of the mechanical equipment that enters into our business. We have employed every known test to determine its fitness for the job. But, have we been as careful in the selection of the human element, chosen to interpret our business and the organization we have set up, to the public? In the end, the public will think of us as they think of the men and women whom we have associated with us as the interpreters of our business to those intimate circles with whom these men and women come in contact. The question, therefore, of so-called Industrial Relations is at the very heart of our Public Relations.

The Industrial Relations Committee's Job

The Industrial Relations Committee of the Public Relations National Section has been formed for the purpose of giving to this all important phase of our business, the intensive study which we have hitherto given to the mechanical aspects of the business. No man or woman should be selected for a position in an electric light and power organization until, at least, every known test by which his fitness for the job and the determination of whether or not he possesses the qualifications to assume greater responsibility, has been applied. This is not enough. He must be so informed about the business in which he is engaged that he can properly and adequately interpret this business to his neighbors and friends, and I am of the belief that, to the extent that he goes beyond the sphere of his ordinary activity to extend opportunities for this interpretation to that extent does he merit recognition and advancement. Nor yet is this sufficient. In the mechanical field, we are won't to test from time to time the condition of the equipment employed, properly to discharge its functions. What about the human element of our business? Are we concerned about the conditions under which the men and women employed in our industry work, and do we go beyond the hours of employment and learn of the stresses and strains that may sap their mental energies and may impair their fitness for the job? In too many instances, I fear not.

When we have given at least as much attention, care, thought and study to the human element of our business as we have given and are giving to our mechanical equipment, then, and not until then, shall we have the right to expect our employees enthusiastically to help us build our organizations into, and a part of, public confidence and goodwill.

In the past year the Industrial Relations Committee has issued two serial reports. These reports are the result of special surveys made to determine what methods and means have been employed in the selection and training of electric light and power company employees, and what measures have been adopted and followed by progressive companies in safeguarding and promoting the health and happiness of employees. I commend these reports to your earnest consideration, feeling, as I do, that they are a real contribution to our business.

Recommendation by the Customer Ownership Committee Approved

The Customer Ownership Committee brings to the industry a very definite recommendation. On the theory that our responsibility to our stockholders does not end with the acceptance by them of our securities; on the theory that the good name of the industry is something of which we should be most jealous, the Customer Ownership Committee feels that there should be some sort of impartial tribunal to which men and women, who have purchased our stock and are offered in exchange therefor other securities known to us to be of doubtful value, may appeal, with a consciousness that they shall secure an unprejudiced verdict. Therefore, the Customer Ownership Committee recommends cooperation on the part of electric light and power companies with the Better Business Bureaus of the Nation. These bureaus are doing a great work. They have the facilities for impartial investigation. They should be supported. The recommendations of the Customer Ownership Committee have been approved by the Executive Committee of this section, by the National Executive Committee and by the Public Policy Committee.

Public Speaking and Employee Training

The Public Speaking Committee has had a remarkable year of achievement. More talks by employees about our business, in an unselfish effort to interpret it to the public, have been made this year than ever before. But, the important phase of this public speaking program is not the number of talks that have been made, but that "something," which once an employee has been able to give expression to the thoughts that are in him, wells up in him and makes of him a different man or woman. As a method of employee training, I commend to the electric light and power companies of the country, public speaking.

Our relations with financial institutions were never better. We enjoy the confidence of the investing public.

Women's Committee's Activities Praised

I cannot close this report without paying a tribute to the marvelous spirit that has been developed among the women of our industry through the activities of the Women's Committee, cooperating, as it has in that most estimable of all recent departures, the Home Service movement. Pointing the way, as its leaders have done, to the women of the industry to enlarge their opportunities for service, and to broaden their sphere of activity. Encouraging, as this committee has, our women to know their organization, to know its policies and its hopes, and, knowing, to interpret these policies to the women of the nation; this committee has made a lasting contribution to the industry.

We owe to Miss Malicki and her devoted staff a debt which is beyond our power to liquidate.

The women of our industry have demonstrated in many, many cases, that it is possible for the public to know us as we know ourselves to be.

It has been my good fortune during the past year and a half to come in contact with many of the leaders of our industry. I say to you in all frankness and sincerity, that I do not believe there will be found in any other line of business, on the whole, men and women more genuinely interested in the wellbeing and welfare of those whom they serve. I have found, by and large, that these men and women are recognized in the communities in which they live as leaders of thought and leaders of action. They are known to be good citizens. They are a part of, if not leaders, in every movement in their communities, making for progress and community betterment.

Past Record Assures Future Progress

Friends, these men and women, and not a few scattered individuals who may have so far forgotten themselves as to exploit the public for their own individual selfish ends, constitute the electrical industry in these United States. These energetic, honest citizens, engaged in our great business, might hurl into the teeth of their critics this query: "What, sir, have you contributed of your energy to the wellbeing of labor and industry? How have the fireside, the farm, the mine and the factory and those toiling therein been benefited by your life? We, of the electric light and power industry have hazarded our all in bringing to our citizenship opportunities for greater leisure, greater comforts, greater happiness. What have you done, except to carp and criticize, and to hinder? Are we, the honest men of the industry, to be pilloried because a few have gone the way of many other men since the dawn of society and departed from the straight and narrow way, and is not the startling record of our accomplishments in the past forty years worth something in the balance?"

The accomplishments of the past are but an index to what the accomplishments of the future may be. Our industry will continue to be a constructive force in the life of the nation only as we deserve it. It will be stable only as we are right. Being right, as I believe the industry is, as nearly as it is possible for any human agency to be right, let us not hesitate to continue to give to those for whom we are trustees of a very important service, an account of our stewardship. Let us continue to fight for what we believe to be in the best interest of the American people. Let us not stoop to pettiness. Let us not sully our great industry by deeds that will not bear the searching light of day. The record of our accomplishments reveals the contribution to society and the race too valuable to need anything but straightforwardness to insure lasting prosperity of the electrical industry.

PRESIDENT ARKWRIGHT: Mr. Owens gives evidence of the wise plan of former directors in the organizing of this Association. We always have a better president coming on.

MR. C. E. GROESBECK: Mr. President, I want to suggest that we send a cablegram to Mr. Benn, telling him that his pictures were shown to this distinguished audience of about twelve thousand people from all over the country, expressing our great appreciation of the wonderful message that he has sent to us. I think it would be a proper, right and fitting thing to do. (Applause).

PRESIDENT ARKWRIGHT: Mr. Groesbeck suggests that it would be appropriate for this audience to send a cablegram to Sir Ernest Benn of London, expressing our appreciation to him for the wonderful message he gave to us. We can't do it in person to him, although it seemed that he was here in person. I think it is a most appropriate suggestion.

If you favor it, will you please say "aye."

[The motion was adopted.]

In connection with the talking motion picture, it is the purpose, as Mr. Clapp explained, to have a talking motion record made of this convention to be sent to the various geographic divisions. It is a very useful, graphic means of presenting matters and subjects. Those of you who are interested might find it profitable to visit the exhibit of the Electrical Research Products, a subsidiary of the Western Electric Co., and a member of this Association, which is featuring a display of commercial talking pictures in the exhibition hall.

The next number on the program brings to us a gentleman who is not new to the electric light and power industry, a lawyer, and associated with the Pittsburgh companies, over a long period of years, previously president of the Philadelphia Co., merely changed from one capacity to another. He is now the Chairman of the Board of the Westinghouse Electric & Mfg. Co. In that particular capacity this is his first general public appearance. He will talk to us this morning on the subject of the "Customer's Side of the Meter," and it is a great pleasure to present to you Mr. A. W. Robertson, Chairman of the Board of the Westinghouse Electric & Mfg. Co. Mr. Robertson. (Applause).

THE CUSTOMER'S SIDE OF THE METER

By A. W. ROBERTSON

Chairman of the Board of the Westinghouse Electric & Manufacturing Company.

As is often the case, this brain-child of mine had to be named before it had seen the light of the day, and after I saw it I realized that instead of calling it "William Ganson," I should have called it "Bill," because it is altogether too simple a story to have this broad title ("The Customer's Side of the Meter"); in fact, a sub-heading of this nature, "The chain from the power plant to the customer's service is no stronger than the weakest link," would be more appropriate. When we know what a marvelous change takes place in the electrical product, as it moves from the power plant to hot coffee in the customer's house, I think we realize that that chain is a long one and has many links.

Far back in the dim past it was probably true the meters between the public utility company and the consumer formed a Chinese wall that separated one from the other, but that wall has long since been broken down and now the customer's service receives the best thought of the industry and that thought is not entirely prompted by reason of the fact the customer's side of the meter shows the number of kilowatt-hours consumed from which we figure the bill.

It would not, however, be wise to discuss the consumer's side of the meter, if the public utility's side had not already received thorough attention.

The other day I attended the ceremonies at the Hell Gate Station of the United Electric Light and Power Company in New York, celebrating the placing in service of two giant 160,000-kw. turbines—the largest and most economical in the world. Each of these enormous machines is capable of furnishing electric current to light a million homes. Today, all over the United States, machines very similar to these are generating electric current at a cost which, years ago, would have made Thomas Edison and George Westinghouse exclaim in unbelieving surprise.

We know that before the enormous quantity of electric current being generated in America reaches the homes it serves it must be transmitted over thousands and thousands of miles of wire, it has to pass through transformers to curb and tame it for domestic use, and its path must needs be protected by expensive switches and automatic circuit-breakers to guard it from its cousin—the lightning of the skies—and from its own inherent tendency to break through all restraint and vanish into universal energy.

The Magic of Electricity

The magical development of the art of producing electric current is a story with which we are all familiar, as it happened within the lifetime of most of us. Sometimes I think our very familiarity with this story destroys for us the glory and majesty with which it is surrounded. No other conquest of the forces of nature can compare with it. Here we have an energy which is beyond the reach of our senses—which we can neither see nor hear nor touch—which is created in such a powerful form that it is death for us to ascertain its characteristics directly—and yet we cause it to fly along the wires with the speed of light—seven times around the world in the wink of an eye—and we deliver it to all points on the system—gentle, harmless, and ready to serve our customers as they may desire.

Into the producing of this electric current, billions of dollars of investors' money have gone for building power plants, transmission lines, cables, substations, and all the rest that goes to make up the great generating and distributing facilities of the industry; more billions have been spent to reduce the cost of electric current, with the result that it is today recognized as being one of the cheapest commodities in America; while still more billions have been utilized in making electric power service a synonym for reliability.

Reliability Wins Confidence

This thought of reliability brings to my mind the fact that, during the past year, it has been the custom of some agencies to attempt to discredit the light and power industry in every possible way; but, without complete confidence in the power companies, would investors universally depend upon them for the power needed to make productive their investments in factories, hotels, theaters, halls, apartment houses and homes? In the old days, every factory had its own power plant, for no one would depend upon a disinterested third party for the power which alone could make a factory operative; but today, every modern factory buys its power from a public utility company, no one thinks this reckless or imprudent, because everyone respects the good faith and the integrity of the power companies, and the maligners of the industry have yet to find one single customer who can show that the power companies have ever been untrue to the confidence placed in them.

This, I claim, is one of the proudest records to which any organization can point, and it explains why the nefarious propaganda of a few people has been unable to disturb the prosperity and steady growth of the power companies. As long as they continue to deserve this confidence, so long will the slanderous tongue of the envious be harmless to them. It is no wonder, therefore, with this proud record back of us, that so much attention has been given to the producing side of the meter.

The Customer's Side

But, we must not forget the other side. The customer's side is vastly different from the company's side. On the company's side are kilowatt-hours, amperes and watts, circuit-breakers, turbines, condensers and countless other things. On the customer's side, there is not even electric current, as the producer thinks of it; no kilowatts, no amperes, no watts.

What the customer buys is, first of all, light—not electric current, but light. Then he buys heat; or, rather, hot fragrant coffee, crisp bacon, hot toast and waffles, and all the magical things that come out of the chafing dish and off of the electric range. Finally, he buys some form of action, such as is manifested by the vacuum cleaner, the washing machine, the ironer, the electric fan, and many other devices—but none of these things purchased by the consumer have the remotest connection in his mind with kilowatt-hours, or watts.

Customer's Interpretation Important

All this is very simple and is very well known to all of you, and I fancy that some of you are saying:—"Well, what of it? We know very well what the consumer does with electric current!" But the importance of it lies in this fact:—if the consumer is primarily interested in buying hot coffee, rather than kilowatt-hours, from the great power company that serves him, then that great power company must interest itself in furnishing that coffee; provided, of course, the customer cooperates to the extent of providing a few coffee beans and a little water to help out the transaction.

Someone started the legend in China that people pay the doctors to keep them well. I can imagine some time in the future that consumers of a public utility company will pay it for keeping their appliances well. In other words, the public utility company will furnish a service over and above what it furnishes in the way of electric power, namely, the servicing of the appliances which the consumer has, keeping the cords in shape, and so on, so that every appliance is ready to do its appointed task, but whether the problem be solved in this way, or some other, it is undoubtedly the path of wisdom for all of us to serve to the end that the customer may be served in the manner which pleases him, and there is something about the idea of the power company being interested in furnishing hot coffee that pleases all of us as individuals. I, myself, when I drive up to the Standard Oil service station get a real thrill when the Standard Oil Co. wipes off my windshield. I think we are all alike in that respect.

Service in Terms of Things Wanted

How are we meeting this problem of furnishing the customer not with electric current, but with the services which flow from the proper use of electric current? One thing is certain—the response of the customer in the use of electric current will be exactly commensurate with the service he receives expressed in terms of the things he wants. In other words, if the electric iron works perfectly, the housewife uses it frequently and buys another as soon as it wears out—if a modern iron ever does wear out. If the vacuum cleaner is reliable, it is constantly in service and is replaced by a new one as soon as it is done for—and so on.

But if the iron is unsatisfactory, due to some fault in the iron, or the circuit, or what-not, it goes onto the shelf and the housekeeper sticks to the good old-fashioned things she was brought up with. So it would appear to be the better part of wisdom to see that the facilities which enable consumers to receive in their homes those comforts and conveniences which they want are maintained in a high state of efficiency. Their reliability must be unquestioned—they must be economical—they must be convenient—they must be serviceable—and they must, of course, be fool-proof, so that they may be used frequently without any danger whatever.

Who Is Responsible to the Consumer?

We have already reached a high degree of perfection in meeting this standard, but it is a field where there is much yet to be done. Neither the power companies nor a few manufacturers control the situation. The facilities used in the average home are produced by more than 1000 manufacturers and are for sale in more or less variety in at least 25,000 electrical, department, hardware, and other stores. The power company might well say that if it controlled the appliances the consumer fastens to the sockets, it could then be sure that the service would be exactly what the most exacting critic would require; but inasmuch as the consumer is free to buy his appliances from anyone, the power company is absolved from all responsibility. There is nothing to prevent the power company from taking this attitude, but that will in no sense relieve it from the criticism the consumer is going to make when he fails to get the hot coffee which he conceives he is buying from the power company. In other words, the power companies and the electrical industry as a whole are going to be blamed for the failure of any member of the industry, whether he is a maker of switches, coffee percolators, Christmas tree devices, or what-not, all of these simple things contribute to making electric service good or bad, as far as the consumer is concerned; and if it is bad, he is dissatisfied and lends a willing ear to the gossip of the faultfinder.

As I said in the beginning, much has already been done along this line, but I believe we can do very much more if we will look upon our merchandising facilities, not only as money-making departments to be run on a sound economic basis, but also as places where the right type and kind of appliances at different price levels are on display for the information of the customers of the power company.

We should stimulate architects and builders to put into new homes and apartments only standard, high-grade appliances. Encourage in every way possible the use of right appliances as against unreliable devices, which, if they should fail, bring down upon the heads of manufacturer, public utility, and all of us, criticism which is difficult to answer. (Applause).

PRESIDENT ARKWRIGHT: We thank you very much Mr. Robertson.

The next item on the program is a report of the Constitution and By-Laws. Mr. R. F. Pack, Chairman, former president of the National Electric Light Association. Mr. Pack.

REPORT OF CONSTITUTION AND BY-LAWS COMMITTEE

BY R. F. PACK, *Chairman*

(For Committee Personnel, See Appendix 4)

The Constitution and By-laws Committee has suggestions to make of revisions to the Constitution. These recommendations have already been approved by the Executive Committee. The purpose of these changes is to adjust the dues of Class "F" and Class "H" member companies, so that these members may pay more nearly the cost of servicing them. Section 6 of the Constitution provides the dues to be paid by company members under Class "F." These dues are on a sliding scale, and it is probably unnecessary to read them to you now. It is proposed to amend Section 6 of Article IV to read as follows:

> "SECTION 6. The annual dues of Associate Company Members (Class 'F') shall be based on the gross sales from the sale of electrical apparatus, equipment, appliances, publications or service by the company, firm or individual during the preceding calendar year. The rate of dues for Class 'F' members shall be one one-hundredth of one per cent (1/100 of 1%) of such gross sales for such period. The minimum dues of any Class F member shall be Twenty-Five Dollars ($25) per annum, which minimum dues apply only when the gross sales during the preceding calendar year were not greater than Two Hundred and Fifty Thousand Dollars ($250,000)."

It is proposed also to amend slightly Section 7 of Article III. This provides the designation of Class "F" members, and among other companies it refers to electrical jobbers. Inasmuch as electrical jobbers are now more generally known as "electrical wholesalers," it is proposed that Section 7 shall read as follows:

> "SECTION 7. Class 'F' members shall be companies or firms of electrical wholesalers, contractors, dealers, electrical or mechanical engineers, publishers and associations—corporations or individuals—who are interested in advancing the use of electrical energy, and are not engaged in its production or distribution. They shall have the same privileges as Class 'D' members, except the right to vote at executive sessions."

Finally, it is proposed that Section 8 of Article IV now reading as follows:

> "SECTION 8. The annual dues of Foreign Company Members (Class 'H') shall be Twenty Dollars ($20)."

shall be revised to read as follows:

> "SECTION 8. The annual dues of Foreign Company Members (Class 'H') shall be Fifty Dollars ($50)."

Mr. President, I understand that under the Constitution it is necessary to appoint a Constitutional Revision Committee which will report later on the suggestions of the Constitution and By-Laws Committee.

PRESIDENT ARKWRIGHT: You have heard the report of the Committee on Constitution and By-Laws. The Constitution requires that this report before being acted upon must be referred to a committee elected by the Association and resubmitted on their report, and requires a two-thirds vote of Class "A" and "B" members present to adopt it.

It has been customary to appoint as the Constitutional Revision Committee the same personnel which compose the Constitution and By-Laws Committee. That personnel consists of Mr. Pack and the President and four Vice-Presidents of the Association.

MR. H. M. EDWARDS (New York Edison Co., New York): Mr. President, I move the adoption of the suggestion that the personnel of the Constitutional Revision Committee be the same as the personnel of the Constitution and By-Laws Committee.

The motion was seconded by Mr. L. B. Herrington (Kentucky Utilities Co., Louisville, Ky.).

PRESIDENT ARKWRIGHT: The motion has been made and seconded. Is there any discussion? If not, I will put the motion.

[The motion was put to a vote and carried.]

PRESIDENT ARKWRIGHT: The next item on the program is the eelction of a nominating committee to present nominees for the various offices of the Association for the ensuing year.

MR. SIDNEY Z. MITCHELL (Electric Bond & Share Co., New York): Mr. President, I nominate Mr. W. W. Freeman.

[Mr. William H. Taylor (The Philadelphia Electric Co., Philadelphia, Pa.) seconded the nomination.]

[MR. CHARLES L. EDGAR (Edison Electric Illuminating Co. of Boston): Mr. President, I nominate Mr. R. J. Graf.]

[Mr. W. Paxton Little (The Niagara Falls Power Co., Niagara Falls, N. Y.) seconded the nomination.]

MR. THOMAS N. MCCARTER (Public Service Electric & Gas Co., Newark, N. J.): Mr. President, I nominate Mr. Franklin T. Griffith.

[Mr. Louis H. Egan (Union Electric Light & Power Co., St. Louis, Mo.) seconded the nomination.]

MR. HERBERT A. WAGNER (Consolidated Gas, Electric Light & Power Co. of Baltimore, Md.): Mr. President, I nominate Mr. C. E. Groesbeck.

[Mr. F. R. Phillips (The Duquesne Light Co., Pittsburgh, Pa.) seconded the nomination.]

MR. GUY W. TALBOT (Pacific Power & Light Co., Portland, Ore.): Mr. President, I nominate Mr. Martin J. Insull.

[Mr. D. C. Barnes (Stone & Webster, Inc., Boston, Mass.) seconded the nomination.]

PRESIDENT ARKWRIGHT: Are there any other nominations?

MR. R. F. PACK (Northern States Power Co., Minneapolis, Minn.): Mr. President, I move that the nominations be closed.

The motion was seconded by Mr. J. E. Davidson (Nebraska Power Co., Omaha, Neb.)

PRESIDENT ARKWRIGHT: Those in favor of the motion made that the nominations be closed please say "aye." Opposed, "no."

[The motion was adopted and nominations closed.]

PRESIDENT ARKWRIGHT: If you vote to elect the gentlemen named, W. W. Freeman, R. J. Graf, Franklin T. Griffith, C. E. Groesbeck, Martin J. Insull, as a nominating committee, please say "aye." Those opposed, "No."

The "ayes" have it, and the motion is unanimously adopted and they are elected.

Before adjournment I should like to call attention to the fact that two of the national sections of the Association have their meetings this afternoon. The Accounting Section at the Hotel Chelsea at 3 o'clock; the Engineering Section in this hall at 2:45 o'clock. There will be no general sessions, that is, if you call these general sessions and those not, but they are very instructive and educatioanl and desirable to attend, and the reason why the so-called "genearl" session is not continued into the afternoon is that we may have an opportunity to attend these various section meetings. I hope very much you will do so.

The next general session will be held in this hall tomorrow morning at 10 o'clock. We hope to start it as today, promptly at 10.

In addition to the other features of interest, variety will be added to the meeting, for you will have a different presiding officer. (Laughter.)

I wish to thank you for your prompt attendance, your kind attention, for your responsiveness to the speakers, and remind you that it began on time, moved promptly and ends early, as I hope they all will. The meeting is adjourned. (Applause.)

[The meeting adjourned at 12:40 p. m.]

SECOND GENERAL SESSION

WEDNESDAY, JUNE 5, 1929

[The meeting convened at 10:05 a. m., President Arkwright presiding.]

PRESIDENT ARKWRIGHT: The convention will please come to order.

Mr. Matthew S. Sloan, Vice-President of the National Electric Light Associatoin, will preside over the first half of the morning session. Mr. Sloan!

[Mr. Sloan took the Chair.]

CHAIRMAN SLOAN: The first order of business on the morning program is the announcement of the Memorials Committee. The President asked me to say that he has appointed Mr. W. H. Onken, Jr., Chairman of the Memorial Committee.

We will now have the report of the Exhibition Committee, presented by Mr. E. W. Goldschmidt, Wagner Electric Corporation, New York. (Applause.)

REPORT OF EXHIBITION COMMITTEE

BY E. W. GOLDSCHMIDT, *Chairman*

(For Committee Personel, see Appendix 4)

Our constitution declares the object of the Association to be "to advance the art and science of the production, distribution and use of electrical energy of light and power for public service," and that in furtherance of this object its activities should be largely educational and for the fullest development of the electrical engineering arts and sciences in all its branches.

I don't want to make any extravagant statements, but I submit that the exhibition in the adjoining hall conforms to the object as stated and meets the specifications as to educational value.

The Association membership includes every branch of the industry. Every firm or individual, active or only interested in advancing the use of electrical energy, is welcome to apply for membership.

The practical application of electricity to the service of humanity actually began with Mr. Edison's invention of the incandescent lamp and the means to use it effectively through a system of electrical distribution. This event we now celebrate on its fiftieth anniversary. In all cities electrical service has become a commonplace, but a vital necessity to our standard of living. The service is now being rapidly extended even to our farms. Further expansion is inevitable and apparently without limit.

All Classes of Membership Cooperate

It is only through the real cooperation of all the classes of membership in our Association that the marvelous achievements in applied electricity have been realized in this country. The spirit of cooperation prevailing among Central Stations, which are naturally non-competitive in their territories, has been passed on to the manufacturers and developed a parallel spirit of cooperation, although they are in keenest competition with each other for public favor. It is most gratifying to note that there is now no longer any evidence of a dividing line in activities between the class memberships of the Association. All are cooperating—working together for the advancement of the common purpose.

Prior to 1908 exhibitions at conventions were dependent entirely upon the initiative of individual manufacturers. The exhibitions were unorganized and haphazard. The invitation circular to the twelfth convention at Cape May in 1890, as printed in the recent May N. E. L. A. *Bulletin,* stated: "Although there will be no exhibition under the auspices of the Association, you can secure a sample room and display your samples in your own way to the hundreds of users of such supplies who will be at this convention." Some contrast!

In 1908 the Executive Committee authorized the manufacturer members to organize a committee from their own members for the purpose of conducting exhibitions at the conventions of the Association. The exhibitions were, for a number of years, held biennially (with some interruptions, such as the war years), but for the last four years have been annual convention events. They have grown quite steadily and consistently, in extent, educational value and participation. In 1908, 41 exhibitors took 3650 net square feet, an average of 89 square feet per exhibitor. In this 1929 exhibition we have 226 exhibitors taking 97,926 net square feet, an average of 433 square feet per exhibitor. The Class D (Manufacturers) membership has grown to 415. Some 200 or 300 more manufacturers whose activities should interest them in membership in N. E. L. A. were given the opportunity of becoming members. Participation privileges at the exhibitions have always proven strong incentives to manufacturers, influencing them toward membership in the Association. At least twenty-five additional firms this year indicated desire to join the N. E. L. A. provided they could secure space in this exhibition. Unfortunately, their interest was not manifested until all available space had been assigned and it had become impossible to accommodate them.

The 1929 Exhibition

Is today's exhibition not a remarkable accomplishment and a direct expression manifesting the manufacturer's unity of purpose to advance the entire industry and not only their own individual interests? No such exhibition as we have here today would be possible without their complete cooperation to this end. It is truly a great exhibition because it has, first, the most magnificent setting imaginable, one of grandeur and extent not available elsewhere in the world; second, because of the outstanding character of the exhibiting manufacturers who have cooperated to make this exhibition; third, because of the quality and variety of the products displayed and the individuality, originality and attractiveness of the individual settings provided by the respective exhibitors to match the standard of magnificence of the exhibition hall; fourth, because of the character of the manufacturing company representatives personally in attendance at this particular convention and exhibition. The result is this finest illustration of what may be accomplished by competitive cooperation on a large scale.

Spirit of Fairness and Cooperation Prevails

I have been honored with the Chairmanship of the Exhibition Committee for three conventions and have, therefore, been privileged to observe the spirit and attitude with which our manufacturing members responded to the Exhibition Committee's invitation to them to cooperate in making the exhibition a success. I am, therefore, well qualified to testify as to this particular spirit. It was participation in its actual work that completely convinced me of the Committee's spirit of utmost fairness to every member regardless of size or influence, and complete equality of members in participation in any and all privileges accorded the Class D members. This conviction is the reverse of a misapprehension which I felt when first elected to membership on the Committee. I believe this impartial treatment is largely responsible for the cooperative spirit which prevails.

I want to take this opportunity to express on behalf of the Committee appreciation for the splendid support that we have had during our work from President Arkwright, not only this year, but during the years of his vice-presidency. His enthusiasm, his stimulating expressions at every opportunity have been a great help to the Committee in spurring them on and making greater effort to have the exhibition a success.

I want also to make acknowledgment publicly here of the very great help that the manager of this auditorium, Mr. Lincoln Dickey, has been to us in making and completing the arrangements, enabling us to install the exhibits here without any disorder or any confusion whatsoever. The expressions we have had from our exhibiting members have all been extremely complimentary. Thank you very much. (Applause.)

CHAIRMAN SLOAN: The next order of business is the report of the Engineering National Section Committee. This report will be presented by Chairman E. C. Stone, of the Duquesne Light and Power Company, Pittsburgh.

REPORT ON ENGINEERING NATIONAL SECTION

BY E. C. STONE, *Chairman*

An outline of the activities and findings of the committees of the Engineering National Section was presented in my report to the Section at its session yesterday afternoon. The report embraced more detail than would be of interest to this general session. At this time I wish to call your attention only to one or two of the matters covered, as follows:

All of the committees of the Engineering National Section have been in active operation during the past season, and have functioned with their usual effectiveness. The objective of "more System Capacity per Dollar of Investment" has been definitely reflected in their work, as is shown in the marked attention given to the development of designs and methods which will make for greater economies.

Interest in Work Increases

The increasing interest in this work is shown by comparative analysis of the organization personnel for the administrative years 1927-28 and 1928-29. The number of member organizations participating in the work of the Engineering National Section increased from 201 to 221, or 10 per cent, and the number of individual engineers having membership on the various committees increased from 550 to 630, or 14½ per cent.

"More System Capacity per Dollar of Investment" is emphasized because of the increasingly important part that fixed charges are playing in the total cost of electric power service. With fuel efficiency at its present high level, the cost of generation has become almost a minor item, so that system investment now offers the greatest field of opportunity for further major economies. In the past, attention has been centered on reducing fuel and other operating costs. In the future it will be devoted particularly to economical system design and control of construction costs.

The two new committees, Power Systems Engineering and Special Engineering Research, which were organized last fall, have given a good account of themselves in the first year of their existence. The Power Systems Engineering Committee provides for study of the now very important subjects of system planning and design, and rounds out the organization to meet present-day conditions. This Committee has found a very definite, well-crystallized and uniform opinion among those executives who have developed planning organizations in their own companies that comprehensive future planning will bring about important savings in overall investment and operating costs, and therefore offers the definite recommendation that a planning department should be set up in every growing electric power utility.

Engineering Research Studied

The Special Engineering Research Committee, after making a comprehensive survey of the status of engineering research in the power industry, finds that there exists considerable duplication of effort which is wasteful of time and money, although entirely unavoidable under the circumstances, and concludes that proper coordination of research work in the industry can be best obtained by setting up a paid secretary at Headquarters. The duties of such a secretary, who would naturally be placed in the Headquarters Engineering Staff, should be to maintain a complete file on research projects of interest, to arrange for adequate publishing of information regarding results as rapidly as they can be made available, to arrange for the initiation, placing and financing of new and desirable research projects, and in general to do all that a staff man can do to coordinate and guide research work so that it will be of maximum use to member companies.

The Executive Committee of the Engineering National Section has approved this recommendation, and it is earnestly hoped that appropriate provision for carrying it out will be made in next year's budget of the Association. The situation in respect to engineering research in the power industry is such as to make the adoption of this recommendation of primary importance.

An important step in standardization was made possible when the Executive Committee of the Engineering National Section approved the report of the Joint Committee of the N. E. M. A. and N. E. L. A. on preferred voltage ratings for alternating current systems and equipment. The adoption of the recommendations of this report generally by member companies will simplify the manufacturers' lines of apparatus, will bring about better adaptation of equipment to its service under prevailing conditions and will generally improve conditions for the interconnection of adjacent power systems. While the recommendations cannot be uniformly adopted at once, it is to be hoped that member companies will direct their system development toward the complete acceptance of the preferred voltage recommendations as soon as practicable.

The Year's Developments

Engineering developments during the past year have been along the line of better understanding of the problems of design and operation, and further refinements in equipment. The major radical development of importance was in the field of circuit interruption, where material advance has been made in the design of high duty circuit breakers not requiring oil. The so-called "Deion" circuit breaker has been successfully tested on a large power system.

Two major problems of power system engineering, system stability and lightning protection, have received much attention during the past year. Increasing interest in these subjects is logical, in view of the constantly increasing importance and volume of the power companies' business. Marked advances have been made toward satisfactory solutions of both of these problems.

Considerable public attention has recently been directed toward electrical hazards in the home. This is probably because, while such accidents are very few, they are necessarily spectacular in nature when they do occur. Recent statistics of the National Safety Council, indicate that the chance of a fatal accident in the home from a fall is sixteen times that from electricity. Nevertheless, the Accident Prevention Committee has sensed the need for some sane recognition of this situation and prepared, with the cooperation and approval of the Commercial National Section and other interested parts of the Association, a safety in the home pamphlet under the title of "Common Sense." This pamphlet will be available shortly.

Resuscitation Booklet Builds Good Will

The booklet on "Resuscitation" prepared last year jointly with other interested organizations, has had a circulation unprecedented for N. E. L. A. publications. Including reprints issued by insurance and manufacturing concerns this circulation has reached into the millions. The work of the industry in educating the public in methods of resuscitation is having a very beneficial effect in building public good will.

In recognition of the probable engineering requirements in connection with the intensive load building effort that will be put forth in the next few years, the Utilization Subcommittee was created this year in the Electrical Apparatus Committee to deal with the problems involved in the utilization of electrical energy including the engineering of present applications and the development of new uses. During the past years the Headquarters Staff has cooperated with the Commercial National Section in dealing with problems of wiring, oil burners and water heating.

Headquarters Engineering Staff

The Headquarters Engineering Staff, under the able direction of Major Bennion, is now very effectively organized, and although undoubtedly undermanned, has given an excellent account of itself during the past year. The engineers of the Staff are at the same time the sentinels and ambassadors of the industry in engineering matters. On the one hand they keep in close contact with the activities of many other organizations whose work may affect our interests and promptly bring to the attention of the proper parties all matters on which action may be required. On the other hand, they constitute an official point of contact with outside organizations and provide a channel for effective cooperation in engineering matters. Thus they not only protect the engineering interests of the power industry, but also make possible the cooperation of our industry with others in such a way as to bring about coordinated physical development and general good will. The engineers of Headquarters Staff are doing well a very important work, particularly in the code situation and on the problems of coordinated construction with other utilities. They should receive generous support and be permitted to expand their organization as the growing industry they represent throws additional burdens upon them. For example, last winter, in accordance with the recommendation of President Arkwright, company code representatives were designated by many member companies to serve as channels for information to and from Headquarters direct to member companies. The arrangement throws an additional heavy task on Headquarters Staff to maintain this contact, but the records which are being built up as a result of this plan and the solidarity which results from the closer contact is going a long way toward solving the code problem which has been confronting the industry in recent years.

Committees of Geographic Divisions Progressive

The engineering committees of the Geographic Divisions have made further progress during the past year in finding themselves, and their activities have been more extensive and more effective than heretofore. With the more definite understanding of their purpose and scope, the geographic organizations are being molded to specifically meet the local conditions. While the national organization is being used as a guide, each division is setting up only those committees in which it has a direct interest, while in some instances special committees have been organized to meet special conditions. This is as it should be. Such encouragement and advice as appeared useful has been given by the officers of the National Section to the geographic organizations. The chief recommendation has been maximum simplicity of organization to meet clearly defined local requirements. In the working out of geographic engineering activities, a definite trend has been noted toward the conference form of activity. That is, the various engineering committees of the respective divisions have met together once or twice a year for general conference and exchange of ideas. Definite programs have been prepared in advance with carefully selected and well-qualified speakers to cover the subjects set up for discussion. These programs have been advertised in advance. The result has been most gratifying, and indications are that this method of carrying on divisional work will be generally adopted. Very favorable comment must also be made of the valuable serial reports on timely engineering subjects which have been prepared by a number of the divisions. These reports form an important part of the work, but, after all, must be considered secondary to the major purpose of bringing together the engineers of the various companies for interchange of ideas and discussion of mutual problems.

Movement for Standardization

One of the objectives of the Engineering National Section is constructive cooperation in the national movement for standardization. It seems evident that standardization affecting the power industry up to the present time has been generally advantageous, and has resulted both in economy of power production and in extension of power uses. There may, however, be a possibility in our present enthusiasm for standardization of allowing the pendulum to overswing. The kind of standardization which established frequencies, utilization voltages, ratings of the equipment, factors of safety of equipment, has been a major factor in developing the use of electricity in this country. In the field of simplification, however, which results in a reduction in the capacities of equipment or qualities of material available, the immediate result is a less close adaptation of the available products to the service for which they are to be used. This fact alone means some economic loss. On the other hand, the results of simplification bring about economies, such as reduced costs of manufacture, reduction in stocks to be carried, and so on. It is thus necessary to balance the advantages and disadvantages of a given standardization project of this kind in order to determine its true economic value.

The major purposes of standardization, to effect economies and extend use of product, must be kept in mind in setting up the standardization program. It is suggested that the Engineering National Section during the coming year should give study to the subject of standardization, with a view to determining the lines along which standardization may be promoted to best advantage and wherein over-standardization with economic loss is a possibility.

Keep Informed Through Serial Reports

A report on the work of the Engineering National Section would not be adequate if it did not call attention to the very valuable serial reports which are published from time to time by the various committees of the Section. These reports together constitute a complete, up-to-the-minute exposition of the latest and best engineering practices and methods of the electric power industry throughout the country, and are authoritative because they are compiled by the members of the engineering committees, who in turn are the engineers actually responsible in their own companies for the work covered by the reports. It is earnestly recommended that all member companies place standing orders with Headquarters for new reports of the various committees as they are issued, in order that their engineers may keep fully informed on the engineering developments in the industry.

CHAIRMAN SLOAN: The next order of business is an address by Mr. Britton I. Budd, President of the Public Service Company of Northern Illinois, Chicago, Ill., on the Electrification of Railroads.

ELECTRIFICATION OF RAILROADS

By BRITTON I. BUDD, *President,*

Public Service Company of Northern Illinois, Chicago, Ill.

The history of steam railroad electrification commenced in 1895 when two short sections were electrified in the United States. Since then electric power has to greater or lesser extent been adopted by the railroads in 29 different countries in all of the six continents and some of the principal islands. About 10,000 miles of line are now electrified out of a total of 600,000 miles in these countries. The electrified mileage thus constitutes about one and two-thirds per cent of the total route miles in the countries involved.

Switzerland has the highest percentage of line electrified, namely 43½ per cent. Morocco has nearly 18 per cent electrified, Austria nearly 11 per cent, Italy and Sweden slightly more than 7 per cent, Chile 4½ per cent, England and France about 2½ per cent, and the United States only ¾ of 1 per cent.

Viewed from the standpoint of actual miles electrified, at the end of 1928, the United States has 1900* miles of line electrified, Switzerland 1500 miles, Italy slightly more than 1000 miles, Germany nearly 1000 miles, France and Sweden each more than 700 miles, England and Austria each between 400 and 500 miles. Other nations with 200 miles or more electrified are: Chile, Brazil, Australia and the Union of South Africa.

Status of Electrification in the United States

With special reference to the United States, there are 20 railroads having some electric operation. The length of route electrified is 1900 miles, of all main track 3100 miles, and of all tracks, including yard and side tracks, 4300 miles.

In the past year the Boston, Revere Beach and Lynn Railroad has been completely changed to electric operation. The Great Northern and the Pennsylvania have added considerable mileage to their previous electrifications and several new projects have been announced.

The three large electrifications now under way are on the Pennsylvania, the Reading, and the Lackawanna. The Pennsylvania's undertaking is impressive, and for magnitude of traffic is the largest undertaking ever turned over to electric motive power. Briefly, it consists in complete electrification of freight and passenger traffic on 325 miles of line and 1300 miles of track. It will extend from New York and Philadelphia to the Susquehanna Valley and involve the capital investment of $100,000,000.

The two other large projects are the Philadelphia suburban service of the Reading Company with 50 miles of line and the suburban service of the Lackawanna in New Jersey opposite to New York City. The latter comprises 78 miles of line. The three big undertakings together will add 450 miles of line and 1580 miles of track to that already electrified in this country. Although all arrangements have not yet been announced, it is expected that a large amount of the electric energy will be furnished by the power companies in the territories involved.

A number of other railroads are making studies with a view to electric operation. In the past 25 years, I think it safe to say that there has not been a year in which several important sections of our railroads have not been investigated with regard to the adaptability of electric power and its relative cost. Some of them have been studied and restudied in the aspect of changing conditions and new inventions. This process will probably go on indefinitely and we of the electrical industry should be prepared to cooperate with the railroads whenever the opportunity offers.

Railroad Requirements Must Be Studied

We can do a great deal to familiarize ourselves with the technicalities of railway power supply which is quite unlike most of our other power business. It is not sufficient merely to have power stations and transmission lines available. We must know something about the practical operation of railroads and must be prepared to offer them the kind of service that they need with contracts suited to that particular business.

We must clearly remember that the railroads are in the transportation business and use motive power only as a means to that end.

I would recommend to power companies generally, if they are so located as to now or in the future supply power to steam railroads, that one or more members of their staff be thoroughly familiar with railroad operation and the problems which a railroad has to meet in connection with its motive power. In the case of every other industry where electricity has been used, the power companies have had trained men, experienced in the manufacturing processes, as well as in the power business, and this kind of talent was responsible for the introduction of electric energy for a great variety of uses in industry; but, without the aid of men possessed of this training and knowledge, little progress would have been made. Many power companies have had experience in furnishing electric energy to street-railway and interurban systems, but the problem of furnishing power to steam railroads is entirely dissimilar, and a comprehensive knowledge of railroad requirements must be obtained if that problem is to be handled with the same intelligence and understanding as in other fields of power application.

For several years I have had the honor of directing the activities of this Association's Committee on Electrification of Steam Railroads. We are following the subject along the broadest possible lines in its ramifications all over the world. We are publishing every year general statistics on railroad electrification that are the most complete in existence.

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*EDITOR'S NOTE: The figures in Mr. Budd's paper for lengths of line electrified and in process of electrification are larger than the corresponding figures in Mr. Gibbs' paper which follows. This is due in the first case to inclusion of some small railroads not included by Mr. Gibs, and in the second case due to inclusion of the whole program of electrification of the Pennsylvania Railroad extending over eight years, while Mr. Gibbs has included only that part being worked upon at present.

I hope that the publications of the Electrification Committee are having as much circulation and study in the electric-power industry as they are having in the railway industry. They represent a vast amount of work and study and the painstaking effort of experts for the instruction of everyone interested in the subject.

This year a Subcommittee, consisting of engineers representing railroad and power companies, was sent to Europe to study the development of electrification. They spent two months traveling through England, the Netherlands, Sweden, Germany, Switzerland, Italy and France. They were very well received and every opportunity was given to afford a good understanding of what was being done there.

And here I want to acknowledge the gratitude of this Subcommittee to many prominent executives in our industry in this country for the letters of introduction which opened the doors not only of the various managements connected with the operation of electrified railroads in Europe, but of all the great industrial concerns who might be interested and helpful in showing our Subcommittee around.

Railroad Electrification in Europe

The interest of European railway engineers in this subject is very intense, probably more so than in this country for some special reasons which I shall try to make clear to you later. Many of the railway men interviewed on the Continent had been in this country to study our electrifications. Many of them are coming back again and are planning to send numbers of their younger associates to see the electrifications in the United States. When these engineers visit our country, I hope every courtesy will be extended to them by the members of the National Electric Light Association and that they will be given the opportunity of seeing what we are doing here.

The European railway engineers are particularly interested in our railroads on account of the heavy tonnage per train, both freight and passenger, operated in the United States. In general, their roadway and structures and cars are lighter than ours, the drawbars and couplers of much lower capacity, and the use of air or vacuum brakes is limited largely to passenger equipment. In Europe freight trains of 300 to 500 tons are the limit on many roads. Two thousand tons is the maximum under any circumstances. Six hundred tons is the limit for passenger trains. In this country, as you know, freight trains of 6000 to 12,000 tons are in daily service. Our passenger train loads run between 1000 and 1200 tons maximum.

I mention the difference here, not in any disparaging way, as they operate under very different conditions, but simply to indicate that we cannot follow their designs and methods in all respects.

On the other hand they have had considerable experience with electrification. They have great ingenuity and inventive capacity and have developed some very fine mechanical and electrical equipment for their railroads.

In Europe where electrification has taken place on the railroads there has been some special or compelling reason for the change from steam to electricity. There are several nations that do not have domestic coal resources, like Sweden, Switzerland and Italy. All these countries are well supplied with water power. This has led them to make extensive use of electricity on the railroads as a national policy to develop their own resources and become independent of foreign fuel supplies while at the same time improving their balances in international trade.

In each of the three countries mentioned, electrification has been introduced first on the most difficult lines to operate, those having heavy grades and tunnels. The other criterion is unit coal consumption, or tons per year per mile of route. Where adopted as a fuel saving method, the greatest saving in proportion to the investment can be made on the lines of heaviest fuel consumption. This was the reason why the Stockholm - Gothenburg line in Sweden was the choice for first electrification after the War, and it has been the basis on which some of the French railroads have selected the sections on which to apply hydraulically generated power.

Italy, Switzerland and Germany have been pioneers in the application of electricity to railroads since 1900. They did a great deal of experimental work toward developing the three-phase and single-phase systems to their present standards in Europe. England made an early start but did not go farther than the electrification of suburban service, except in an experimental way. None of the countries of Europe had more than a few hundred miles of electrification up to the time of the War, and then development was necessarily checked for a few years. The greater part of the European electrifications have come into existence since the War, in the years between 1922 and 1928. The growth during recent years has been to a great extent the result of fuel shortages during the War which all of the nations with hydraulic resources are eager to guard against in the future.

National Standards Adopted Abroad

Several of the countries in anticipation of extensive electrification and desiring to promote interchangeability, have adopted national standards for electrification. England has adopted direct current with 750 volts maximum for third rail operation, 1500 volts for main line service, and 3000 volts optional for the latter in special cases. France has adopted 1500-volt direct current for future work, with either third rail or overhead contact, and 3000 volts optional for special cases. Netherlands, Belgium, Spain and Czechoslovakia also favor 1500 volts. Norway, Sweden, Germany, Austria and Switzerland are committed to high-voltage single phase of low frequency. The trolley pressure is

15,000 volts at 16.7 cycles. Italy has a large installation of three-phase at the same low frequency. About 70 per cent of the extensive electrification in Italy is three-phase at 3000 to 3700 volts. The first electrifications in Italy were made in the mountainous regions of the North. The three-phase system was developed here and now extends as far south as Florence and Leghorn. Since 1925 the Italian State Railways have been at work on 120 miles of 3000-volt direct current between Naples and Foggia. Part of this line has been in service for some time and it is now the intention to use this system in the central and southern part of the country, retaining the three-phase system in the north.

All of these various systems in the different countries seem to be functioning satisfactorily. The choice of systems was originally made by the railways and the adoption of national standards followed. There has only been a small amount of change to comply with later standardization, except in France.

A Review of Foreign Progress

In England the electrification so far has been confined to suburban service around some of the larger cities. One railroad, the Southern, has at London the largest suburban electrification in the world. After the war all of the trunk line railways in England were consolidated into four systems for the purpose of operating economies. Each of the four has some suburban electrification. Some of the power is generated and some purchased from neighboring power companies.

In Holland, the lines are electrified between Amsterdam, The Hague, and Rotterdam, using multiple-unit trains and 1500-volt overhead. International trains and freight are still hauled over the same lines by steam. Power is purchased from three adjoining power systems and conversion is done for the most part by mercury arc rectifiers. This is a very recent electrification.

In Sweden there are two principal lines of the State Railways electrified. Each is about 300 miles long. One, in the northern part of the country, serves the iron mining regions, and carries a heavy tonnage of ore to tidewater. The latter was electrified before the War, using local water power developed by the State Power System. The reason was to increase carrying capacity. The other line, from Stockholm to Gothenburg, was recently changed from steam as a part of the national economic program. This line connects Stockholm, the capital and largest city, with Gothenburg, the principal port. Next to the northern line it carries the largest traffic in the country. Power for the Stockholm-Gothenburg line is supplied from the central interconnected zone of the State Power System of which the principal source is the large water-power station at Trollhattan.

In Germany there are four principal districts of electrification. The largest is in Bavaria where nearly all of the trains out of Munich move by electric power. Electricity is purchased from a large water-power system in which the State of Bavaria is largely interested.

In the mountain districts of Silesia, between the cities of Breslau and Gorlitz, there is considerable electrification for the purpose of utilizing local coal of rather poor grade that cannot be economically transported elsewhere. The power station for these lines is owned by the Government Railways.

In Middle Germany between Magdeburg, Leipzig and Halle is the other large district of main line electrification. This was established to utilize the brown coal deposits which are hardly more than a peat and contain about 60 per cent of moisture. This fuel has to be consumed on the spot and the Government Railways has a power plant especially adapted to consume it.

Most of the operations on these divisions of the German railways are conducted with locomotives, but they have also developed some very interesting motor cars to run on the 15,000-volt system.

The fourth important electrification of the German Government Railways is at Berlin. This comprises the whole suburban service including the so-called City and Ring Railway. Nearly 150 miles of line are involved. Current is supplied to multiple-unit trains with a third rail at 800 volts, direct current. This installation is well along toward completion and is noteworthy for the conversion equipment. There are 48 substations equipped with mercury arc rectifiers and supervisory control. There are from 2 to 8 rectifiers at each location and 119 in all. Power is purchased from local steam power companies over 30,000 and 110,000-volt lines.

In Switzerland, the principal standard-gage roads are the Federal Railways and the Bernese Alps Railway. The Federal Railways operate most of the important lines, except the Loetzchberg tunnel route operated by the Bernese Alps Railway. The Federal Railways have about 60 per cent of their line electrified and the other road is all electric. It is stated that 85 per cent of all traffic, ton-miles of both passenger and freight, is now hauled by electricity. The three longest tunnels in the world are operated by these railways, namely, the Simplon, St. Gotthard, and Loetschberg. The Federal Railways have constructed, mostly since 1918, a very extensive power generating and transmission system. There are six hydraulic stations totaling 377,000 kilowatts and 600 miles of transmission at 66,000 and 132,000 volts. This system is also interconnected with several large power companies, although the low railway frequency of 16.7 cycles makes direct connection impossible.

In Italy there are six types of electrification used by the State Railways. The two principal ones have been described above. The State Railways have been actively at work on electrification since 1901. They have also taken a leading part in development of hydraulic resources. They are interconnected with a large network of power companies in the north and with other systems in the central and southern parts. They buy and interchange energy and have some recourse to steam reserves in the northern part of the country. As in Switzerland, the interchange involves use of special 16.7 cycle generators by the commercial power companies, in the zone of 3-phase electrification, or else frequency converters.

In France the railways are privately owned, except one system operating in the territory between Paris and the coast. This line, called the State Railway, has a zone of suburban electrification on the west edge of Paris which was started in 1900. They use a third rail at 650 volts and purchase power from one of the Paris companies.

The Paris-Orleans Railway has electrified some suburban service and about 130 miles of main line extending south from Paris. They use 1500 volts with overhead contact line. They have developed water power along their line and are also interconnected with the steam stations of Paris.

The Paris, Lyons and Mediterranean Railway is using third rail at 1500 volts in the southeastern part of France. They have had a trial installation, on 16 miles of double track, in service for three years and are now extending it over some of their most difficult mountain lines. They purchase power from nearby water-power companies.

The Midi Railway has the most extensive electrification in France. Its territory extends across the southern end of the coutnry in a belt about 100 miles wide, including the northern slopes of the Pyrenees Mountains. Water power is abundant and they are farthest removed from the country's coal mines. They also have several long tunnels including the Somport tunnel between France and Spain, and another international tunnel now building. They have developed their own water powers and transmission system, and were also one of the first railways to make use of mercury arc rectifiers for 1500 volts.

Tendencies in Europe

Among the interesting tendencies in Europe are the following generalizations: (1) Electrification where adopted has been due to special conditions or national policy, and (2), there is a tendency toward closer working relationship between the railway power systems and the commercial networks in most countries, even though there are differences of frequency.

In conclusion, we in our country can congratulate ourselves that we do not face the complications of many governments, frontiers, policies and national standards. We have but two types of electrification in the United States—direct and alternating currents. Both are performing efficiently, and the power companies and manufacturers should unite in furnishing the railroads energy and equipment of whatever type they wish to purchase and on the most liberal terms and at the lowest possible cost, as the prosperity of the railroads and the efficiency and economy of their operation are vital to the welfare, growth and further development of our country. (Applause.)

PRESIDENT ARKWRIGHT: We are very grateful to Mr. Budd and his Committee for the very valuable work they have performed and the interetsing expression of it.

I have asked Chairman Sloan to let me intervene for just a moment. It has been suggested that you might like to send to Mr. Owen D. Young at Paris a cable conveying our congratulations on the apparent success of the German Reparations Conference, and expressing our pride in the part he has played in assisting in bringing this about. I will read to you the suggested cablegram:

"MR. OWEN D. YOUNG,
Ritz Hotel, Paris, France.

"The National Electric Light Association in convention assembled extends its heartiest congratulations to you on the successful culmination of your work as Chairman of the Committee of Experts on German Reparations. Such a notable contribution to the cause of international amity and peace reflects great glory and honor on all the delegates, and particularly on those Americans who were privileged to have a guiding hand in it. We, your countrymen and friends, want you to know how proud we are of this accomplishment, and take this means of apprising you of it."

If you would like to have the Association send this cablegram to Mr. Young on your behalf, will you please indicate it by saying "aye."

It is unanimously adopted. (Applause.)

CHAIRMAN SLOAN: The next speaker, Mr. George Gibbs of Gibbs & Hill, Consulting Engineers of New York City, has made a special study of railroad electrification in this country and abroad. He recommended and is responsible for the system of electrification of the underground railway of London. He is an authority on railroad electrification, consulting engineer for the New York, New Haven & Hartford Railroad, Pennsylvania Railroad, the Norfolk & Western Railroad, the Illinois Central Railroad and the Virginian Railway. It is with great pleasure that I present to you Mr. George Gibbs. (Applause.)

RAILWAY ELECTRIFICATION

BY GEORGE GIBBS,
Consulting Engineer, Gibbs & Hill, New York

The subject upon which I am permitted to address the Association is Railway Electrification. It is such a broad one that only certain of its high spots can be touched upon. I shall trace, therefore, very briefly, the reasons for electrification of steam railways, the results obtained, economic and otherwise, its limitations and, especially, the problem of power supply.

It will be noted that my remarks repeat, to some extent, some of the facts and thoughts expressed so admirably by Mr. Budd, the previous speaker. I trust the unintentional repetition will be pardoned.

The electrification of steam railways in the United States began over 30 years ago in a small way, at a time when the art was in its infancy, and when there was no real data available from actual experience as to the reliability and economy of this form of traction. Its growth of application was slow but fairly regular until the World War introduced a period of stagnation in new enterprises. Post-war adjustments, and the return of the railways to private ownership made it possible for the railway companies to proceed with major improvements, consequently numerous projects for electrification were proposed and several important ones put under way. This early history has been well set forth in the reports of the Electrification of Steam Railroads Committee of the Association.

It is interesting to note that the mileage of electrified railways in the United States, while considerable, does not present a very impressive total compared with that of all railways. There are over 250,000 miles of steam railways in the country, having an aggregate of about 420,000 miles of track, and there are about 63,000 locomotives in use. Electrified railways in operation total about 1665* route miles and 3990 track miles, and use about 450 electrified locomotives and 1780 motor cars. New projects now authorized and under way will add about 230 route miles and 720 track miles.

Purposes

The several reasons for adoption of electric traction by steam railways may be illustrated by following its step by step use on one of the great systems of the country—the Pennsylvania Railroad.

In the year 1902, that company determined upon building a great passenger terminal in the heart of New York City. It contemplated an underground station and yard to be reached by sixteen miles of tunnels passing underneath two rivers. A form of motive power for the trains other than steam was essential to the project. Economy was not a factor, it was only necessary that it be adequate and reliable.

For extensions to cross-country lines the case was different; and as the advantages of electric over steam might be important and had been at the time undetermined, the company undertook the electrification of its line from Camden to Atlantic City, N. J., a distance of 75 miles. This installation was completed in 1906 and may be regarded as an effort to determine the traffic-fostering possibilities, economy and reliability of handling long distance passenger services by electric motor-car trains.

Electrification of the Long Island Railroad

About the same time as these two projects were in progress, a subsidiary road—the Long Island—was faced with the necessity of removing its tracks from the surface of a street (Atlantic Avenue, Brooklyn). This was done by constructing tunnels and an elevated road. It was desired, also, to use the new Pennsylvania tunnels and terminal in New York City for certain of its suburban services. These various conditions necessitated the equipment of 90 route miles in various branches for electric operation to serve the two underground terminals within the city. This electrification was also one of necessity to conduct passenger services terminating within a great city, and under physical conditions prohibiting the use of steam locomotives.

The next undertaking of the company was at Philadelphia, and its purpose was an essentially different one. The Broad Street Station is a stub-end terminal serving all trains, through and suburban. The approach is by a long, elevated viaduct restricted in width by important city streets on either side. With growth of business, congestion and delays constantly occurred, largely on account of the great number of movements through the throat crossovers. A considerable number of these movements were "idle," i.e., empty suburban trains and their locomotives to and from the yard. It was imperative to do something for relief; the most practicable solution, adequate for a time at least, was to electrify the suburban services in order to use motor-car trains into the terminal. The reduction of idle movements thus secured, it was figured, would be equivalent to a 24 to 30 per cent increase in station capacity, depending upon the number of lines electrified. Even if the project should not result in important direct-operating savings over a steam traction, these would at least amount to something and relief from former congestion would be secured, whereas a widening of the approach viaduct would not give any operating saving. This case illustrates the possibility of effectively employing electric traction to increase capacity under certain special conditions.

The next undertaking was the electrification of the New York Connecting Railroad, finished in 1927. This is a two- and four-track line, largely for freight service but also for passenger trains into the Pennsylvania Station from the New York, New Haven & Hartford Railroad. The connection is over the Hell Gate Bridge and thence to the Pennsylvania company's tracks in Long Island City for passenger services. For freight the line connects with the Long Island Railroad, passing around the congested districts of the city to a terminal at Bay Ridge in the lower harbor, from which a car ferry runs to a large yard on the New Jersey shore. The purpose of this electrification was to effect operating economies and save time in the dispatch of freight from New England points to the South and West by avoiding a change from steam to electric engines within the city and to increase train weights handled over the heavy bridge grade. Also to deliver local freight electrically to industrial plants within the city.

Most Extensive Project Now Under Way

The latest and most far-reaching plan of the company involves full divisional main line electrification for all services on its four-track main line from New

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* EDITOR'S NOTE: In the preceding paper by Mr. Budd the figures for lengths of line electrified and in process of electrification are larger than the corresponding figures in Mr. Gibbs' paper. This is due in the first case to inclusion of some small railroads not included by Mr. Gibbs, and in the second case due to inclusion of the whole program of electrification of the Pennsylvania Railroad extending over eight years, while Mr. Gibbs has included only that part being worked upon at present.

York to the South and West. It is by far the most extensive and costly project of the kind yet undertaken anywhere in miles of track to be electrified, in volume and density of passenger and freight business handled and in size and amount of equipment required. It will be done in sections; the first, from Philadelphia to Wilmington, is now complete; the second, from Philadelphia to Trenton, N. J., is under way; the other sections will follow immediately. The work is to be completed for through passenger trains hauled by electric locomotives at the time the new main passenger station at West Philadelphia is ready for service, and for operation of all suburban services by motor-car trains into a new underground terminal adjoining the present Broad Street Station. It will enable longer passenger trains and much heavier freight trains at high speed to be operated. This means an important saving in time and a clearing up of existing congestion on the New York Division. By making at the same time improvements in freight terminals and yards, new and desirable operating methods will be possible. All of these changes will, it is figured, result in large direct and indirect economies, and will increase business, especially in perishable commodities, and thus bring additional revenue to the company. This important electrification project may, therefore, be said to be for economy, for relief of congestion, as a revenue producer, and for the handling of through passenger service into two underground terminal stations (New York and Philadelphia) without change of power en route. The results, economic and otherwise, of this great undertaking will be watched with keenest interest by the railway world.

Other Important Electrifications

These enterprises of the Pennsylvania Railroad illustrate the progressive steps taken to develop heavy electric traction for all kinds of traffic, and for the general reasons which have usually guided railways in taking up such enterprises. As further illustrating the capabilities of the new motive power, there should be mentioned the installations on the Norfolk & Western and the Virginian Railways over the Alleghany Mountain grades. These—especially the latter case—employ the heaviest train units operated anywhere in the world. The Norfolk & Western electrification has been in successful operation since the year 1915; the Virginian started electrical operation in 1925. The reasons for both of these undertakings were the expected superior economy of electric traction for long freight train operation over heavy grades, the possibility of increased running speeds, and the consequent elimination of congestion at critical points on the lines. In these cases the roads were obliged to obtain in some way increased capacity at certain points which constituted "bottle-necks" in the divisional operation. Electrification obviated the necessity of undertaking track additions in a country where this would be unusually expensive, so that the estimated cost of the otherwise essential double-tracking might be considered as a credit against the cost of electrification. Under such circumstances, the direct savings from electric haulage, for the volume of business conducted, have more than carried the additional fixed charges and made the electrifications directly profitable.

Electric Haulage in Freight Yards

There is one other special field in which electric haulage has been found efficient and economical, and that is in freight yards for shunting and classification purposes. In such work electric locomotives are greatly superior to steam shifters in ease of control and prompt starting characteristics—a matter of importance in making short runs and numerous cuts; they are also very economical because they waste no fuel when not in motion. Electric shifting has been most largely employed up to date by the New Haven Railroad Company in one of their terminal yards. A profitable future field for yard operation by electricity will doubtless be found on many railways.

It is evident from the sketch above given that electric haulage has been tried out for every condition met with on steam railways; it has demonstrated by years of trial that the present development and perfection of apparatus from the power house down to the propelling wheel of the train will produce reliable and useful results from an operating standpoint; it is an efficient tool for railway use in effecting economies, and is often a "business-getter."

This is not a technical paper and, therefore, I cannot attempt to explain the electrical characteristics and differences of "systems." They may be defined and classified by the kind of current, "direct" or "alternating," used to propel the motors of the train. To the general public, the noticeable difference between systems is in the contact means used to furnish power to the train itself, as this feature obtrudes itself to view everywhere. It is either a contact rail alongside of and at or near the track level, or a wire and its supporting structures placed overhead. The first mentioned of these devices has a limited application. Therefore, as electrification has tended to extend its application to all railway distances and conditions of traffic, the third rail contact device has become out of date and has now practically disappeared from the picture; the overhead contact device has become the standard for all new railway electrifications. In starting upon the design of a traction installation, the plans determined upon as to system and power supply should be comprehensive enough to apply to unlimited extension of the electrification, and to conduct any and all the services of a trunk line railway; this means that any system adopted should possess the characteristics of flexibility and applicability to unlimited extension and unlimited power requirements at the train. All electrical traction systems now in use employ a centralized source or sources of primary power supply to be transmitted along the railways to local points, where it is transformed or converted into power suitable for use on the trains.

The first cost of electrifying a railway is very great. Speaking in very general terms, the equipment costs may be divided roughly into three parts, each of substantially the same magnitude, namely, one-third for the power generation, transmission and conversion; one-third for the distributing and contact elements, and one-third for the motive power on the trains. All of these are naturally subject to considerable variation, in accordance with the traffic and physical conditions of the particular railway. In addition, the application of electric traction requires a more or less extensive track rearrangement, the acquisition of additional real estate, changes in or removal of many structures, and radical changes in signal and communication systems. These taken together add a considerable sum to the first cost of an electrification.

It is because of high first cost that the progress of electrifying steam railways has been quite slow; even if the superior economy and the indirect advantages resulting could be shown to warrant the departures from steam traction, the prodigious outlay of new capital required has often made the changes impossible. The direct economies secured from electric traction are practically all in fuel saving, in train labor and in cost of repairs of motive power. These direct economies are produced in part by changes in operating methods, that is, by using heavier and fewer trains for a given volume of traffic and the elimination of stops, such as for coal and water; the saving is further influenced by changes in train speeds. All of these direct economies taken together may amount to a considerable sum, but unless traffic is very dense or the conditions very peculiar and favorable, such as heavy grade work, they will, unfortunately, not be found sufficient to pay a profit over and above the additional fixed charges which the railway must assume for the new equipment, and will sometimes not carry the charges even. The indirect savings are advantages anticipated; therefore are always very important in deciding upon an electrification.

Improvements in Steam Traction

During the past fifteen years great progress has been made by the railroads in effecting more intensive and economical use of their equipment and facilities. For instance, the accomplishments in improving steam locomotive design are impressive. In spite of large growth in business, there are actually fewer locomotives now in service than there were in 1914—63,000 now against 63,500 in 1914. The reason is that the amount of work performed per locomotive has greatly increased. Practically, the steam locomotive has been completely redesigned during this period. Its hauling capacity has been raised so that from the same number of locomotives the combined tractive effort is now 2,676,000,000 lb. against 1,932,000,000 lb. in 1914. The average locomotive weight has risen from 86 to 112 tons. The gross ton miles per locomotive have increased from 8810 to 19,679, and the average freight train speed (running and standing times included) has risen from 10 to 12.8 miles per hour.

The locomotive improvements made are in many directions—increased size and adhesive weight; larger boilers which require less forcing; automatic stokers; superheaters; feed-water heaters; improved valve motion, compounding; also the use of cast steel to lighten parts. While some of these add complication, the cost of repairs per locomotive mile has actually been reduced, and greatly reduced per ton mile hauled. By these improvements fuel economy has been increased and is now very satisfactory. In other ways also the railways have succeeded during the past few years in effecting more intensive use of their existing facilities, so that it becomes more and more difficult to make out a good case for the substitution of electric traction, as regards direct economies produced. This, of course, tends to reduce the field for same to special cases and for special conditions. This does not mean that electrification will stop, but it does mean that the complete supersession of the steam locomotive by the electric is in the far and dim distance. It also emphasizes the importance of proceeding with projects of the kind only after careful investigation of the probable returns to the railways and the public.

Compulsory Electrification

Agitation aimed to force railways to electrify should be discouraged; especially legislative enactments passed with little or no regard to cost or results. Such will only delay progress in meritorious projects. Thus, a number of years ago an ordinance was passed in Chicago compelling all railways to electrify within the city as a smoke abatement expedient. An impartial investigation of the probable results to both contending parties, by a committee of the Association of Commerce, showed that as regards smoke production the railways stood fourth on the list of industries in the city. The elimination of the steam locomotive would, therefore, not improve atmospheric conditions in very marked degree. As regards cost, the report showed that electrification within the city would cost on a pre-war basis, $190,000,000, and the "precipitated costs" outside $96,000,000 additional; these figures would be doubled, at least, now. The net yearly saving possible was shown to be only $2,337,000. This meant an annual deficit of $14,610,000—a huge continuing burden sought to be placed upon the railways and the public. Fortunately, the report was convincing and killed the project, but the whole incident has made the railways there hesitate to undertake any electrification for fear that a start would entail being forced to extend it beyond their ability to assume the burden.

A similar situation confronts the railways at present in New York State. The enactment of a legislative act seeks to compel them to discontinue the use of steam by electrifying all lines and services within the limits of cities of 1,000,000 or over population. As an example, this means for the Long Island Railway alone an expenditure of $23,000,000, of which about $10,000,000 would be required outside of the city to make such service usable. This is a staggering burden for a small road and must be assumed in advance of any real need for it or a sufficient practical return to any one.

All this sort of thing is very discouraging as regards real progress; railway companies should be trusted to adopt electric traction where it will increase comfort and attract business, or will reduce expenses so as to better meet decreasing rates and competition from other methods of transit. I am sure this association can be relied upon to favor this point of view and to oppose tendencies of a kind which may injure the railways.

Purchased vs. Railway Generated Power

As this association represents producers and distributors of electric energy for all public purposes, it is fitting that I should touch somewhat fully upon the characteristics of a suitable supply for heavy railway traction.

The services to be met are various, and introduce different load conditions; suburban traffic loads have high morning and afternoon peaks, the latter corresponding to commercial lighting peaks and coinciding roughly in time; heavy grade work—especially for freight—shows peaks occurring at random, due to the starting and bunching of long trains; accidental peaks occur in all services, due to congestion of business and power derangements which may occur at any time in any electrification and may spread over several hours' time. There may be, furthermore, abnormal passenger train peaks as the result of special movements, such as race meets, excursions, and the like. As electrification extends on a road and becomes divisional and is used for all services combined, the normal power curve smooths out and the load factor improves, but seasonal variations will still occur.

Formerly, and before the days of great commercial power companies having inter-connected systems, the railways were obliged to construct their own power plants for electric traction loads; now these outside wholesalers of power are found almost everywhere and are available for railway power supply. Mr. Samuel Insull, in his forceful paper before the American Institute of Electrical Engineers, in 1912, gave an elaborate analysis of the effect of railway loads in producing a diversity factor for a centralized power system, and in this way making it possible to reduce capital requirements and to effect a reduction in power rates of all kinds to the community at large. This paper is very interesting and, while out of date, it nevertheless accurately foretold some tendencies which have operated recently to concentrate the production of electrical energy for all purposes in the hands of a few large companies with modern plants inter-connected so as to produce reservoirs of power, each serving a large section of the country. This modern development is an important one and follows from the perfection of power house machines, high voltage transmission line construction, and especially in the perfection of switching and control apparatus, which make the huge reservoirs of power safe and usable.

The railway companies are much interested in this development, and in every sense of the word they wish to encourage it; it means cheap power for commercial purposes and the expansion of industry, which brings business. But it should be recognized that it will generally be detrimental from the power company's standpoint, to allow railway loads to be taken at random points on their distributing systems. Such loads, both as regards the power company and the railway itself, should be treated as block supply at a few points and as far as possible delivered on lines directly connected to the main load centers or power plants.

Requirements to Be Met

Discussing now the conditions under which a railway company can make use of this power supply, it is obvious that the energy furnished must be suitable, reliable and cheap. As to reliability, it may be conceded that a centralized commercial power system meets this essential. So does an up-to-date railway power plant; it has been found dependable. I should be willing to bank upon either source of supply in adopting an electrification project. It has often been pointed out that purchased power is produced by specialists while railway power is not. This, in a sense, is true, but in another it is not; railways have always specialized in power; every locomotive is a power plant; they surely can care for the central plant of an electrification. The question is, will they? Unfortunately (or fortunately, as you choose to look at it) it is difficult to bring this about. The power house is an incident only in a complicated chain of factors, making up the production of transportation, and the importance of keeping a power plant up to maximum efficiency and of taking advantage of progress in the art, not always fully understood by the higher officials who are responsible for expenditures. It is difficult, therefore, to get prompt authorization for large expenditures for modernization. With commercial companies, on the other hand, the power house and its successful operation are major considerations; the man in charge is a manager of the business, not a minor officer, reporting through the various departments up to the official who controls policy in making large expenditures.

The next point which should be referred to is that the purchase of power will relieve the railway company from a considerable capital expenditure for a plant of its own, and the periodic and heavy expenditures for modernization. These are undoubtedly advantages and constitute an inducement for a railway company to buy its electrical energy—but these advantages are not reflected in power costs as interest and depreciation charges accrue in either case and are elements in cost.

Considering the Final Cost

The third and most important consideration, however, is the final cost of energy delivered at the railway distribution system. If the electrification is a minor one, requiring a limited amount of energy, a small plant only is needed and this cannot compete in production cost with a large one. But in the case of a large and growing electrification, the fact should be recognized that a railway company can design and build a large, modern plant of its own, at a reasonable cost and can secure from it cheap and reliable power. Therefore, for an outside company to compete as to energy cost it is necessary that it should have in mind the following:

1. The effects of high capital costs of the power house, transmission and real estate. In some cases, apparently, excessive first cost has been due to the proximity of the plant to a large center of population; in others to an ultra-refinement of plans, aimed to produce energy at the lowest possible cost. A railway company can generally place its own plant in a cheap locality, centrally to its electrification and adjoining its right-of-way, and thus, by careful planning, reduce first cost of plant and transmission, and make competition with it difficult.
2. The relatively high interest charges paid by the power company for capital. This, together with high taxes paid and sometimes franchise taxes in addition, produce a high fixed charge, which becomes a part of the "demand" rate of the contract.
3. High staff and general office charges. A railway has a very low management overhead chargeable to power cost.
4. The small benefit which a company is apparently willing to accord the railway for the "diversity factor" produced in connection with its own load. In some kinds of railway traffic, such as suburban, there is probably little diversity obtainable by the power company taking over such a load, as suburban traffic peaks coincide roughly with the lighting peaks of a power company. If, however, through passenger and the various kinds of freight services are included, there may be a considerable diversity secured and which would help out a commercial power system. A railway may reasonably expect that its own load shall be considered a unit, both as to the requirements for its different services and as to location.
5. The amount of spare generating capacity allocated to the railway load. In a plant of its own, a railway company would, of course, provide for reserve capacity, but would exercise its judgment as to how far it would depend upon this in extraordinary emergencies, and how it would arrange its traffic in case of a shortage in emergencies. Commercial power companies generally go beyond this in figuring reserves, and I am not criticizing their policy; we expect them to safeguard our normal demands—perhaps more fully than we do ourselves; but the railways should not be penalized for the extraordinary emergency conditions heretofore mentioned by the establishment of new and higher "demand" charge. In other words, the railway should be able to obtain extra emergency power at "energy" cost, if and as the power company may have the capacity to supply it. It is not intended to ask that spare capacity be set aside for these occasional extra demands, in fact, many times the emergencies would come on the power company's off-peak times; but if the company has unused capacity during the emergency it should give it to us; the contract should not be punitive. If this policy be followed it would tend to reduce a high demand rate of the power company, and thus make purchased power more attractive to the railway.

Contract Provisions for Low Cost Power

The manner in which these various essential provisions for the production of low cost power to the railways have been incorporated in an important existing contract is summarized in the following:

1. The charges or rates are based on the actual cost to the power company of producing power in its generating stations and transmitting it to the railway supply points. This "actual cost" includes fixed charges, general expenses and all other items properly entering into the total cost, but it is based on production in large modern plants, not counting old and small plants, and is also based on certain allocated portions only of its transmission network.
2. In order that the railway may be protected against any unforeseen high cost of energy, such as a radical change in company set-up, the power company guarantees that the demand charge and the energy charge shall not exceed certain fixed values. Such guarantees are based on specific costs of coal and labor. Maximum rates for fixed charges are also stipulated.
3. The demand is determined monthly and is based on three maximum normal clock hours per month, with the stipulation that the demand in any succeeding month shall not be less than 75 per cent of any previous monthly demand.
4. Abnormal demands resulting from accidents, derangement of power supply, abnormally heavy traffic or unusually severe winter weather conditions are disregarded in determining the monthly demand.
5. If more favorable terms are subsequently made to other consumers under similar conditions of supply, the railway shall be entitled to the lower rates.
6. Power may be supplied at several points, but the demand is determined by combining the readings at all points; in other words, the railway gets the benefit of its own diversity factor; proper allowance for the company diversity is also reflected in the determination of the demand charge.

It is necessary now to close this short address upon a large subject. The remarks made in connection with power supply are offered only in the spirit of helpfulness to make possible the use by railways of power drawn from the great commercial supply systems, which are becoming an important national factor in aid of industry. It was necessary, in doing this, to emphasize the fact that cheap power is essential to the establishment and growth of electrified railways; that the direct savings in such form of operation are at the best, small, and the first cost very high. Therefore, both the railways and the power companies should cooperate in establishing contract conditions which will eliminate as far as possible all unnecessary handicaps to cheap power in order that the use of purchased energy for electrification may extend and benefit the community generally.

CHAIRMAN SLOAN: Because many of you may not have had an opportunity to see and hear the Talking-Movie presented yesterday morning by Sir Ernest Benn, of London, England, on "The Superiority of Private Enterprise," it will be shown again this morning. It will be followed immediately by a Talking-Movie address by Dr. Alberto Pirelli, of Milan, Italy, President, International Chamber of Commerce on "Electricity's Contribution to Commerce." This feature will be presented by W. H. Onken, Jr.

ELECTRICITY'S CONTRIBUTION TO COMMERCE*

BY DR. ALBERTO PIRELLI, OF MILAN, ITALY

President, International Chamber of Commerce

By way of introduction, may I extend to you and to the electrical industry throughout the United States, but more particularly to the great American savant and inventor, Thomas A. Edison, my personal congratulations as well as those of the International Chamber of Commerce, on this Golden Jubilee celebration.

Mr. Edison happens to have been born in the United States, but he belongs to the world. It would be idle for me to dwell on his many and beneficent inventions. Labor has been incessant with him, and his life is a song of hope to the youth of all lands. For none of us lives unto himself. Centuries ago a great poet of my own country expressed it thus: "Sic vos non vobis mellificatis apes." That is to say: "Not for yourselves, but for others do you produce honey bees."

As President of the International Chamber of Commerce, I am happy to voice the admiration of business men of forty-six nations, for the work of the inventor and for the development of scientific research. And in no place is this work more manifest than in the United States.

Your country is magnificent in its ideals, its citizenry, its power, its wealth and its possibilities. America is indeed "a land flowing with milk and honey," and it possesses besides a very real and extraordinary vitality giving to its work a freshness and a force which astonishes, and at the same time commands the admiration of the world.

Growth of Spirit of Brotherhood

It is a pleasure also for me to note the growing spirit of brotherhood shown by Americans generally toward other and older civilizations, especially in international and interracial relationships. The tendency is no longer to employ the American standard as a measure with which to judge others; but to study a country, its background, its people, its traditions and its psychology, and thus to find a way to live in a world of individuals with varying standards, varying ideas and ideals, varying strengths and weaknesses, and to understand them sympathetically. It is in this understanding of others, this getting into their lives and appreciating them, that the hope for international conciliation lies.

But my purpose is to bear tribute to the splendid record made by your industry, and to the position of the United States in matters electrical. No one knowing anything about the electric light and power industry can picture it as being or becoming static in any country, and least of all in the United States. Public appreciation of electricity arrives long before its economic victories. It was accepted that it would do the things that people expected of it, and it always exceeded expectations.

World Is Indebted to Edison

One great asset of electricity is that it has enabled countries like Italy, Switzerland, Norway, Sweden and others possessing little or no coal to develop their water powers for civic, domestic and industrial use, and has also made possible the conservation of other natural resources, to the great advantage of civilization. It has brought untold benefits to industry and commerce and has provided comforts and leisure for the home, so that great multitudes enjoy a freedom and a dignity beyond that which earlier civilizations allowed. And for much of this the world is indebted to the inventive genius of Edison.

Years ago Beethoven was conducting a performance of his Ninth Symphony. So moved and entranced with the beauty and majesty of the music did the audience become that they stood and applauded the composer enthusiastically. But Beethoven heard not, heeded not, for his ears were deaf to their cheers. For years Edison also has lived in the silence which Ibsen calls "the home of the strong," and my hope and heart's desire is that, if he cannot hear, he may at least sense how great is the gratitude of a world which his day salutes and cheers him as one of its worthiest inhabitants.

PRESIDENT ARKWRIGHT: Some things are beyond praise. To attempt to say anything in approval of this feature we have just had, would, I think, be to detract from it. I would, however, like to express again our great appreciation for these features, to W. H. Onken, Jr., and to the Western Electric Company, through whose generosity we were able to secure them.

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* Presented as a "Talking-Movie."

The remainder of the morning session will be presided over by Vice-President J. F. Owens.

[Mr. Owens assumed the Chair.]

CHAIRMAN OWENS: The next speaker on the program will be the Chairman of the Commercial National Section. It is interesting to note that he was born in that great treasure house of the Nation, the Southwest. (I say that with all modesty.) (Laughter).

Mr. Sampsell has had a long and varied career in the utility business. In this Association, of which he is Vice-President, he has contributed much of his experience and his talents, and in no greater degree than the contribution he has made during the past year as head of this important Commercial Section. His contributions to that section, to the industry and to the Nation are great indeed. It is a pleasure to introduce Vice-President Marshall E. Sampsell, Chairman, of the Central Illinois Public Service Company, Chicago, Ill.

REPORT ON COMMERCIAL NATIONAL SECTION

By MARSHALL E. SAMPSELL, *Chairman*

If we have made commercial progress this administrative year, a great degree of credit belongs to Mr. Greenwood, the Vice-Chairman, committee Chairmen and committee members. We have received inspiring assistance from the officers and members of related committees throughout every Geographic Division, helpful counsel from Mr. Clapp and Headquarters, splendid cooperation from the other National Sections and Committees, and profited in large measure from our contacts with The Society for Electrical Development. It has been a pleasure and revelation to me to be associated with the sound-thinking, well-informed men and women who are so successfully carrying forward commercial work.

The Commercial National Section has approached its work this year with full appreciation that the Electrical Industry is a predominant factor in constructive upbuilding of American production. We realize the unique relationship of our industry with all commercial and industrial activities daily carried on throughout this country has afforded unequalled opportunity to reduce production costs by invention, science and standardization, thereby helping to establish and maintain exceptional wage and living conditions.

Our light and power companies can be justly proud of their contributions to the practical needs, comfort and welfare of the public generally and the millions of customers they serve. They cannot, however, rest complacently on past performance. To remain an agency for constructive achievement, they must take full advantage of present abundant opportunities and be ever alert to future possibilities.

We have kept in mind the billions of dollars our light and power companies have expended for facilities to conduct their business. We know, too, these dollars were not secured, except in small part, from earnings; but from the sale of bonds to financial institutions, preferred stocks to individual investors, including a veritable army of company customers, and common stocks, in most part, to investment companies, without whose assistance through such purchase and extension of general credit, management and engineering skill, our operating companies could not have properly kept pace with their rapidly expanding business.

The Industry's Present Problem

We realize we are no longer living in the years during and following the war, when we were seriously put to it to provide facilities to serve our fast-increasing loads. Our problem during those trying years was: How can we finance additions to our properties to carry the loads brought to us without solicitation? Our problem now is: How can we most intelligently bring about greater diversification in the distribution of our product—electricity—to more surely safeguard the heavy investments already made, and yet to be made, for generating capacity and distributing facilities?

To protect investments made in transmission lines interconnecting smaller communities and extending into rural districts, where there exists little industrial activity, requires larger volume of electric service in small-town homes and on the farm. To successfully meet these obligations, we must sell more kilowatt hours through intensive development of new markets that will improve load factor. To bring about and proportionately enjoy intensive development of these new markets is no boy's play. In this undertaking we are forced to meet keen, well-organized competition from other industries, equally anxious to grow and prosper.

To intelligently educate our present customers and others to greater and more diversified use of our service, provide them with suitable energy-consuming devices to enable them to so use the service, and obtain more helpful information for the industry, the Commercial Section was reorganized last August into four bureaus, namely: Lighting, Merchandising, Commercial and Industrial Power and Heating, and General. Each bureau, except the General Bureau, embraces certain committees of related activities and is under a Vice-Chairman. The General Bureau committees report to the Section's Chairman. This arrangement has coordinated our own committees, harmonized more completely with Geographic

Division related committees, permitted separate bureau meetings, and made unnecessary frequent group meetings of the Commercial Section. Excellent cooperation from Geographic Division has resulted in increased attention to commercial development throughout the country.

"More Kilowatt Hours Through Group Teamwork"

The slogan of the Commercial National Section last year was: "More Kilowatt Hours Per Capita." Our slogan this year is: "More Kilowatt Hours Through Group Teamwork."

If our industry is to secure a large share of the consumer dollar, the executives of our operating companies must bring about closer departmental teamwork within each company, so that our engineers, accountants and other principal operating officials may look beyond the specific work they perform into the commercial field where cooperative effort is now required. This cooperative effort will lessen sales resistance and assure new service income that will result in financial advantage to the company and rate advantage to the customer, whose consumption of more kilowatt hours, better diversified, provides the basic source of net earnings for the company.

Group teamwork is equally essential between our National Association and the respective Geographic Divisions and State Associations. Our National Sections were undoubtedly created to better perform work most closely related to subjects assigned them, and it is only by group teamwork between these separate National Sections and corresponding sections or committees of Geographic Divisions that we can expect to properly handle the mass of work involved at least expenditure of money, time and human effort.

It would therefore seem the slogan, "More Kilowatt Hours Through Group Teamwork," accurately describes the goal we have in mind for our Association, whose avowed purpose is: "To Advance the Art and Science of the Production, Distribution and Use of Electrical Energy for Public Service."

The need for group teamwork between our four major national associations and the electrical leagues was the impelling reason for reorganization of the Society for Electrical Development in 1927, resulting in more sympathetic understanding of the commercial problems that so vitally affect the electrical industry.

We have kept before us our common need for greater consumption per unit of industrial power and domestic service and the existing possibilities for scientific development and diversification of commercial and industrial power and lighting. Consequently, we have been studying the principal handicaps to our commercial progress and planning how to deal with them.

Handicaps to Commercial Progress

One of the most serious handicaps to commercial progress is adequacy and price of wiring, due largely to code restrictions. The principal reason wiring in general is not adequate is that ADEQUACY has not been sold. Present costs of wiring are perhaps not too high under the conditions of present wiring jobs. Our Wiring Sales Committee has been working with the Codes and Standards Committee and Engineering Section on the National Electrical Code and the whole wiring situation. We have had several joint meetings with representatives of the National Electric Manufacturers Association respecting certain drastic changes in grounding rules. These meetings have been of value to the entire electrical industry and afford concrete example of the advantages of group teamwork.

Another serious handicap to our commercial progress is that our rate structures are not sufficiently conducive to broad promotion of electricity. It is not contended these rates are too high, but that their form is not calculated to encourage the most liberal use of energy, which must result in a lower average rate to the consumer. The price of energy is one problem over which our electric light and power companies have most control, and, if we can solve that problem, we can better compose commercial problems in which others have a mutual and beneficial interest. The Promotional Rates Committee of our Section has been studying rate forms for domestic service and the relation of existing rates to development of household appliance loads.

Another handicap to our commercial progress is price of energy utilization equipment and quality standards in types of appliances. Prices may not be too high for the present demand, but are they not too high to permit universal acceptance and use of them by the average housewife who perhaps needs them most? Our Section is carefully examining quality standards, as affecting costs, performance, and market acceptance of both low and high-priced models.

Our intensive study of handicaps to commercial progress has not caused us to lose sight of other avenues for load building.

Training of Commercial Men

We appreciate our business is each year becoming more highly specialized. To stimulate intensive training of commercial men working in specialized fields, training schools have been held during the year, covering Electrical Advertising, Home Lighting, Industrial Heating and Commercial Cooking. The success of these undertakings merits repeating them.

Higher Standards of Illumination

Our Section has made conspicuous progress in impressing the advantages of proper illumination, instead of lighting for vision only. Through group teamwork with architects and lighting departments of our companies, we are bringing about more adequate wiring for higher standards of illumination. The method of marketing electricity for electrical advertising and lighting of streets and highways is being pushed, both for its commercial value and civic betterment.

Our power committees are studying commerce and industry to more intensely promote electricity for every power and heating need. Highly creditable reports covering specialized fields have been developed to equip our salesmen to show the advantages of electric power over supposedly more efficient means offered by our competitors.

Another phase of our Section's work has consisted of searching for facts concerning particular classifications of our business.

Water Heating Survey Underway

A Water Heating Survey of national importance is under way, the field work being done by the Engineering Section, at Headquarters. This survey will doubtless clearly indicate the water heating service is of value to the customer and affords wide opportunity for desirable revenue.

Farm Appliance Sales Committee Active

Another fact-finding undertaking of consequence to rural customers and our business is the work of the Farm Appliance Sales Committee. Its personnel includes representatives from the Rural Electric Service and our Merchandise Sales Committees.

Plan of Refrigeration Committee

An activity deserving particular support is the plan of our Refrigeration Committee to nationally point out the relationship of food preservation to health. This plan is non-commercial, includes all groups interested in food preservation, and will be carried to completion by the National Food Preservation Council, of which Matthew S. Sloan is President. The details of this program will be outlined to you at this morning's session by P. B. Zimmerman.

Electrical Industry Sales Conference

Under the auspices of The Society for Electrical Development, the Commercial Section is taking part in a thorough-going search for facts as to adequacy of wiring in typical American homes; number and nature of electrical appliances used in the average household, consumer interest and appreciation of the value of electricity, and ways and means to develop a larger market for electricity in the homes of this country. This survey was made by a leading advertising agency under specific instructions of the Sales Plan Committee of the Electrical Industry Sales Conference. At this afternoon's session of the Commercial National Section, W. W. Freeman, President of the Society for Electrical Development, will discuss the present status of this plan, its value as an agency for intensive development of our markets, its advantages as a messenger of good-will and far-reaching benefits to all elements in the electrical industry.

"Service Suggestions" Supply Useful Information

Our Association's monthly Bulletin has carried the Service Suggestions of the Customer Relations Committee. The informative and useful data furnished through this committee has doubtless been followed with interest by all commercial executives and field men.

Our Section is cooperating with the Accounting Section, through a joint committee, in further effort to adjust the accounting problems our enlarged commercial activities have occasioned.

Merchandising Methods Studied

The Commercial Section has been closely studying merchandising methods of others engaged in selling household electrical equipment. Despite our close contact with our domestic customers, we can never satisfactorily develop a maximum volume of appliance sales until we have the complete and cordial support of all other classes of merchandisers of electrical appliances. It is not to our interest nor have we the slightest desire, to monopolize the appliance business. It is our desire to so plan our sales programs as to encourage and assist the manufacturers and dealers who are helping us promote acceptable labor-saving and convenience services. It is respectfully recommended that the Declaration of General Merchandising Principles agreed to by all concerned and the electrical merchandising standards suggested by the General Merchandising Committee of our Association be followed as guideposts to better trade relations.

Participation in Light's Golden Jubilee

Just a few years ago, the local craftsmen carried on the manufacturing of the country and business consisted of small isolated transactions. There was no such thing as massed production, massed capital or corporate machinery. Events of importance were known many moons after their occurrence. Light came to us from the tallow candle, kerosene lamp, and open fireplace. The kilowatt hour, the untiring helpmate of humanity, was a stranger in the home. workshop and on the farm.

Today we are fully advised of the world's activities when and as they take place. The radio, telephone, and telegraph and transportation on rail, rubber and in the air make time and place factors of small consequence. The availability of electricity for countless light, heat and power purposes has raised man's stooping shoulders from endless labor and relieved the weary housewife of hours of toil.

To one man, above all others, is due this marvelous transition from primitive days into an era of ever-increasing growth and expansion of industry, business, transportation, and communication. He has made it possible for us to translate the dreams of our electrical industry into time and labor-saving realities.

The commercial members of the light and power companies throughout our land are impatiently anxious to participate with all the world in honoring that man, Thomas A. Edison, and through Light's Golden Jubilee, to felicitate him on the occasion of the fiftieth anniversary of his invention of the first practical incandescent lamp and the system of electrical distribution that has made possible our own great industry whose good name we so zealously guard. (Applause.)

CHAIRMAN OWENS: This most eloquent presentation is one of the most valuable commercial presentations, I think, that has been made to any convention. It is also, in my judgment, one of the best public relations talks I have ever heard.

The next speaker on the program will be P. B. Zimmerman, Secretary, National Food Preservation Council, the functions of which have been alluded to by Mr. Sampsell. Mr. Zimmerman will speak on the National Food Preservation Program.

NATIONAL FOOD PRESERVATION PROGRAM

BY P. B. ZIMMERMAN
Secretary, National Food Preservation Council

Teaching the millions that 50 degrees is the danger line on the thermometer, for the proper preservation of food, is the object of a nation-wide activity now being rapidly organized by the National Electric Light Association. The thermometer, as is illustrated on the stage, will be the emblem of this campaign. At the suggestion of the Refrigeration Committee of the Commercial Section, the movement, as it has been undertaken, will be known as the Food Preservation Program. It will be centered so far as the public attention is concerned, in the month of September, although preliminary work will be going on actively throughout the year. The fundamental purpose of the whole program will be to impress the American public in a campaign so dominating and so widespread, that it will cover every part of the nation.

The Program's Objectives

The four principal objectives are as follows:

First, to establish the relationship between food, spoilage, and health.

Second, to establish in the public mind, a perishable food temperature of 50 degrees, or less.

Third, the causes of food decay and bacteria growth.

Fourth, the vital need for proper all the year around refrigeration.

Every avenue of advertising and promotion, national and local, will be employed to focus public attention on the benefits to health and the economy of proper refrigeration. Dominant advertising in national magazines will be the primary instruments. Newspaper advertising and radio broadcasting will add to the effect of the magazines, as well as magazine articles by recognized authorities on the need for proper care of food to prevent decay, addresses before community gathering, and complete local tieup with the program by the factors interested in public health and in the merchandising of refrigeration.

The month of September was selected for the program for two reasons: First, because it offers an opportunity to emphasize to the American public the need for the proper refrigeration the year around; second, because it will stimulate sales at a time when there is a tendency to relax selling effort. It has been accepted by many merchandisers of automatic refrigeration, in the northern states particularly, that concentrated selling effort has been worth while only in the summer months. The program will point out that the Weather Bureau's records show that 50 degrees, the danger line in food preservation, is maintained in outdoor temperature only 19 days a year, as a national average.

The governing body of the program will be the National Food Preservation Council. Matthew S. Sloan is President; Vice-Presidents are J. E. Davidson and C. E. Greenwood; Mr. Sampsell has taken the chairmanship of the Executive Committee.

On this Council will be the representative heads of each of the food industries who are being invited to participate in this movement.

How the Program Will Be Carried Out

The program will be carried out by both national and local advertising,—the national activity directed by the Council and its committees, the local activity by the local councils which are being set up through a regional organization that will extend into every community. For this purpose, the entire country has been divided into 20 districts. Regional directors have been appointed for each district, and are now at work. The Council has engaged the services of 10 traveling specialists who will assist the regional directors in their field service. The local Council will, in most cases, center around the electric leagues where they exist, and will include all the electric interests—the gas company, the ice company, the milk company, merchandisers of refrigeration, and the purveyors of perishable food. The medical societies in many cases, and also women's clubs, will be primary factors in the local associations. The national trade and public health associations, which have been invited to participate in the program and to appoint representatives on the national council, are the following: The American Medical Association, The General Federation of Women's Clubs, The American Gas Association, the National Association of Ice Industry. The National Refrigerator Manufacturers' Association, the International Association of Ice Cream Manufacturers. The plan for the national activity includes full-column advertisements in the national magazines, which in most cases will be distributed both during August and September, as well as items by authors, whose names will carry weight with the American public, on the benefits which the habit of proper food preservation will induce in the health of the nation. Full editorial support of this program has been promised by a number of publications, among them the principal women's magazines of America. The Speaker's Bureau is another activity of the National Council. Arrangements have been made with health authorities—women who are widely-known for their interest and development of better health and science.

Another division of the Council is the preparation of material such as newspaper advertisements, articles, window displays, truck cars, special banners, and a complete set of dealer advertising material.

National Idea Contest

Lastly, there is a National Idea Contest, for which $25,000 has been appropriated. The principal prize will be an electrical home. The national program will be supplemented by similar programs of activity throughout the month in every community of the country, under the supervision of the regional directors, with the active control in the hands of the local committee. There will be extensive newspaper advertisements. The National Council is also supplying service such as outdoor advertising and many special forms that have been demanded by the committees.

Women's Committees to Help

The entire energy of the women's committees which have done such an effective work for many utilities will be directed along the food preservation lines for this month.

Time is brief and I shall not enumerate the many details of the plan. A plan book will be sent to each member company.

This is the first opportunity, we understand, that the electrical industry has had to cooperate with the food industries. The average American family is spending $629 for foodstuffs. It has been estimated that some 10 per cent of this goes to waste, and that if there were a full realization of this 50 degree danger line, we might save, in this country, something like a sum of $700,000,000 that is wasted. Economically it would pay for this great service, and it would be a great benefit to the public and to this industry.

We, therefore, solicit the active cooperation of each member company when the regional director calls upon you for help and service. (Applause.)

CHAIRMAN OWENS: The next speaker on the program, like Mr. Sampsell, was born in the Southwest. He has had an interesting experience, having been identified with several of the light and power companies in that section. He is now President of five companies supplying light and power service to the Greater New York area. He is a past-president of the Edison Illuminating Society. He is First Vice-President of the National Electric Light Association. It is with great pleasure that I present to you Matthew S. Sloan, who will now address you.

SALES INCREASE OR RATE INCREASE

By MATTHEW S. SLOAN

President, The New York Edison Company, New York

The title I have chosen for this paper is not intended to indicate an alarmist state of mind. It is intended, however, to call to the attention of our industry, facts which seem to me worthy of our careful study. The situation is not at present one which should alarm us. It should not be permitted to get to a point where it does become alarming.

Trends in our industry over a period of several years show that it is slowly being squeezed between the jaws of a pair of pincers.

One jaw is a decline in the kilowatt hour sales and revenue for each dollar of investment.

The other jaw is a rising investment per kilowatt of installed generating capacity.

In spite of this squeezing, our rate of return has lowered only slightly in the period under consideration. The return has thus held up because of a splendid steady increase in operating efficiency produced by our engineers, and economies in financing and other phases of management produced by consolidations and groupings of operating companies. The excellent financial showings the electrical utilities in general are able to make at present are a tribute to technical progressiveness and administrative ability. They must in time, however, reflect the trends in sales and investment if those are not corrected.

The pictures I am using in this paper were collected by the Statistical Department of our Association from its own records, and data of the Census Bureau. They cover the entire electricity supply industry of the country, with inter-company sales eliminated.

In 1922 there were sold 7.54 kw-hr. for each dollar invested in plant and equipment. In 1927 this figure dropped to 6.61 kw-hr., a decrease of 12½ per cent.

The average price a kilowatt hour sold in 1922 was 2.81 cents, while in 1927 it was 2.71 cents, a decrease of 3½ per cent.

The revenue for the dollar of investment in 1922 was 21.1 cents. In 1927 it had decreased to 17.9, or 15 per cent.

The 1922 rate of capital turnover was once in 4.72 years. In 1927 it was once in 5.58 years, or 18 per cent longer.

In this period, from 1922 to 1927, the installed generating capacity increased 78 per cent. The average generation per kilowatt installed increased 4 per cent. The investment per kilowatt installed increased from $312 to $367, or 17½ per cent.

The balance available for interest, dividends and surplus showed an average rate of return for the
7.30 per cent. In 1927 it was 7.48 per cent.
industry in 1922 of 7.58 per cent. In 1926 it was

In order that these facts may be seen in their proper relationship, it is necessary to interpret them by the introduction of paralleling facts. As we all know, there have been, in recent years, many rate reductions, particularly in domestic or household rates. As an industry, we take pride in the fact that electricity is the only item in the cost of living figures, compiled by the Federal Government, which is lower now than it was before the World War. That, in part at least, accounts for the steady decrease in the revenue received for each dollar of investment.

Built Ahead of Demand

Since the war, our industry has carried on a tremendous building program. In the last few years, which have been a period of great business activity, general prosperity and easy money—that is, capital readily available on good terms for enterprises of merit—we have vastly enlarged our plant capacity and transmission and distribution equipment. As an industry, we have invested in such extension each year three-quarters of a billion dollars, or more. We have made up for any deficiencies of construction during the war period and have built ahead of demand, as it was our duty to do. We have built into less densely populated territory, into the smaller and more remote communities, into rural districts, to reach farm customers wherever practicable. The net result of that has been that costs of transmission and distribution facilities have been heavier in proportion to the unit of energy sold than when we were dealing with large city groups, or even the average of urban population.

This condition will continue. In very large degree, the urban population of the country is now on our lines. Aside from the natural growth of population, the new customers we shall obtain will be those in the outlying districts, so it is not reasonable to suppose that investment costs will turn downward.

Now with those elements taken into consideration, what do our figures show us?

First, the average revenue a kilowatt sold to the ultimate user is just about stabilized. The tendency, however, is downward.

Second, the trend of revenue in relation to the dollar of investment is distinctly downward.

Third, the time of capital turnover is markedly lengthening.

Fourth, the investment per kilowatt of installed generating capacity is increasing.

Fifth, the return on the investment has been approximately stabilized since 1922.

On that showing, the question, "Shall we increase our sales or our rates?" becomes distinctly and sharply pertinent.

Sales Increase the Only Answer

There can be but one answer to that question. We do not want to seek rate increases. We want to continue the course of our industry's development, which has been marked by a steady decline in prices charged for service. We could not afford to raise the prices now even if we did want to, for such a policy would inevitably decrease our sales and antagonize the public.

The answer to this question then is that we must increase our sales. We must sell more kilowatt hours for each dollar of investment, making our equipment work harder and steadier, and the place to sell more service, in my judgment, is in the home. There are nineteen million homes on our lines. The average use of electricity in these homes is figured at 456 kilowatt hours during 1928. That represents an increase of 27 kw-hr. over 1927, which year produced an increase of 25 kw-hr. over 1926. It is gratifying that there were these increases, yet their size really does not seem anything to cheer about.

This figure of 456 kw-hr., please remember, is the average for the country. In many districts of the country it is exceeded largely. There are, for example, annual sales of 546 kw-hr at an average price of 4.94 cents, of 580 kw-hr. at 4.52 cents, of 577 kw-hr. at 4.84 cents, of 717 kw-hr. at 4.88 cents, and 735 kw-hr. at 3.3 cents.

It is obviously not likely that every electric utility can equal such sales. It is distinctly possible, however, for most companies so to increase their domestic sales that the average for the country will jump a good deal more than 25 or 27 kw-hr. a year.

Reasons for Stimulating Domestic Sales

Domestic sales should be vigorously stimulated for several reasons. The first is that they are and always will remain the backbone of our business. Industrial use of electricity, and to a somewhat less extent, commercial use, will fluctuate with the state of business health of the country. We have seen this in recent years. In 1922 industrial sales were about 6 per cent below the average. In 1926 they were about 6 per cent above.

There is very little fluctuation in domestic use of our service. Household habits become fixed. A household accustomed to the convenience and value of electricity will curtail its use only under the direct necessity. When we add to the domestic load, therefore, we put on what amounts to a permanent increase in business.

Another reason is that domestic business is highly desirable business. Once the customer is beyond the point of use, which pays for the fixed expenses of serving him, the chief expense incurred by the company in furnishing additional kilowatt hours is that of generating the energy. Moreover, increased domestic load is an important element in improving the company's load factor.

The third reason is that the customer who makes the largest use of service is, in all human probability, the best satisfied customer. We seek to improve our relations with the public by furnishing information about our business, by public speaking, by advertising.

We have every possible incentive to create a body of customers in homes all over the land who are using so much service and getting so much comfort and convenience out of the use of service that they thoroughly and genuinely appreciate its worth.

A fourth reason is that we have a social duty to increase the domestic use of electricity. Electric utilities are not alone business enterprises. They are also organizations for public service. They obtain their franchises on that basis. With them they acquired certain responsibilities. One of these responsibilities, as I see it, is to do everything possible to make their service most widely useful to the public. Naturally, as a matter of plain ordinary business policy, we seek to sell as much service as we can. My point is that we have for sale more than kilowatt hours. We have for sale, comfort, convenience, time-saving and freedom from drudgery. We have for sale better home conditions, higher standards of living.

Making Electricity More Used and More Useful in the Home

It is our privilege and duty to approach our sales problem from that point of view as well as from the point of view of increasing our revenues. If we neglect it, we may be sound business organizations but we fail to live up to our responsibilities as public utilities. Our industry has been criticized not a little on just that point, and I think we deserve the criticism in exactly the measure in which we omit any effort, practices or policies, which may properly be adopted to make electric service more used and more useful in the home.

It seems to me more than a coincidence that in every case I know of a reduction in domestic electric rates has been followed by increased use of service. There may be instances where this was not true, but they have not come to my attention. It was true in Brooklyn under conditions which covered a series of reductions over a period of several years. It has been true in upstate New York, in New England, in the Middle West, and on the Pacific Coast. Those companies which show the highest annual domestic sales also show the lowest rates. We have, therefore, in the experience of our industry what may be accepted as a guiding principle in stimulation of sales of service for domestic use. The way to increase such sales is wisely and properly to lower the domestic rates.

The Inducement Rate

Moreover, there is within the experience of the industry in recent years, a guide to the general form of rate schedule effective in increasing domestic sales rapidly, what has come to be known as the inducement rate. In this there is either a minimum charge or a charge for the first few kilowatt hours at sufficient rate to cover the fixed charges of serving the customer, after which comes a kilowatt hour charge lowering rapidly as the use of service increases.

You are all familiar with the theory itself, whatever its variations in rate structures for particular localities. This theory works. Such a rate schedule actually does what the name indicates. It induces larger sales of kilowatt hours, and that, it appears to me, is what we are all after.

For a number of years we have been patting ourselves on the back over the million and a half new homes brought on our lines each year. In truth, the figures have represented a high tribute to the value of electric service and have been something about which we might properly be gratified. Yet, having obtained these customers, we have not been doing our full duty to our companies in respect of them, neither have we been doing our full duty to them. We have not been selling these customers all the electric service they could profitably use in the various processes of running a modern household.

Here with our nineteen million domestic customers is a field to cultivate which will yield us, properly cultivated, more sales to the dollar of investment without adding to that investment; which will increase the average revenue to the dollar of investment, even on lowered rates, which will tend to shorten the time of capital turnover, which will produce a practically permanent increase of sales not subject to the fluctuations due to business depression. These advantages we stand to gain, plus the great and valuable advantage of having this enormous body of customers better satisfied with our service because it is doing more for them.

Who Knows the Limit of Domestic Sales?

Here is a situation, it seems to me, which concerns all companies in our industry, because however well any may be doing in respect to domestic sales, none has reached the limit of possibility. Indeed, who can tell what the limit is when Mr. Edison himself says that electricity will not have done its full job as long as humanity uses for any tasks some agency which electric service could better. Obviously each company will have to meet this situation according to its own local conditions and in its own time and manner. Each company, however, will have to meet it. Our nation's standards of living do not stand still. They are constantly being revised upward. Society's demands upon our industry do not stand still. They also are constantly being revised, and on the whole I believe in no unfair spirit.

Clearly, the demand now is for a way of making possible more use of electric service in the American home. That demand coincides with our need as an industry, and there is within the industry the experience and general indication of how to meet it with mutual benefit. (Applause.)

CHAIRMAN OWENS: I am sure that no greater contribution to the industry and to the nation, in the form of a speech has ever been made in the National Electric Light Association Convention. I desire to compliment the audience on the degree to which they have listened and have remained in the hall. I assure you that you have a treat before you in the next speaker. Before I introduce him, I ask your indulgence to make a brief announcement.

Tomorrow morning the front center sections will be reserved for the Edison Pioneers and their Ladies.

After the next speaker has concluded, you will have a very interesting, and I assure you a very unique announcement to be made by Mr. Sidney

Mitchell, President of the Electric Bond & Share Co. I hope no one will leave, because I am sure that this will challenge you.

The next speaker has had a most colorful career. It seems to me as I read his record, that about all the honors that could come to any single individual in engineering or in business life, have been given to him. He is the vice-president of one of the greatest business organizations in the world, The American Telephone & Telegraph Co. I am proud to present to this audience, Mr. John J. Carty, who will now address you. (Applause).

SCIENCE AND PROGRESS IN THE INDUSTRIES

By JOHN J. CARTY

Vice-President, American Telephone & Telegraph Co., New York.

On this occasion which marks the semi-centennial of the incandescent electric light, it is my privilege to address the National Electric Light Association on the subject of "Science and Progress in the Industries."

The unparalleled advances which have been made by the members of this Association, in extending the benefits of light and power even to the most remote hamlets of the land, are due to many causes, scientific, economic, and administrative. You have made enduring contributions to the economic welfare of the country, which are destined as time goes on, to bring about in our social and industrial life still greater improvements, the nature of which we can as yet only dimly perceive. Fifty years ago, service such as you are now rendering to the public was unknown; it did not then even exist. But today this service which you have organized is so vital that without it the present industrial structure itself could not exist. Behind all this lies a story of American enterprise, of administrative capacity, and of a public service effectively rendered, which is worthy of the admiration of all.

The historian of the future, writing with that perspective and with that detached state of mind which comes with the lapse of time, will find in the achievements of the members of this Association material for one of the most interesting chapters in the history of American industry. While he will justly appraise the effectiveness of your organization and the spirit of service which actuates your employees, he will show much better than can now be done how dependent is progress in your industry upon the advancement of science.

It has been said that next to the verdict of history, the observations of foreign contemporaries are calculated to give a trustworthy estimate of the achievements, the progress, and status of a nation. There may be enough truth in this to afford some measure of justification for me, as an engineer outside of the electric light and power industry, in venturing to discuss some of the relations of science to the remarkable progress which you have made. I shall speak, therefore, as one interested in the advancement of science, but detached from your activities —commenting as an observer who has followed attentively the progress which you have made in your industry from the time of its inception.

One of the outstanding factors in the success of the electric light and power industry is its encouragement and support of laboratories for research in applied science. In the operation of these laboratories, millions of dollars are expended each year, and thousands of men are employed, including engineers and scientists distinguished for their achievements in so many departments including physics and chemistry. They have perfected generators, motors, transformers and prime movers. They have made contributions to transportation, commerce and industry. They have provided agencies for the advancement of medicine and surgery, and they have contributed in countless ways to the social welfare. Every individual, whether on the farm or in the office or workshop, whether at home or in a hospital or at church or in the theater, is receiving the benefits of these achievements. Whether traveling on land or at sea or in the air, our safety and comfort and ease of transport are dependent far more than is yet realized upon the work of your industrial scientists. Volumes would be required to show how their manifold products have transformed and enriched our daily lives.

Research and Cost Reductions

But let me give a specific illustration which seems to be in a special manner appropriate on this occasion which marks the semi-centennial of the incandescent electric light, which was the invention of our great scientist and inventor, Thomas A. Edison, Let us go back only to the year 1907, which marks the introduction of the metallic filament lamp, and consider some of the progress which has been made in the electric lamp since that date.

By the year 1907, the improved carbon lamp, as the result of incessant scientific experimentation, had reached an efficiency giving an illuminating power of about 3 lumens (3.4) for each watt of energy employed. In that year, 1907, and as the result of profound research conducted by distinguished scientists in your industrial laboratories, a great forward step was taken in the introduction of the metallic filament lamp, which rapidly displaced even the best of the carbon lamps.

The tungsten filament lamp of 1928 which is the one now in general use, yields more than 14 lumens (14.5.) per watt of energy. Thus it is more than 4 times (4.26) as efficient as the best carbon lamp of 1907, assuming in the comparison the same average size and the same hours of life.

Trustworthy figures show that in the United

States alone, during the year 1928, the total expenditure by the public for lighting by means of the incandescent lamp was, in round figures, $600,000,000. If that same amount of illumination had to be provided by means of the best carbon light of 1907, then more than 4 times (4.26) as much electrical energy would have been required, and the bill for lighting which the public would then have to pay would be multiplied accordingly. The $600,000,000 would become $2,556,000;000. Were it not for the reduction in the cost in the generation and distribution of electric current which you have brought about since 1907, this figure would have to be increased by $300,000,000. From this it will be seen that the total reduction due to these items alone, is now well over two billion dollars a year ($2,256,000,000.)

This sum, almost incredible in amount, represents a cost reduction brought about by one of the products of the electric light and power laboratories—the modern tungsten filament lamp—and by the improved methods of generating and distributing current which your scientists have developed. These figures will grow larger each year, even though no further improvements should be made. They take no account of the savings due to the prices at which incandescent electric lamps and electrical machinery are now sold when compared with the prices of 25 years ago. Nor do they include any appraisal of the contributions which your industrial scientific research has made to the present unexampled prosperity of the American industries.

These figures furnish the simplest method of emphasizing the progress which science has made in your industry in the generation and distribution of electric light and power. But taken alone they do not tell the whole story, for upon reflection it will be seen that without these reductions in cost a large proportion of the public now enjoying the benefits of light and power would be wholly deprived of the advantages which they now derive from your service. The remainder of the public which would still be carried on your books as customers, could not afford to use the electric current in such large quantities as they now do, and to employ it in such a great variety of useful and profitable ways.

The slowing down of the industrial and other activities of the country which would have resulted from such a curtailment in electric service, would connote an economic loss which it is impossible to state in pecuniary terms. Whatever it may be, the sum which represents the debt of society to your industrial scientific laboratories must be so large as to be almost incredible.

Appraising the Value of Research

In endeavoring to appraise the value to the public of research in applied science conducted by your industry, I have employed a method which I have used in estimating in pecuniary terms the value to the public of applied science in the telephone art. On previous occasions I have given the results of these estimates so that at this time I will only say that there, likewise, I have found that as a result of the scientific researches in the company laboratories, sums of money similarly great have been saved to the telephone users, while the service has been constantly improved and extended into every section of our country, and across the ocean, even now rapidly bringing the nations of the earth into speaking communication with each other.

Let me pause for a moment to mention the name of Alexander Graham Bell, the inventor of the telephone. It is only a few years since he passed away. If he were still alive, we can feel sure that he would be here upon this occasion to pay tribute to his friend and fellow-citizen Thomas A. Edison, the inventor of the incandescent light, who is also the inventor of the carbon telephone transmitter and the inventor of the phonograph. This unites his name in an especial manner with that of Bell. The one revealed the method of transmitting the human voice through the vastness of space, and the other, through the ages of time. As a long-time friend of Mr. Edison, and as one who so greatly admires his genius, I wish that I could adequately express my appreciation of his achievements. This I could hope to do if I could speak in the eloquent language that Bell himself would use. But it is not within my power to put in words the message which one of these immortals would give to the other. It gives me great satisfaction to be able to join with so many millions of others in honoring Mr. Edison and adding to theirs my own congratulations and felicitations.

The scientific industrial research conducted in your laboratories is often called "research in applied science." Applied science must submit its findings to the criterion of utility. It must produce practical results, things that can be used with advantage, perform new services, or bring about new economies. It must continue to pay for itself and yield a profit. Otherwise it must cease. The figures which I have presented and the evidence which I have submitted, abundantly prove the extraordinary value of the researches conducted in your laboratories. Your applied science does pay for itself, and more. Your industry could not exist without it. You cannot allow it to cease, and you will continue to prosecute it with ever-increasing success.

Extending Boundaries of Knowledge

But I have already said so much and there is so much more that could be said, showing the importance of scientific research conducted for the sake of utility and economy, that there is danger of losing sight of another form of scientific research which has for its primary object neither of these things. I refer to scientific research conducted purely for the sake of extending the boundaries of knowledge, discovering the laws by which nature operates, and determining the principles of mathematics, astronomy, biology, chemistry, and physics.

Pure scientific research is conducted with a philosophic purpose, for the discovery of truth and for the advancement of learning. Investigators in pure science may be likened to explorers who discover new continents or islands, or hitherto unknown territory. They are continually seeking to push forward the frontiers of knowledge. Their work is conducted without any utilitarian motive, for, as Huxley says, "that which stirs their pulses is the love of knowledge and the joy of discovery of the causes of things . . . the supreme delight of extending the realm of law and order ever farther toward the unattainable goals of the infinitely great and the infinitely small, between which our little race of life is run."

The Advance Guard of Civilization

The pure scientists are the advance guard of civilization. By their discoveries they furnish to the engineer and the industrial chemist and the other applied scientists the raw materials to be elaborated into manifold agencies for the amelioration of the condition of mankind.

Let me illustrate this by the work of Scheele, a Swedish scientist, who, in 1781, made a fundamental discovery respecting tungstic acid. He furnishes a classic example of the motive and achievements of the investigator in pure science. Aside from his pioneer work in tungsten, independently of Priestley he discovered oxygen. He also discovered manganese, chlorine, barium, and molybdenum. Truth, not utility, was his criterion, for in one of his letters he said: "It is the truth alone that we desire to know, and, oh, what joy there is in discovering it!"

Subtract from our present stock of scientific knowledge the body of truth which he contributed, and applied science as we now know it would be dwarfed, and it is impossible to imagine what would be the backward state of the industries based upon it.

Growing out of the discoveries of Scheele and inspired by his example, two of his pupils, the brothers d'Elhuyar, were the first to isolate and produce metallic tungsten. Were it not for the knowledge gained by these researches in pure science, the very existence of tungsten would be unknown. The tungsten filament lamp would be an impossibility, and the manifold benefits and economies which the public now enjoys as a result of its use, would not be realized. As to the effect of this upon your own industry, you yourselves can make the best conjecture.

Let me give some other examples of the results which have ultimately followed from scientific researches conducted only for the purpose of discovering new truths or principles.

In the early part of the last century, Hans Christian Oersted, Professor of Natural Philosophy at the University of Copenhagen, made the great discovery that an electric current flowing in a wire could move a magnet; and less than one hundred years ago, Michael Faraday, conducting researches at the Royal Institution in London, discovered that a moving magnet could generate a current of electricity, and that one current could generate another. Joseph Henry, a Princeton professor, and later Secretary of the Smithsonian Institution, independently of Faraday, discovered the laws of current induction. He also made other fundamental contributions to our present stock of scientific knowledge.

This list could be extended at very great length, giving the names of thousands of investigators in the domain of pure science who have contributed knowledge which is indispensable to modern industry and to applied science in all of its branches.

"Knowledge Is Power"

But let us consider the incalculable benefits which the whole world has derived from the knowledge of scientific principles and laws contributed by only three of these great men—Oersted, Faraday, and Henry. If we did not have this knowledge, the electric telegraph and the electric light would be unknown; neither Bell nor anyone else could have invented the telephone; there would be neither dynamo nor motor, and your industry would never even have been thought of; your association would not exist, and we would not at this time be celebrating the great achievement of Edison in the invention of the electric lamp.

I have stated in terms of money some of the debt which we owe to your own workers in applied science, but it would tax the powers of the human mind to estimate the prodigious sums which have been added to the wealth of nations by the contributions of the investigators in the field of pure science seeking only to discover the truth.

Further Fundamental Discoveries Awaited

I have spoken of the past, and now let me speak of the future. There are countless practical problems now confronting mankind which never can be solved by the applied scientist in the present state of scientific knowledge. He must await further fundamental discoveries and new scientific generalizations yet to be furnished by the investigator in pure science. Unless the work of the pure scientist is continued and pushed forward with ever-increasing energy, the achievements of the industrial scientist, in the course of time will become more and more restricted. Already the applied scientists have perfected your dynamos and motors and transformers, so that they are working at 95 per cent of their theoretically perfect efficiency.

While without any increase in our present stock of knowledge in the realm of pure science, the applied scientists would find abundance of profitable work to do, nevertheless, in the long run, they can proceed no faster than the discoveries of pure science permit. It is of the greatest practical importance, therefore, that we should do everything in our power to encourage and support the work of the pure scientists who are to be found in all of our universities and scientific institutions. The discoveries made by these learned men have no immediate practical value, and could not, therefore, bring to them or to their institutions, any pecuniary return. Unlike applied science, pure science cannot support itself. It must depend upon contributions of money from the public, from far-sighted patriotic citizens and men of affairs; from business and commerce and the industries which derive their prosperity or very existence from this field of human endeavor.

The Possibilities of the Future

The possibilities of research in pure science are boundless, because the resources of nature are without number. Great as are the scientific accomplishments of our day, they are small compared to the possibilities of the future. Two centuries ago, Sir Isaac Newton, the discoverer of the law of gravitation, who ranks perhaps as the foremost scientist the world has ever known, expressed his faith in the infinite possibilities of science in these words: "I seem to have been only like a boy playing on the seashore, and diverting myself in now and then finding a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before me."

The scientific developments since the time of Newton so strikingly confirm this vision of the great philosopher that we can feel certain that, if pure science is properly supported, the discoveries of the future will be enormously great in comparison to those which have already been made. Future generations of Americans may look upon us with our present limited knowledge of the forces of nature, as we now regard the American Indian, who, cold and shivering in his scanty clothing, was ignorant of the coal at his feet, with its stores of heat and power.

Now Attacking Most Fundamental Problem

Although seriously hampered and restricted by the lack of funds, American investigators in pure science are pushing forward their work with courage and determination. Among the thousands of problems which occupy their attention, they are attacking the most fundamental of all—the ultimate constitution of matter, the structure of the atom, and the nature of the electron. On the summit of Mount Wilson, in California, the astronomers are observing in the sun and in the stars and in the nebulæ, not only worlds in process of evolution, but what is most astonishing, the evolution of the chemical elements themselves. In laboratories at the base of the mountain, chemists and physicists are attempting to reproduce with increasing prospects of success, conditions which have been discovered in the depths of the universe. They are splitting the atom into its parts, and their work is filled with the greatest promise. From it I believe science will some day learn how to take the elements apart, and put them together again in new and most remarkable combinations. Already they have found that in the depths of space, hydrogen is being transmuted into helium, oxygen, silicon, and iron. They have discovered that the material substance of the faint companion star of Sirius has a density of one ton per cubic inch; while a cubic inch of the material composing another faint star recently studied at Mount Wilson may weigh as much as seven tons.

I believe that in the course of time, if these investigations can be carried forward to success, our applied scientists will be able to provide new structural materials and metallic alloys, lighter or heavier, as may be desired, cheaper and more durable and capable of resisting corrosion. Researches such as these should be multiplied a thousandfold. They will give us the answer to the great problem of drawing upon new sources of energy, and of utilizing those already available with the highest economy and efficiency. No inquiries could go more deeply to the foundations of industrial progress than these, and none could hold forth such promise of continued prosperity and of such advancement in all human affairs.

If there were time to do so I could show the necessity for conducting pure science research not only in those fields which I have already indicated, but I could explain why it is essential to prosecute such researches with the utmost vigor, in every department of science without any exception whatever.

Measuring the Value of Science

Because it was convenient, I have stated some of the results of science in terms of money. But the value of science can best be measured in terms of human achievement, the mastery of the forces of Nature, the elimination of poverty and disease, the prolongation of life, the advancement of learning, the growth of right living and sound thinking and of good understanding among men. Pure science research is indispensable to the attainment of all of these ends. According to the present vision of science, life must no longer be regarded as a struggle among men for a limited store, where one man's gain or one nation's gain must be another's loss. Under the banner of science, we are asked to join with our fellow-men working together in controlling and utilizing the bountiful forces of nature.

"Science," said Pasteur, "is the soul of prosperity of nations and the living source of all progress." American business and commerce and industry and the whole of the American public are being asked to give and to continue to give to pure science research, in our universities and elsewhere, that support which it so greatly needs. For all the benefits which it is conferring upon us, science asks only that we provide its zealous workers with an opportunity to multiply their efforts in our behalf. Upon the answer to this call depends the future prosperity of the nation. (Applause).

Chairman Owens: I feel sure you will agree with me that no more scholarly address has ever been presented at the National Electric Light Association Convention.

Mr. Carty, we are indebted for a great contribution to this industry, and to the nation and to the world, in this address.

Again I want to call your attention to the fact that the convention, except for the introduction of the Benn talk, would have been run exactly on schedule.

I will ask Mr. Mitchell if he will now make the announcement which I am sure will be of very great interest to you. Mr. Sidney Mitchell:

INTRODUCTION OF FOREIGN VISITORS

By SIDNEY Z. MITCHELL,
President, Electric Bond & Share Company.

We are accustomed to think in an intense way, of the great electrical developments that are being made in this country for our own benefit, and also for the benefit of the world. I doubt if we realize to what extent the remainder of the world is also thinking of practically the same things that so greatly absorb our thoughts here.

It has been my privilege to investigate electrical developments very generally throughout the world in the last two or three years. While I have found, as you all know, that in most respects, the developments in the foreign countries are perhaps not pushed ahead in a general sense as far as in this country, yet in some respects, they are even better. In many ways they can teach us a number of things that are useful for us to know. The greater portion of the foreign countries are taking their cue now as to the commercial developments from the United States, because they found upon investigation that we have intensified and pushed and refined the commercial side of the business in a way in this country that cannot be found anywhere else.

You know that some of the countries that are being developed electrically in an intense way today are 7000 miles from us. That is rather far for the transmission of power or for the interchanges of power, but, it is not at all too far for interchange of ideas and of good-fellowship. I think that is shown by the fact that at this convention we have by far a larger number of important men from foreign countries who are here to extend the hand of fellowship to us, and to exchange ideas with us, than ever before.

Another thing that brings them here is the fact that they all recognize, as we do, that Mr. Edison has been the real, great Father of the Electric Light Industry, and they have come here to join us in doing him honor by helping us celebrate the Fiftieth Birthday of the Incandescent Lamp.

Looking around the room I have been able to find only a few of these foreign friends at the moment, but they are very important ones. They have been enjoying the pleasure of interchanging ideas with you gentlemen, and seeing you, and I know you would enjoy the pleasure of seeing them in a more or less individualized capacity. Therefore, I have asked them to kindly consent to come on the stand in order that I may present them to you one by one.

Visitors from Japan

The first gentleman whom I am going to present to you is the "C. A. Coffin" and "Owen D. Young" king of electricity in Japan. He is the president of the great Toho Electric Power Co. and a director of the Tokyo Electric Light Co. He is also the president of the Japan Electric Bond & Share Co., a man who is known not only throughout the Orient, but throughout the world to everyone who is cognizant of electrical conditions in Japan and knows who is who over there. Gentlemen, I have the great pleasure of presenting to you Mr. Yasuzaemon Matsunaga. (Applause).

While I am talking to you about this doer of things, this great leader of the Flowery Kingdom of Japan, the land of the cherry blossoms and many other beautiful things, I want to also present his right hand man in the doings of so many worthwhile things. Let me present Dr. Tadao Kamiya. (Applause). In this country he would correspond with what we would call the first lieutenant of this great doer of things.

You know, we have had a great many people from foreign countries who have come here and become Americanized. I doubt if you know how many people go to Japan and fall in love with the country and become Japanized. There are numerous learned and very able men of that type, some Americans and some British. We happen to have one here of British origin, yet who is now a citizen of Tokyo. I want to introduce to you the general manager of the Nippon Denki Shoken Kabushiki Kaisha, Mr. H. A. Chapman, also of Sales & Co., London. You see I have been practicing on this name (laughter) because in English it means Japanese Electric Bond & Share Co. I wish I could know as much as 1 per cent of what he knows of the Orient. I might be helpful then in promoting better trade relations with our country.

Latin-American Visitors

I am going to move over about 7000 miles in another direction. We have representatives here from many Latin-American countries. Unfortunately, in the short time at my disposal I could only find a few of them. Yet, as I said before, they are the leaders in the electrical industry of their particular countries. Here is one of them particularly I would like to introduce to you. He is one of the pioneers of the great sister Republic of Argentina, a country, as our American Ambassador told us the other day, which has a cash circulating medium—this is going to astonish you—of from 40 to 50 per cent more per capita than the United States. I think that will surprise many people. This gentleman was good enough to let us come in as partners in a small way in Argentina with him. He controls down there about 120 towns and cities. The business is growing 20 to 25 per cent a year. His country sells corn and hogs, beef, wheat and things of that kind; in fact, it is the food storehouse for Europe.

Gentlemen, I have great pleasure in presenting to you Mr. Mauro Herlitzka of the Compania Anglo-Argentina de Electricidad of Buenos Aires, Argentine. (Applause).

Now I would like to present to you another gentleman who, I think, was born in this country but who is now Brazilian. He has been very helpful in bridging over the differences in language and in customs for many American business houses in Brazil, including the one with which I happen to be connected. They love him in Brazil, and he is, like all other good people who know how to join any good country, much more Brazilian than if he had been born there.

I take great pleasure in presenting to you Illustrissimo Senhor Guilherme Haile of Rio de Janeiro. (Applause.)

We have some other sister Republic representatives here who came to help us do honor to Mr. Edison, and to exchange ideas with us, and from whom I have been learning many things. I would like to present now the eminent electrical man and lawyer as well, from Santiago, Chili, Dr. Samuel Claro (Applause).

I would also like to present to you the general manager of the Compania Chilena de Electricidad, Limitada, of Santiago, Chile, Mr. Harvey Diamond. This Chilean company was German up to the beginning of the war, and then became British. It has just joined our American and Foreign group in the last few months, and the gentlemen who are here representing this Chilean company are part of the Lord Cowdray staff of the British ownership.

I am now going to present a young man who has a star reputation; in fact, he carries the flag of honor for being the greatest commercial developer, the greatest salesman of appliances, in pushing for business, that I know in the Latin countries. He is the commercial manager of the Empresa Guatemalteca de Electricidad, of Guatemala City. Gentlemen, Mr. Carlos Dorion, from Guatemala City. (Applause.)

In conclusion, I would like to say that the Association wishes to tender to our foreign delegates a luncheon at 1 o'clock in the Blue Room of the Hotel Shelburne, and I would like to ask all the foreign delegates present, and all you can find, to leave their names and the names of their companies, at the executive offices of the Association. All the foreign delegates are invited, and we hope we will have 100 per cent attendance at this luncheon tomorrow, at 1 o'clock.

[The meeting adjourned at 1:30 p. m.]

THIRD GENERAL SESSION

THURSDAY, JUNE 6, 1929

[The meeting convened at 10 a.m., President Arkwright presiding.]

PRESIDENT ARKWRIGHT: The meeting will please come to order.

The first item on the program is the announcement of the Prize Awards by the Committee. Mr. W. H. Onken, Jr., Chairman of the Committee, will make the announcement.

REPORT OF PRIZE AWARDS COMMITTEE

By W. H. ONKEN, JR., *Chairman*

(For Committee Personnel See Appendix 4)

Through the generosity of their respective donors, the Prize Awards Committee has made the following awards for 1929.

The titles of the winning papers and their authors are as follows:

HENRY L. DOHERTY GOLD MEDAL

"Investment Merit of the Electric Utility Industry," by Everett W. Vilett, Public Service Electric & Gas Co., Newark, N. J.

HARRIET BILLINGS AWARD

"The Human Side of a Balance Sheet," by P. O. Johnson, Northern States Co., Minneapolis, Minn.

MARTIN J. INSULL AWARD

"A Public Relations Yardstick," by Rob Roy MacLeod, Buffalo, Niagara & Eastern Power Corp., Buffalo, N. Y.

J. E. DAVIDSON AWARDS

1. "A Study of Merchandise Advertising," by Keo Currie and Ray Warren, Public Service Co. of Northern Illinois, Chicago, Ill.
2. "Specialized Merchandising for the Central Station," by Donald D. Parry, Central Hudson Gas & Electric Corp., Poughkeepsie, N. Y.
3. "Winter Humidity and Comfortable Homes," by Edwin Fleischmann, Niagara Falls Power Co., Niagara Falls, N. Y.

JAMES H. McGRAW AWARDS

1. "Operating a Hydro-electric System for Best Economy," by E. B. Strowger, Niagara Falls Power Co., Niagara Falls, N. Y.
2. "The Electric Water Heater," by H. George D. Nutting, Detroit Edison Co.
3. "Peak Load in Steam Plants and Its Economical Generation," by Francis Heisler, Public Service Co. of Northern Illinois, Chicago, Ill.

H. M. BYLLESBY AWARDS

1. "Six Words in an Accountant's Life," by William A. O'Neill, Electric Bond & Share Co., New York, N. Y.
2. "How to Increase the Usefulness of the Accountant in the Public Utility Industry," by F. L. Barry, Electric Bond & Share Co., New York, N. Y.
3. "The Accountant in the Public Utility Industry," by Harold V. Bright, Southeastern Power & Light Co., New York, N. Y.

FRANK W. SMITH EDUCATIONAL AWARD

Raymond H. Young, Public Service Electric & Gas Co., Camden, N. J.

PRESIDENT ARKWRIGHT: I wish to announce you will find on sale downstairs in the special booth near the registration desk, the special Edison Stamps. They were put on sale for the first time yesterday at Menlo Park. That was immediately followed by placing them on sale here. I am sure everyone will want to get them and use them.

Mr. N. H. Boynton, for the Committee, will announce the plan for Light's Golden Jubilee. Mr. Boynton!

PLANS FOR LIGHT'S GOLDEN JUBILEE

BY N. H. BOYNTON

President Arkwright has asked me to discuss very briefly with you the plans for Light's Golden Jubilee. Light's Golden Jubilee had its inception, as you all know, with the Edison Pioneers at their annual meeting at Hotel Astor on Thomas Edison's birthday, February 11. And when the Pioneers called into being a great Sponsoring Committee headed by our President, Herbert Hoover, Light's Golden Jubilee became a nation-wide celebration, in which the electrical industry was a small but important part. Today we face the celebration of the Fiftieth Anniversary of the invention of the incandescent lamp and the establishment of the electrical industry with a great epoch-making event in which we all are eager to participate.

I want to read to you what our Chief Executive, the Honorable Herbert Hoover, said in accepting the Honorary Chairmanship of Light's Golden Jubilee Committee, because this will form the keynote for your thought and action in celebrating the event. In accepting the Honorary Chairmanship, for Light's Golden Jubilee, Herbert Hoover said to President Barstow of the Edison Pioneers:

"I shall be delighted to act in any capacity that will be a genuine tribute to Mr. Edison's services."

With that thought in mind, your Industry Committee has already carried out a great many plans.

Early in the planning for Light's Golden Jubilee, we realized that Thomas Alva Edison is still with us in the flesh, and very much in the spirit; that we could pay a very handsome tribute to a very wonderful man, a man to whom we, the electrical industry, owe our origin. So those of us who were giving this occasion some thought were inspired to go ahead with our plans entirely on the basis of paying a fitting tribute to a grand man. As our ideas developed and as we gave the tribute more thought, we realized that while it would be fine to pay this handsome tribute to Thomas Edison, still it should not be our sole objective. An even grander thought captured our imaginations, and that was simply this: The character of the American youth is very definitely influenced by the heroes at whose shrines the American youth is wont to worship. The Washingtons. The Lincolns. The Lees. These grand characters of American history go to make up the character of the American youth.

The Object to Be Advanced

In Thomas Edison we must realize that we have another national character, a character which has been made not through the ballot box, not through military genius, not through the fortunes of war or politics, but through the energy exerted at the work bench, through the energy and untiring patience and diligence that has come out of constant research work. So through Light's Golden Jubilee I believe we will find that we are canonizing another great character, that of Thomas Edison, the epitome of hard work and perseverance, the man who coined the phrase "genius is one per cent inspiration and 99 per cent perspiration."

So I believe that as you think more and more of the celebration of Light's Golden Jubilee you will come to realize that this grander thought to which I refer is the great object to be advanced through this celebration.

The organization of the movement is a very simple one. The Edison Pioneers, through a subcommittee, have called into being a great Sponsoring Committee which, as I have already told you, is headed by the President of the United States. That Committee consists of some sixty men and women from all sections of American life, none of them associated with the electrical industry directly, and these people are enthusiastic in their efforts to properly guide the future course of Light's Golden Jubilee. The Edison Pioneers have also called into being an Industry Committee. Many of you are serving on that Committee.

Beyond that, there is no organization—and it requires no organization, because this celebration will come from the heart. Does one need to be told how to celebrate Christmas, or the New Year, or Fourth of July? One just celebrates. Who then is there who needs to be told how to celebrate this glorious fiftieth anniversary of the electric light. Furthermore, as you get the leading men in your community interested in the subject they will have as many, if not more, ideas on how to celebrate than any committee could bring to them.

Plan Book Prepared

To assist in this work the National Electric Light Association has prepared a Plan Book. Limited copies are available today and will be sent to you upon your return to your homes. Plan Books can be had at any of the booths of the lamp companies, the Westinghouse, the Edison, or the National Lamp companies today, and at those several booths are men who have given a great deal of thought to this general subject and who will be glad to discuss the matter with any of you.

Briefly, the plan should be developed, we believe, along these lines. You will find a great interest on the part of the business community in your cities. Therefore, it seems best to organize locally with the leaders of business in your community. As the head of Light's Golden Jubilee Sponsoring Committee in your city, you may be sure to find the leading local man or woman intensely interested in the Jubilee.

The greatest respect that we can pay to Mr. Edison is to have him realize that the American public, the world public, if you will, appreciates the great effort that he has put forth and the many priceless gifts that he has bestowed upon us. That is really the great reward for service—the knowledge of good rendering.

You will find when you begin to organize in your community that everyone knows of the great invention that was made fifty years ago, knows of the great Age of Progress, which it engendered. You will also have means at your command to let them know. The best thing that you can do is to organize all your local service clubs, Rotary, Kiwanis, Chamber of Commerce, and the like.

The Local Program

Set aside a program in which Mr. Edison and his great achievement can be discussed, presented probably by a member of your own company, or by someone made available to you by the Speaker's Bureau of Light's Golden Jubilee. See that every luncheon club, every business club, every church, every school and every lodge, pays its respects to this great leader of ours. Each will be anxious to do so.

Beyond that, the program can be whatever your local community desires, In Atlantic City you have seen the great Festival of Light, a glorious display of light on the boardwalk; on Atlantic and Pacific Avenues; and, many of the side streets and hotels are paying their respect and tribute to Thomas Edison on this occasion, for this week has seen the beginning of Light's Golden Jubilee here in Atlantic City. Not many cities will want to go as far as Atlantic City has gone in this direction, but many of them will want to do some special festival lighting in their own way. They will want to have many public gatherings where Mr. Edison receives the tribute of the people. Whatever direction the local plans take, you will be on the right road to a successful celebration, because the citizenry will be paying respect to our great founder.

So I urge you to get a copy of the Plan Book which will explain in detail what may be done. I urge you to act early. I urge you to select from the business organizations in your town the leaders to sponsor the celebration in your particular community, and work up to a great climax on October 21, this fall, which is the fiftieth anniversary day of the perfection of the incandescent electric lamp by Mr. Edison. This day, I believe, will be a red letter day not only in the electrical industry but in the history of the United States, because I believe there will be by far the greatest outpouring of gratitude to Mr. Edison on that night that has ever been paid to any one individual.

When History Repeats Itself

An outstanding feature of that evening's program will take place at Dearborn, where our distinguished Edison Pioneer, Henry Ford, has caused Menlo Park to live again, just as it was fifty years ago. And there in the company of a few of the Edison Pioneers, and a few of Mr. Ford's personal friends, will be re-enacted, in the old, original laboratory, the scene of fifty years ago. Mr. Edison will actually make the incandescent lamp as he made it October 21, 1879, and Graham MacNamee will tell the world, over the radio, about the scene that is being enacted there. Mr. Edison will work in the light of the old kerosene lamp, as he did in his laboratory fifty years ago. You and I on that night will be sitting at home with our families, in the light of the kerosene lamp or candle, and we will be listening to the description over the radio of this great occasion.

Then as Mr. Edison completes the lamp and goes to the old engines which have been retrieved and reconditioned by Mr. Ford, and as he lets the steam from the old rejuvenated Wilcox boiler, fired as it was fifty years ago, into this old engine, and as the engine starts to boil, and the voltage builds up, the lamp will be re-born. The light will come on feebly at first; then it will grow brighter, and finally as it comes to full voltage and full brilliance, lights all over the world will be turned on in glowing tribute to this great inventor.

The occasion will be a grand one. I think we will all be glad to be a part of it. We owe it to our communities to see that they appreciate the wonderful benefits that have come through Mr. Edison's great invention, and that October 21, 1929, will go down in the history of the electrical industry and of the world as a red letter day.

And so I urge you, with these few brief remarks, to be active in your community. See that you have a plan that will embrace the entire public within your community; and see that no one shall fail to realize that this is the golden anniversary of a great invention. If you do this, then a rose to the living, to our Mr. Edison, our great hero, will be tendered. We should all be eager to take a part in this great movement. (Applause.)

PRESIDENT ARKWRIGHT: It is a privilege to have the distinction and honor for the National Electric Light Association to inaugurate Light's Golden Jubilee in celebration of the first successful demonstration of the electric incandescent lamp, invented by Mr. Edison on Oct. 21, 1879. With its coming, the terrors of dark were banished; useful time was lengthened; available space was widened; efficiency was increased; safety was increased; quality of production was better; quantity of production was increased; earnings of men were enlarged. Living conditions were made better; convenience, comfort, happiness and joy of mankind were increased. It is the cheapest light the world has ever had, a hundred times cheaper than candle light; many times cheaper than oil light. Indeed, it can be demonstrated that it is cheaper than daylight, and it is better than daylight, too. As important as the lamp was, the idea of the lamp in Mr. Edison's brain, or the experimental model in his laboratory would have served no useful purpose. It was necessary to bring it into service of mankind, and Mr. Edison thereupon developed the central station, machinery, appliances, methods and plans. Not only did he develop the plan of it, but he established it with courage and far-sightedness and risk and devotion. He couldn't do that very well all by himself, and he gathered around him a band of devoted men, industrious and intelligent, standing close to him, working along with him, aiding him to develop and bring to mankind the invention of his brain.

Not only do we honor Mr. Edison today, but those pioneers who served with him, not perhaps taking the greatest credit to themselves, but as useful, as necessary as even he himself was.

We are very proud of the fact that a number of them sit before us in the middle section. Everything, every circumstance surrounding this inaugural is so favorable, the fine, new auditorium with this display of what electric incandescent lighting can be, even the sun has shined brightly all the week. The skies themselves seem to smile upon the occasion as in evidence of the favor of heaven, of the bringing forth of so useful an invention and so useful a service for the happiness, joy and comfort of mankind.

It seems especially propitious to me that all week long we have the clear, bright sunshine when through the year clouds of suspicion seemed to have been blown upon the industry that Mr. Edison founded. It looks almost as if the One who searches men's hearts and knows all has confidence in our integrity of purpose and believes that we are trying our very best to do a useful service. As the clouds have disappeared in the bright sunshine of our week's convention, so it seems that with the truth of light the clouds of suspicion on our industry would be swept away also.

We couldn't have this inaugural ceremony this morning just by those of us who followed in the footsteps of those who founded and made the industry. We call to our aid those great Edison pioneers, so that greater honor may be given those men who in the pioneer days couldn't possibly foresee what it could be, but with the vision and belief almost of what it has become, went into it and built it up. We have had as an advisory committee for this morning's exercise, Mr. John W. Lieb, Mr. C. L. Edgar, Mr. Samuel Insull and Mr. S. Z. Mitchell, who sponsor this particular session of our convention.

Among them we have asked to preside as honorary chairman the first electrician, the first engineer of a central station that ever the world had known, with no past experience, with no facts demonstrated by actual experience as to what to do. He had to start out on a course uncharted, developing through his own mind and his own devotion and his own intelligence how best that light could be brought to people, and the ideas of Mr. Edison's genius and the central station, worked out through his mind and his efforts, could be made to usefully, satisfactorily, adequately and dependably serve mankind.

It is a great honor to have with us as Honorary Chairman, Mr. John W. Lieb, and it gives me very great pleasure and I take very great pride in presenting to you as Chairman of this session, Mr. John W. Lieb. (Applause).

[Mr. Lieb assumed the Chair.]

CHAIRMAN LIEB: Mr. President, Edison Pioneers, Ladies and Gentlemen: In giving expression to our admiration of the accomplishments of Mr. Edison by eloquent tributes of praise expressed in addresses and also visually as manifested in these glorious illuminations celebrating the Golden Jubilee of the incandescent lamp, we should not fail to signify our appreciation, however lightly, of his many accomplishments in the other fields of applied science in which he achieved wonders no less marvelous and appealing.

We justly celebrate the convenience and comfort the world enjoys and the triumph over drudgery and labor that has been accomplished through the innumerable applications of light and power service. We must not forget, however, that a wide field has been opened to mankind for the utilization of the leisure hours thus made available and enjoyment of the happiness thus acquired through other manifestations of Mr. Edison's genius.

In that wonderful and genuinely original apparatus, the phonograph, in his pioneer work in the development of the moving picture, the foundation of a vast industry catering to the pleasure and enjoyment of people in every nation and in every clime, and in his contributions to the transmission of intelligence culminating in the carbon transmitter, we have disclosed vast fields of progress in which pleasure and joy are brought to our homes, all of these being incidental to the development of the electric light and power service.

The hours of play and recreation are no longer limited by the setting sun, but by economy of labor and improvements in the standards of living incidental to the extension of light and power service, we are enabled to enjoy a fuller life, wider opportunities for recreation and enjoyment.

It would seem appropriate that this convention send a message of felicitation and congratulation to Mr. Edison on this occasion, and a resolution is now offered which I beg leave, with the approval of the President, to submit to the convention for its consideration:

"Whereas this year marks the fiftieth anniversary of the invention of the practical incandescent lamp by Thomas Alva Edison; and

"Whereas, the electric incandescent lamp is the foundation upon which the magnificent superstructure of the electric light and power service has been reared to undreamt of heights; now, therefore, be it

"Resolved, by the National Electric Light Association in session at its annual convention in Atlantic City, N. J., by setting aside Thursday, June 8, as Edison Day in the celebration of the Golden Jubilee of the incandescent lamp, the Association acknowledges the everlasting debt of gratitude which it owes to the genius and indefatigable industry of Mr. Edison, whose inventive mind envisaged, not only the development of the incandescent lamp, but also a complete system of electric generation and distribution, necessary to bring the benefits of these and other epoch-making inventions of Mr. Edison to mankind, so that they have now become part of the heritage of the electric light and power industry. And be it further

"Resolved that the National Electric Light Association express to Mr. Edison its hearty congratulations and felicitations on this memorable occasion, rejoicing that it can pay him this homage and do him this honor while he is still in our midst, with his gracious helpmate ever at his side, and while he is still actively living his very full life, so replete with accomplishments, enriched with rewards, and enjoying the love and esteem of mankind. All of which constitutes a marvelous contribution to the happiness, convenience and comfort of civilization in which we are privileged to share. And in this Golden Jubilee Celebration we join all the world in heralding the genius and great accomplishments of Thomas Alva Edison."

Gentlemen, with the approval of President Arkwright, I take the liberty and have pleasure in offering these resolutions for your consideration, to be forwarded in a telegram to Mr. Edison at Fort Meyers, Fla.

All those in tavor of this resolution will signify by the usual sign. It is so ordered, and your mandate will be carefully carried out.

In the application of great inventions, the invention itself constitutes, of course, the great background on which the subsequently developed industry is built up. But it also needs the cooperation of many co-laborers, many workers in the shop and the field, to bring the benefits of a new invention as promptly as possible to the convenience of mankind. Mr. Edison had the good fortune, through a most lovable and engaging personality, to have surrounded himself with a group of enthusiastic workers who were always ready to follow in his footsteps in the lines of development which he indicated, sparing no time throughout the busy days and nights in carrying out his ideas and projects. So throughout the United States there grew up a considerable body of loyal, devoted disciples, with headquarters in our principal cities, who assisted in bringing to the public the benefits of these new developments.

We have the pleasure of having with us today representatives of this loyal band of workers from all over the United States, a band enlisted under the banner of the Edison Pioneers. They are assembled here in the center of the hall, and we extend to them a most hearty welcome. We are very glad indeed that they are here to join us in this celebration.

One of these early workers who played a very prominent part in assisting in the early application and development of Mr. Edison's enterprises is with us today, and it gives me very great pleasure at this time to present Mr. Charles L. Edgar, President of the Edison Electric Illuminating Co. of Boston, Past-President of the National Electric Light Association and a Past-President of the Edison Pioneers, to whom I turn over the meeting as your Chairman.

Ladies and Gentlemen, it gives me very great pleasure to present my very good friend, Mr. Charles L. Edgar, your permanent Chairman. (Applause).

[Mr. Edgar assumed the chair.]

THE INSPIRATION OF A NAME

By CHARLES L. EDGAR

President, Edison Electric Illuminating Company of Boston.

Our President has already announced that we have assembled here today to commemorate the invention of the incandescent lamp by Mr. Edison just one half century ago. There will be those who will stress the inestimable value of this invention and his meritorious work leading up to and succeeding its accomplishment, while others will be more inclined to consider the character of the man himself and discuss the individual rather than his achievements.

The pages of history are illuminated with the names of those who have attained renown through some distinguished service for the welfare of mankind. I shall classify these illustrious personages into two separate and distinct groups.

In the first group the much larger number devoted their individual efforts to a cause which was dear to the hearts of their fellowmen.

The Leaders of a Nation

Washington, the beloved Father of His Country, is a shining example of this type. He was called into service during a great national crisis which existed even before he responded to the summons. It may be said to his everlasting credit and honor that he carried out his task to a most successful conclusion. He found a struggling colony oppressed by the heel of a tyrant; he left a peaceful republic happy in its hard earned freedom.

Lincoln, the Great Emancipator, is another outstanding example of this type of famous men. He was called to preserve a nation. He not only threw off the shackles of the oppressed but he perpetuated a union which was threatened with disruption and disaster.

Throughout all times and in all nations of the world there have been numerous other examples of this devoted type. Many of these, as in the case of Washington and of Lincoln, dedicated themselves to the preservation and upbuilding of their country, while others were inspired to action not by love of country but through their consecration to religion. Contrast with these others who have used their talents in an attempt to break down and destroy civilization. These are the Cæsars and the Napoleons —warriors who have risen to fame as the conquerors of hostile nations, rulers who have reared vast empires to satisfy their ambition and lust for power. The former type working for the upbuilding of some lofty principle, and the later disrupting the order of the world to satisfy their selfish desires, have all obtained the plaudits of the multitude. In almost every case they had been working for a cause, whether it had for its object creation, preservation, or destruction.

It is most difficult to analyze the thrill and emotion with which we look back upon the achievements of these striking personalities to determine how much of it is due to their individual efforts and what part is the result of an interest in the cause which they represented. The two are so closely associated that unconsciously perhaps we have lost sight of the cause and have placed the individual upon the pedestal due to our fascination for the man himself.

The Individualists

The other group to which I refer includes those who have risen to fame through accomplishments which were the result of a thought or an idea originating in each inner consciousness. They were not called to preserve existing conditions, to introduce reforms, or to advance the interests of the church or state. They were pure individualists who assumed their tasks, not in response to a popular demand for a leader to accomplish some desired result, but inspired only by their own visions. They had a conviction that there was some specific object which they could accomplish and they carried their work to a successful conclusion without outside advice or assistance.

The poets, the philosophers, the painters, the musicians, and the scientists are all men of this type. They have delved into the minds of nature's mysteries and have brought to light gems of truth and beauty which have added to the wisdom and culture of the ages, but it remained for Edison to discover the source from which at his magic touch was created a new sun for a new world, dispelling darkness and bringing added comfort into the homes and revolutionizing the life and methods of a grateful world. For him nature revealed her hidden secrets and through him a new industry sprang into being. After centuries of unconscious waiting the world awoke to realize that the dark watches of the night had wasted away and a new day of light and gladness had dawned for mankind.

Edison, the Individual and Friend

I shall not attempt to recount the practical results which have followed this invention. I am leaving that as a theme for others. The thought which is uppermost in my mind has to do with Edison the individual and the friend, rather than with Edison, the inventor and the discoverer. There are many members of the Edison Pioneers scattered throughout this audience, and I feel that their thoughts are running parallel with mine, and that they will agree with me when I state that we are inspired not so much by what he has done as by what he really is. Those of us who have been closely associated with him and know him intimately, have received an inspiration which, though difficult to describe, is nevertheless profound and enduring. While we have been amazed at the volume of his achievements and spellbound by his energy and perseverance, we have been especially touched by the warmth of his affection. Though he may be acclaimed a leading scientist and inventor, though he may be pointed out as the highest type of American citizen, those of us who know him best will ever proclaim him, above all, a staunch and faithful friend.

A Life of Service

Always modest and of a retiring nature, he has not desired fame or honors, although his fellowmen have praised him for his integrity of character, have honored him for his achievements, and loved him for his self-sacrificing regard for others. Throughout his whole life no labor was too great to be undertaken for the accomplishment of a purpose when once his mind was determined to pursue it. Truly his life is a life of service, and we of the utility industry whose basic principle is service, find in his life and work an example which it is an honor to follow. When confronted with a problem the solution of which taxes our utmost powers, we may be encouraged to persevere when we remember how Edison conquered the apparently unattainable by dint of hard work, untiring zeal, and unlimited perseverance. While we credit Edison with a remarkable degree of genius, we have his own modest testimony that much that he has accomplished has been due to hard work and perseverance, and though we lack the natural powers which he possesses we may be inspired by his example to accomplish much in the world if we apply ourselves to the tasks which are ours with his determination and his willingness to labor.

To follow is the lot of the multitude; to lead is the privilege and responsibility of the master mind who dares to stand alone, if necessary, while adhering to the principles which he believes to be sound and logical.

Edison has blazed the trail through unknown wilds while others looked on with unbelief. His was the task to lead the way, and true to his high calling he emerged with the fruits of victory amid the plaudits of those who had been unbelievers.

Like Edison, our lives should be dedicated to the service of mankind, and I believe that like him we are endeavoring to meet our obligations with cheerfulness and earnestness and a desire to accomplish the greatest good to the largest number.

In looking back to review the wonderful results which he has accomplished during his fourscore years, we are again astounded that this man of mature years, but still young in mental capacity and in resourcefulness, has within very recent years taken up a new line of endeavor and we have every reason to believe is about to bring to a successful conclusion an important development in one of the leading commercial industries of our times. Apparently there is no limit to his possibilities, and we may confidently expect that as added years shall yield their opportunities he will continue to carry on for the good of humanity, and when those of us who know him intimately and are inspired by his personality shall have faded from memory, the name of Edison will still live and grow with the years, an inspiration to the sons and daughters of every tongue and every nation who see the light and render thanks to him who invented it.

Edison and His Associates

Speaking again, more especially to those members of the Edison Pioneers who are within sound of my voice, I desire to emphasize the personal relationship which has always existed between him and his associates. It was not my good fortune to be a member of the Menlo Park group. If I had been, I probably should feel even more strongly regarding the personal side of Mr. Edison's character. When one of his boys, as he delighted to call them, in later years made a success of his undertaking, the letter of congratulation signed personally by Thomas A. Edison, and the kindly spirit expressed in this letter has gone a long way toward making the recipient feel that after all life was well worth living.

If I may be pardoned a personal reminiscence, I would like to indicate more specifically why, like all the other Pioneers, I have a warm spot in my heart for him whom we affectionately call "The Old Man."

I still have a very distinct recollection of the first time that I saw Mr. Edison. As a junior at college I visited the laboratory at Menlo Park one summer afternoon and saw standing alongside a work bench three men arrayed in city attire. Sitting on the bench in overalls and swinging his feet was a young man who at first I thought was merely an incident in the picture. I rather took it for granted that these men had accidentally stopped to talk near where the young man was sitting. Someone nudged me and said, "That's Edison." Although I had not given him or his affairs any more thought than that of the ordinary college student, it was rather a surprise to me to see the relationship which apparently existed between him and the men who I afterward learned were his financial backers.

About forty-six years ago I called at his home in Menlo Park one morning while he was at breakfast. I had a letter of introduction from the Professor of Electricity of Rutgers University. I was shown into the parlor and told to wait. I could hear the conversation being carried on in the dining room, and after about half an hour began to wonder if I had been entirely forgotten. Just then Mr. Edison strolled into the parlor with his hands in his pockets and a cigar in his mouth, and said, "Where the dickens did you come from?"

I gave him my letter of introduction. He read it over and his only remark was, "Go down to 65 and see Charlie Clark and tell him I sent you." Somehow or other I realized that that was not the time or place to ask what "65" meant or who Charlie Clark was. I thanked him and walked out, and I am proud to say that from that day to this I have been connected with corporations which have borne his name. I think I am more proud of this than of any other honor which has come to me in my business career. There are undoubtedly many of you who are listening to me today who either do not appreciate or who underestimate what this means. All I can say is that I am sorry for what you have missed.

The Inspiration of a Name

While all of us engaged in the public utility business are proud of our industry and really feel and believe that it is one of the most important as well as interesting businesses in the world, I want you to realize that there are some of us, perhaps few in number, who have a deeper feeling than that felt by the greater majority. It is a feeling of pride, experienced not so much on account of what Mr. Edison himself has done as for what he has inspired us to do. I do not think that anyone could have been associated with him for a generation and not be influenced, perhaps unconsciously, by the spirit which has actuated him. It is hard to put into words just how we feel. Personally I feel like bowing my head and being thankful that my good fortune has enabled me to live my life in the atmosphere he has created and under the inspiration of his name. (Applause).

I appreciate very deeply being asked to substitute for Mr. Lieb. We all regret the necessity for this substitution. He is in all respects the logical man to preside at this notable occasion. His personal relationship with Mr. Edison and with Mr. Edison's family, make this substitution all the more regrettable.

The National Electric Light Association was organized in 1885, and held its first convention at Chicago in February of that year. It was apparently the first attempt to bring together those interested in the public utility business, and things did not go very smoothly when it came to the question of the organization of that association.

We have with us today one who was present at this convention and took a constructive part in starting this association on its right path. Those of you who were engaged in the arc light business in the early years will, of course, remember him by the arc lamp which bore his name. In later years some of you will think of him as the man who was identified with the wonderful work in connection with the gyroscope. He now holds the chief post of honor in one of the national engineering organizations. During all these years he has maintained his interest in Mr. Edison and his accomplishments. I have the honor of presenting to you the President of the American Society of Mechanical Engineers, Mr. Elmer A. Sperry. (Applause).

THE BIRTH OF THE INDUSTRY

By Elmer A. Sperry

President, The American Society of Mechanical Engineers.

It is certainly a great honor to me to be asked to speak here on Edison Day and to pay honor to our great leader, the Nestor of us all. I bring you greetings from the American Society of Mechanical Engineers, one of the world's largest technical bodies with its 49 years of useful service and its membership of some 19,000. The National Research Council also sends greetings through me.

I feel with Mr. Edgar that those of us who have known Mr. Edison longest love him most.

I never appreciated that I was a pioneer myself until recently, but it so happens that this is the fiftieth anniversary of my making my arc light and "dynamo," as it was then called, which was first publicly used to illuminate a Christmas festival in 1879 in Cortland, N. Y., my native town. (Applause). So I will do my best to give you a little picture as I have been asked to do, of the state of the lighting art at this early time.

There is no element of nature, no force existing in the world, that has been so surrounded with romance as has electricity. Even from the earliest time there has always been connected with the manifestations of electricity a romance that attached to no other of the forces of nature. Not even the grandest and most impressive manifestations of

Neptune ever succeeded in stirring men so deeply or striking terror to their souls as did the thunderbolts of the heavens. During the endless ages of the past they have left their impress on mankind and become synonymous with all that is marvelous, mysterious and majestic. Mere romance is at once accentuated and eclipsed. To the Greeks it became the center and symbol of the terrific irresistible vengeance of the gods. In more modern times all discoveries and observations regarding electricity have invariably commanded the attention of the civilized world and modern progress may be said to date from our beginning to comprehend the correlation between magnetism, electricity and motion.

When our own beloved Franklin was presented at the foreign courts, no small part of the acclaim given him came from the fact known the world over, that he had been experimenting with the identification of electricity and lightning.

Coming down later, since the days of our great Henry and his student worker Morse, we have known the electric current as generated by batteries and then its great service to telegraphy. When telegraphy was ushered in about 1840, great romance and great acclaim were again given it, and justly so.

Edison Enters the Electric Art

Then, as you know, Mr. Edison came into the electric art, such as it was at the time. How fortunate it was that electricity had attracted such a great master mind as that of Mr. Edison! He was one of the first to see the opportunity and grasp ways and means for greatly augmenting the usefulness of a single wire running from one city to another. The quadruplex and, finally, the multiplex, were means whereby he attained a very constructive knowledge of electricity and its uses.

When first it was discovered that light could be produced by electricity, then it was that the romance of electricity reached its highest pinnacle of universal interest and acclaim. This was accomplished by Sir Humphrey Davy in 1808. The arc was produced between two charcoal pencils from quite a large battery—a brilliant, beautiful, wonderful light. Davy, it should be remembered, was the teacher and great inspiration of Michael Farraday. All the text books in physics, "natural philosophy" as it was then called, immediately proclaimed the fact that electricity could produce light, and so surrounded it with glamorous embellishment that its thrill made a lasting impression on many a youth, as it did upon me and also on young C. F. Brush in Ohio, as he once told me. However, light was produced electrically, it instantly became a center of interest. People came miles to see electricity produce light.

The "Arc Light and Power Company"

Before 1879 we had a few stations operating arc lights. There was a boiler and an engine and a belt-driven "dynamo." I well remember the relief we obtained when we found we could use one belt over on top of another, placing the second generator a little farther away, and thus run four arc light generators from the two flywheels of a single engine. These stations were distributed in the smaller towns with larger ones in cities. The great Commonwealth Edison Company in Chicago started as the "Arc Light and Power Company"—you youngsters may not know that—with no less a personage than B. E. Sunny its general manager in those days, a prince of a young man who now is in control of the communications and telephone system of Chicago and was for a long time very active in this association.

When the arc light came it was a series system. You can quite well understand why it was a series system. All the uses of electricity up to that time, such as the electric telegraph, had essentially a series distribution. So we put one lamp after another in a single circuit and undertook to make both ends meet by placing these stations in the cities and soliciting custom and city lighting.

I was working out in Chicago, had built a factory, and when I was twenty-one started in to build our arc light system. Soon there were a great many arc light plants in use all over the Northwest and the West. The Thomson-Houston Company, the forerunners of the General Electric Company, operated on nothing else but arc lights at first. So, many arc lights were in operation by the winter of 1884.

Early Problems and Their Solution

There was another romance in electricity born about the same time as the first arc light system. The arc light had about a five-year lead on Mr. Edison's incandescent lamp, as you know. That romance was the telephone, another wonderful use for electricity. When the telephone commenced to be used, the switchboards were often in the kitchen of a house in a moderate-sized town. They were a struggling industry, as were our arc light systems. Just here a difficulty arose. The moment we started the arc light system at night, every telephone in town "went on the blink." They were all using ground circuits and it was that fact that brought the electric light people together and brought into being this great organization.

We held about three meetings, I believe, in the Grand Pacific Hotel in Chicago in the winter of 1884-85 to see if there wasn't some way in which this great conflict between the telephone companies and the operating arc light companies could be adjusted. They claimed that our arcs conflicted with their service, that they weren't of much account anyway, and they only ran at night and then sometimes went out. We claimed the telephones weren't of very much account, were altogether too sensitive, and couldn't be worked over a very great distance, and so forth.

As a consequence of these meetings there was appointed a committee of three men. I had at that time the largest and highest beacon that was then known, on the top of the Board of Trade tower some 303 ft. from the sidewalk. It was about

40,000 candle power, which had attracted quite some attention in and about Chicago.

The committee as named were Sperry, Chairman, Terry and Bowen. The second name is none other than the late lamented F. S. Terry, then a young man of my own age. He had always been an outstanding character, a man of great energy and foresight in the electric light industry and founder of Nela Park in Cleveland, the principal home of incandescent lamp progressive research. At that time Mr. Terry operated the largest electrical supply business in the United States, located in Chicago with branches in various other centers.

The third member of the committee, Mr. Bowen, was a tall, genial gentleman in middle life, who was trying to make both ends meet by the operation of a Vanderpool electric light system in the nearby city of Elgin, Ill. He was also connected with the printing business. A circular inviting the original conference of electric light station owners to assemble in Chicago in February, 1885, was drawn up by Mr. Terry and myself in my rooms in Chicago and forwarded to Mr. Bowen, who had promised to print and mail the circular gratis if we would compile it. When the circular came into our hands in final form we were astonished and somewhat alarmed to find on the cover of the four-page folder a cut of a large electric arc with its scintillating rays competing successfully with a faint half-moon, but that was the way it was sent out.

The Birth of the N. E. L. A.

To our utter surprise some 140 people responded, coming to the Grand Pacific Hotel in Chicago to represent different arc light stations all over the country, from Kansas City to the seaboard. The National Electric Light Association was born at that time. So there is one thing this great body owes to the arc light, and that is its existence. The arc light, however, was eclipsed gradually by the incandescent lamp for all uses but the most powerful and penetrating searchlights, projectors, etc.

One incident occured at this first meeting which proved the greatness of Theodore N. Vail. At that time he was the leader in the telephone business, a personal friend of our last speaker, Mr. Edgar, located in Boston—a great leader. At that meeting the electric light people sat with their sleeves rolled up, as it were, ready to assault anyone that remotely resembled a telephone man. We were hoping Mr. Vail would come himself, but he sent a delightful representative from Boston with a letter. This man got up and modestly read the letter and instantly we were completely disarmed. Mr. Vail went on to say, as I remember: "This matter of interference is our problem. We will work with you until we find some solution and you must do all you can to help and encourage us, but the burden is on us." Of course, we had not a word to say after that. The convention went on and achieved a number of standardizations, and also touched a great many useful points that were common to us all.

The other interesting incident connected with that early history is that General Carty, who is in attendance with us, then a young man working out of Boston on the telephone's side, completely solved the problem before the end of 1885. It seemed they had some very important customers from Boston on the way toward Providence, with whom we seriously interfered as soon as the electric lights were started at night. We see here that even in his youth Carty was running true to form, because in later life he has risen to world leadership in the realm of research, and I doubt if any one act of his in the line of research ever was of such transcendent importance or paid any greater dividends. In desperation young Carty twisted two wires together and eliminated the ground circuit, except for ringing. The problem was solved instantly. Of course the telephone interests at that time were making no money. They were struggling youngsters and they couldn't possibly consider *two* wires for *one* talk, but Carty showed them the way. It was gradually adopted and since that time the path has been wonderfully clear. Strange to say, this cycle of forty years or so has had to pass until this same problem comes prominently before you again.

Mr. Edison's 42-minute Speech

Referring to the great objective of the day, you understand Mr. Edison was a great leader in time of war. He served as head of the Naval Consulting Board. It was my honor to be associated with him in that work. Incidentally, we all have heard that Mr. Edison never made a speech. I remember well in 1893 at the World Electrical Congress banquet in Chicago he was given the choice as ultimatum and actually crawled under his table rather than rise and say a few words. Such is his natural modesty. But at the time I mention he sat and gave us a marvelous talk on his work, especially in connection with camouflaging ships and other most interesting experiments he had been trying, and he continued for forty-two minutes. Somebody timed him. So Mr. Edison has been known to make one other speech beside the one in the movietone to follow. This is quite contrary to popular belief.

As a body the Consulting Board has tried to resign several times, but we are told by the Navy Department that it will take an act of Congress to create another body, we are considered minute men and we must stand by. Mr. Edison has consented to stand by and, of course, we all stand with him, those of us that are left.

He invited some of the Board over a few weeks before he started for the South, previous to his eighty-second birthday. We hesitated to go because he was so busy, but we went, saying we would stay one hour. Six of us went over, and we were met by Mr. Edison in the library or office of his laboratory.

Mr. Edgar has given us all a beautiful picture of Edison, the youth in overalls, swinging his legs from a work-bench at Menlo Park. I want to draw a little picture of Mr. Edison at eighty-two.

When we came in, he spied me, with a cane. He said, "Sperry, what are you doing with that cane?"

I tried to explain that it was only a bad habit of mine that I had recently acquired. He said, "I have no use for a cane, now see me kick!" He jumped up out of his chair and kicked higher than his shoulder instantly.

Of course, we were all wonderfully amused and laughed, I believe I applauded. He said, "Well, if you laugh at that, I will give you something to laugh at. I was away on one of these here vacations." He didn't speak in very respectful terms of a vacation, although I cannot understand how he could resist his friend, Mr. Ford, who sits before you here. I think he was the one who teased him into having his first vacation. He said, "While on one of these here vacations, I kicked like that and Mr. Burbank tried to imitate me and he fell down on his back and hurt the back of his head. Ha! Ha! Ha!"

He laughed as though he were a boy of ten. We could all see that the picture of Burbank picking himself up out of the leaves, and rubbing the back of his head must have been very vivid in his mind as he recalled it because he laughed until the tears ran down his face and we shared in his merriment.

One little word and then I am through.

We noticed Mr. Edison does not walk. He runs. He said to me, "I have a wonderful photograph of Diesel." He asked his secretary, Mr. Meadowcroft, a youth of 76 who is also here with us, "Where is that photograph of Diesel." He commenced to run around the laboratory among his photographs trying to find the picture. Mr. Meadowcroft finally unearthed it. He took me by the sleeve and I could hardly keep up with him. He ran with such speed to where this photograph was and showed it to me. It was an unusually fine autographed photograph of Diesel.

Men Who Know Too Much

Later we went out about half a block in the rain, Mr. Edison without any hat, to a building where he was working on the seventeen thousandth series of plants. He had examined no less than 16,000. He showed us a plant yielding 9.6 per cent rubber, found in a canyon in Arizona. He took from his shelves in a back room notebook after notebook. There seemed to be at least forty of them, some of them in his own handwriting. They were the records of these plants. Full of activity, he said with all the charm of his whimsical smile, "I had to clear out my chemists from this laboratory; they knew too much. I had to get a fresh lot in, mostly youngsters."

You know he is very deaf and it is very difficult to communicate with him, but I made bold to tell him the only story that was told on the occasion, and with apologies to Mr. Ford I will repeat it to you.

I said, "That reminds me of the way your wonderful friend, Ford, works. When Mr. Ford started to think of going into the flax business he said to Mr. Mayo, 'You have a bright young man in your drafting room or among your engineers. Won't you bring him in to me?'

"This young man came. He was almost trembling before Mr. Ford. The latter said, 'Sit down.' He did, and Mr. Ford turned to him suddenly and said, 'Young man, what do you know about flax?'

"The young man said, 'Oh, I'm afraid, Mr. Ford, I don't know a dum thing about flax. I am very sorry.'

"Ford said, 'You're just the man we want.' "

Mr. Edison laughed about it and said it was just his experience with the rubber. He added, "Sometimes it is best to take on men who are unfamiliar with the job."

I am afraid I have taken too much of your time, but this gives you, all too inadequately, a glimpse of this marvelous worker, with all his most lovable, human traits not only preserved but accentuated and mellowed by the years.

I thank you. (Applause).

CHAIRMAN EDGAR: Some four or five years ago the Edison Pioneers sponsored a movement for the erection of a tablet to Mr. Edison, located upon the grounds of his old home in Menlo Park. This consisted, as most of you know, of a rough field stone with an appropriate bronze tablet, and was located alongside the Lincoln Highway, and also close to the tracks of the Pennsylvania Railroad. It is a notable landmark to those traveling between New York and Philadelphia.

Some months after its completion I received a letter written upon the letterhead of the Public Service Electric & Gas Company, suggesting that that company would like the privilege of permanently lighting this memorial at their own expense. This letter was signed by the gentleman that I am about to introduce to you. It was characteristic of the man and of his company, and I take great pleasure in presenting to you Mr. Thomas N. McCarter, the leading spirit in public service in New Jersey. (Applause).

FROM THE LAMP—THE ELECTRICAL INDUSTRY

By THOMAS N. MCCARTER

President, Public Service Electric and Gas Company, Newark, N. J.

Fame is indeed a peculiar thing. Some few years ago Mr. Edison did me the honor to call upon me in my office in Newark. I did not know he was coming and his arrival was announced by a precocious office boy who said to me, "There is an old man outside and he says his name is *Ecdison,* and he wants to see you. He looks like a book agent. Shall I let him in?"

I have only to add that contrary to what happens in the story book, this youthful protegée has not yet supplanted me as President of our company. (Laughter).

As a Jerseyman born, as a citizen, during all of my life of that great State and as an executive of a company which supplies the majority of its people with electric light and power, it is with feelings of particular pride and gratification that I participate in this celebration planned to mark the fiftieth anniversary of the discovery of the incandescent lamp, and to honor the great man whose genius, whose untiring effort and whose ability to translate theory into useful reality made it possible.

New Jersey's Most Illustrious Citizen

Because Thomas A. Edison has been a resident of the State during the period of his greatest scientific and inventive activity, we of New Jersey claim the great inventor as the most illustrious of our citizens, and as one group of New Jersey names—Trenton, Princeton, Monmouth, Morristown—calls to the minds of all Americans the memory of Washington and his heroic struggle for independence, so other New Jersey names will be forever associated with Mr. Edison and his many epoch-making inventions and discoveries.

In Newark he perfected his improvements in telegraphy, assisted in the production of the first successful typewriter and discovered the phenomena which later became the basis for the development of wireless telegraphy; in Menlo Park he produced the carbon telephone transmitter, including the microphone, the phonograph, the incandescent lamp, gave commercial possibility to the generation and distribution of electricity, and accomplished other wonders; in Harrison he established the first commercial electric lamp factory, and at West Orange, he gave to the world the motion picture camera, one of the best of storage batteries, and is still actively at work, mentally and physically capable of further discoveries and inventions.

And, so, speaking for New Jersey, I add the tribute of his fellow Jerseymen to that great volume of acclaim with which the people of the entire world mark this anniversary—not merely of an accomplishment but of a man.

At every recital of the inventions of Mr. Edison, I am astounded at the number of what are now great industries in the development of which those inventions played an important part. Telegraphy, telephony, wireless, radio, motion pictures, electric rail transportation, electric light and power, and so on through the long list, each has been stimulated, each has profited, each has been bettered by some product or products of his almost universal genius. When we consider the remarkable diversity, the remarkable quality and the remarkable quantity of his laboratory output, we can better understand why he has considered, that for himself at least, a 20-hour working day is not too long.

What the Industry Owes to Edison

We of the electric light and power industry owe to Mr. Edison much more than is involved in the discovery of a practical incandescent lamp, important as that discovery was. In my opinion we owe to him the very basis of our industry. He gave to us the first practical commercial central station, and he developed for us the first practical method of generating and distributing electrical energy. From the abstract he produced the concrete; from theory he educed practice; by the magic of his mentality he converted scientific speculation into practical accomplishment, and upon the foundation that he laid has been reared the great structure of an industry, that today plays so great a part in the economic and social life of this nation.

It was my good fortune in November of 1926 to act as Mr. Edison's guide on an inspection trip through the then recently opened Kearny generating station of our company. The plant represented as far as we could make it represent, the latest and best in the way of power station construction and equipment, and constituted part of an electric system that is essential to meet the needs of more than three million people.

"More Trouble Back in the 80's"

It was inevitable that as I stood by the side of Mr. Edison and listened to the humming of the giant generators, whose every pulsation sang a song of energy—of power, that I should in my own mind contrast this latter day development of electric practice with the beginnings of the industry for which my distinguished guest was responsible, and that Mr. Edison had made a similar mental comparison was evidenced when, as he was leaving the station, he remarked, "Marvelous! But we had a lot more trouble back in the Eighties than you have now."

There are those of us, perhaps, who will be inclined to disagree, with the second of Mr. Edison's statements, and who will not hesitate to assert that while the character of that trouble has changed, its volume has increased, but all of us will join with Mr. Edison and the rest of the world in his declaration that the development of the central station of which Kearny was a symbol has been indeed "marvelous."

The story of the growth and present greatness of the electrical industry has been told over and over again in statistics. Figures of investment, of output, of revenues, have, however, become so large that they have ceased to convey anything more than an impression of mere size, and so tend to detract from rather than add to that true perspective, which in fact represents its stature. The most important fact about it, is not that the comparatively few thousand dollars that went into the construction of the Pearl Street Station have grown into an investment throughout the country of more than ten billion dollars—it is that the development of electric service since that day in October of 1879, when Mr. Edison perfected his incandescent lamp, has brought added prosperity to American citizens, has revolutionized American industry and has increased immeasurably the comfort and convenience of American homes.

It is in terms of benefits conferred upon the people—not in terms of kilowatt hours and dollars

—that the astounding results of the discoveries and inventions of Mr. Edison and the many other scientists and engineers who have played their part in electrical development along with far-visioned financiers and executives, may best be recorded.

Wealth Created by the Industry

Even in the realm of statistics we draw too dim a picture, when we attempt to show what the industry has created in the way of wealth by a recital of figures showing investment in the industry alone. Vast as are these totals, they are small beside the figures of wealth which electrical service has built up for the nation in trade, in industry, in transportation, and in our other activities.

Electric service has helped to make our great cities possible—it has given them light and power without which their present character would have been impossible. It has provided for them rapid transit necessary to their existence, and it has changed for the better the habits of living of their people.

Electric service has played an outstanding part in the development of our suburban communities, giving to their inhabitants those comforts and conveniences which, added to their natural advantages, have attracted thousands to new and better conditions of existence.

Electric service extended to our rural communities is bringing to thousands of farms not only increased economy and efficiency in agricultural methods, but improved conditions in their domestic establishments.

Electric service in industry has permitted improvements in methods of production which have made this nation today the most prosperous in the history of the world.

Electric service in transportation, although it has created a system of local and interurban transportation that performs a major function in the upbuilding of our commonwealths, is but at the beginning of its full usefulness, as is demonstrated by the increasing trend toward steam railroad electrification. And in many other fields and in many other ways, electric service has increased national wealth, has accelerated national prosperity, and added to national resources.

Among the millions of our population, there is not an individual whose opportunities for a better, a broader, a more satisfying existence have not been multiplied because Mr. Edison started the electrical industry along the road of practical development and progress, and because men were found to continue that development and to bring to fruition the seeds that he planted.

It is then in terms of the benefits conferred upon the men and women of our country that the story of the electric industry from the days of Menlo Park to the present should be told if its real significance is to be unfolded, for an estimate of its greatness is not so much to be derived from a study of the financial manuals as from a knowledge of the way in which it has relieved men from the burden of labor, women from the toils of household drudgery, and has made easier and more productive the lives of millions of people.

There are a thousand functions that electricity now performs for us that in the days of our fathers involved hard manual labor and an expenditure of time that made working hours long and playtime short, and there is no better way to secure a realization of the changes that electrical development has wrought than to review one's personal activities during even a single day and note how they are affected by the various applications of electrical energy to our needs—the electric appliances that perform for us so many household tasks, the electric car or train that carries us to our places of business, the electric elevator that makes possible the skyscraper in which is located our office, the electric machinery that enters into the manufacturing processes that provide for our various requirements, the use of electricity in our hospitals and by our doctors and dentists, the telephone that is at our elbow as we work, the radio that may furnish our evening's entertainment if we do not patronize the moving picture house or the theatre, where, too, electricity plays an important part, the electric light that not only gives us necessary illumination but contributes new beauty and new grace wherever it is used—these and many more applications of electricity attest the almost revolutionary character of the change that has come over our manner of living since Mr. Edison completed his work upon the electric lamp.

When we consider the electric industry in the light of what it has accomplished, when we reckon the blessings that it has so universally conferred, when we contemplate the wide range of its activities intimately affecting as they do so great a majority of our people, we cease to wonder at the giant growth to which it has attained and to marvel at the magnitude of its financial and physical operations. No industry of lesser size could possibly have accomplished what it has accomplished. No organization of smaller scope could perform the service which it performs.

Development Not Automatic

The development which has resulted in its present widely extended usefulness has not been automatic. It was not enough that Mr. Edison should have perfected an incandescent lamp, should have put in operation the Pearl Street Station. Unless there had been scientists to devote their lives to laboratory and mathematical research, unless there had been inventors to apply the abstract principles thus discovered to practical utilization, unless there had been business men with vision wide enough and with optimism strong enough to foresee the commercial possibilities that lay ahead, we would still be living in the age of our fathers and the economic and social progress of the past fifty years would not have taken place.

The whole world glories in the achievements of that long list of men of science who have contributed to our knowledge of the natural laws that govern electricity; it is not slow to pay its tribute to the inventive genius that has given practical effect to those laws in the application of electrical energy to the requirements of mankind, and the time is coming I believe when it will recognize the service which has been performed in its behalf by those who instituted, who have built up, expanded and improved the great industrial organizations which placed at the command and within the means of so large a number of our people the benefits which the scientists, the inventors, and the engineers have created.

They have been pioneers in the field of economics and of business; they have discovered new laws and new principles governing the operations which they conducted and have not hesitated to apply them to promote public welfare; they have not failed to recognize the close alliance between science and business and have been more than liberal in contributions which permitted research and experimentation on a scale known to no other industry; they have readily accepted as an essential contribution to development the heavy charges for obsolescence which the progress of electrical science entailed.

Private Initiative Essential

With the record of the electric industry in mind, I have no fear of the future. It was conceived and has been developed as a private undertaking. Without the initiative, without the enterprise that comes with private as opposed to governmental operation, it would never have reached its present stage of usefulness. No government would, or should have taken the risk, have incurred the expenses, have suffered the losses that were necessary to its growth and expansion. Nor has the time yet come, nor is it in sight when the industry can successfully function without the same application of initiative and enterprise to its affairs. The industry has new fields to conquer, new realms to explore, and new services to perform. When we stop to think that its basic purpose is to provide energy, power, wherever and for whatever purpose energy and power are needed, we must realize that however great has been its accomplishment in the past, the extension and expansion that is to come will be immeasurably greater.

Upon the industry from its beginning has been imposed a public trust, which has become greater as its activities and usefulness have expanded, and which will continue to increase through the coming years as the essentiality of its service increases.

There has been no betrayal of that trust in the past and upon the members of this Association—executives, engineers, and all of us—devolves the duty of seeing to it that there is no betrayal in the future. We have still a great work to perform, and the inspiration that we draw from the achievements of our pioneers like Mr. Edison, to whom our heartfelt expressions of gratitude and appreciation go out today, will be with us in our onward march toward the goal of greater accomplishment.

Some years ago the Edison Pioneers graciously erected and dedicated with appropriate ceremonies, at which it was my privilege to be present, a tablet to Mr. Edison at Menlo Park. This was and is a fine piece of work. In view of the present status of the industry and its certain future, this tablet seems to me to be quite inadequate as an expression of public regard. His inventions are not commonplace. They are epoch-making and of world-wide fame. A grateful country has erected the Washington Monument and the Lincoln Memorial at Washington. Nearly all battlefields are marked with appropriate monuments. Surely, "Peace has her victories no less renowned than War."

A Noble Project Suggested

Mr. Henry Ford is constructing privately, so I am informed, an Edisonia Museum in Michigan. I offer the suggestion that in further celebration of the Fiftieth Anniversary of modern artificial light, a grateful industry aided by popular subscription erect at Menlo Park a suitable and enduring monument to commemorate the ability and genius of Mr. Edison, that will shine on throughout the ages by day and by night. The fact that Mr. Edison is still living seems to me to add luster to it. If this suggestion meets with favor, I pledge my personal and corporate cooperation in furtherance of the consummation of this noble project. (Applause).

CHAIRMAN EDGAR: I am going to ask Mr. E. Wilbur Rice to make the next presentation. Mr. Rice! (Applause).

INTRODUCTION OF HENRY FORD

By E. WILBUR RICE

Honorary Chairman of the Board, General Electric Company

It is an inspiration to be present and a great privilege to take an active part in the ceremonies of this unique occasion.

You have been given a picture of the growth of an industry by one of its early participants, and have had ably set forth the importance of the incandescent lamp in the development of that industry.

We have obtained some conception of the stupendous importance of electric power to our present social organization, and if, as we believe, this development of electric power was dependent upon the invention of the electric incandescent lamp, the vital and far-reaching character of that marvelous invention of Mr. Edison's, which we are now celebrating, is thoroughly established.

Although arc lighting by the series system preceded that of the incandescent lamp and had attained considerable importance when the Pearl Street Station was founded by Edison, the system developed by Edison was the only one which embodied the fundamental principles which permitted the economic and practical distribution of electric power.

These electric stations were designed to supply current to incandescent lamps, but it was soon apparent that a larger market for current could be obtained if motors were installed. This led by natural evolution to our present electric power era.

It is true that the low voltage of the incandescent lamp restricted the distance to which electricity could be economically supplied from one center; it is true that this limitation was removed by the development of the alternating current system by other men; but it is also true that the method of generation, distribution and use on the multiple arc plan is the system which has survived and has been utilized in all subsequent development of the art, and is today the method employed in all central station power transmission.

An Outstanding Achievement

Therefore, as I have frequently stated, the multiple arc system of distribution which Edison devised for his lamp constitutes one of the outstanding achievements in history. It is the only method by which electricity may be generated, distributed and used in unlimited amounts over unlimited areas and for all purposes.

Now this was all based upon Edison's discovery of the incandescent lamp, as his lamp and the system of generation, distribution, control and measurement of electricity to utilize his lamp formed the foundation of the entire electrical industry. It is for this reason that, when we visualize the industrial progress of the last fifty years we instinctively think of the name and the personality of Edison. His was the genius which made possible the diffusion of light around the world, and he built the foundation and pointed the way to the manufacture and distribution of unlimited electrical power. These two contributions entitle Edison to the distinction of having founded and fathered our present industrial era.

The electrical industry started with a clean slate; it was founded upon science, and the facts which it wrested from Nature's storehouse were greater marvels than any fiction the mind of man had ever imagined. It was fortunate in its leaders—men like Edison and Elihu Thomson—sincere, honest seekers after truth, with the highest ideals of life and of service to humanity.

A Leader in New Business Methods

The electrical industry was not only a pioneer in new technical developments, but a leader in new business methods. The customer was regarded as a friend who deserved good service in generous measure. The old relations between buyer and seller, which taught the buyer to mistrust the seller, were replaced by those of mutual respect and confidence. This has been the happy relation between the electrical manufacturers and the public utility companies for the nearly fifty years of my own personal experience, and this has been the dominating ideal of public electric utility companies in their relations with their own customers.

I believe that the stupendous success of the electric power and light industry has been based as firmly upon the honesty and wisdom of its business policies as upon the excellence and appeal of its technical product—its policies being the expression of the character and personality of its chosen leaders, who have constantly upheld its high ideals—ideals which our Master, Edison, has followed all his life.

Fifty years have passed since the invention of the incandescent lamp by Edison.

Thirty-three years have passed since another great event—the birth of a new means of transportation, the self-propelled motor car.

It has been pointed out that the amazing quantity of horsepower put at our disposal by the electric dynamo and the gas engine for service, now indispensable in the home, on the highway and in the factory is the distinguishing mark of American life at this time.

The individual destined to take a leading part in this new development was originally engaged in the electrical business. He was, in fact, the chief engineer of the Detroit Edison Co. The name of this remarkable genius, of course, instantly occurs to each and every one of you—Henry Ford.

How Mr. Ford Met Mr. Edison in 1896

Mr. Ford tells how at the time he was with the Detroit Edison Co., he first met Mr. Edison at a convention of the Edison Association at Manhattan Beach in 1896.

Mr. Ford was then working on his new idea, but all of his electrical associates had taken pains to tell him that the time spent on gasoline engines was utterly wasted, that the power of the future was to be electricity. Being in the same room with Edison he thought it would be a good idea to find out if the Master of Electricity thought it was going to be the only power in the future.

"I told him," said Mr. Ford, "what I was working on. At once he was interested. (He is interested in every search for new knowledge.) Then I asked him if he thought there was a future for the internal combustion engine. He answered something in this fashion: 'Yes, there is a big future in any lightweight engine that can develop a good horsepower and be self-contained. No one kind of motor power is ever going to do all the work of the country. We do not know what electricity can do, but I take it for granted that it cannot do everything. Keep on with your engine. If you can get what you are after, I can see a great future.'"

Such was his first meeting with Edison, and he did not see him again for many years. Now they are the closest of friends, and no one has paid a higher tribute to Edison's genius and personality than Mr. Ford. Notwithstanding all that Mr. Ford has done, he says that his contributions to society have been made possible only by Edison's contributions in the electrical field. In fact, he has made an even more remarkable statement, "that the distinctive production methods which have made the United States what it is are the direct result of Mr. Edison's inventions and discoveries."

This is a beautiful tribute from a man who himself has made such a great contribution to the happiness, pleasure and well-being of society; a man who has made himself a synonym of that great American idea, mass production; who, at a time when the American public were highly suspicious and unfriendly to great concentration of wealth and power, was permitted to accumulate both, not only without criticism, but with the manifest approval of the public. Incidentally, this may be taken as a rebuke to those cynics who assert that democracy can only appreciate and tolerate mediocrity.

It was no accident that later a great friendship sprang up between these two marvelous men. It was the inevitable result of that subtle but powerful magnetic influence which attracts and binds together kindred spirits. Each is in every sense a self-made man; each the architect of his own fortune; both are apostles of the doctrine that hard work is good for man.

Ford says: "The natural thing to do is to work; to recognize that prosperity and happiness can be obtained only through honest effort."

Visions Made Into Realities

Edison says that genius is largely hard work and perspiration, and that hard work is conducive to longevity and happiness. Both have as their ideal, "to make the world a better place in which to live." Their philosophy of life is evidently much the same, and happily they both have had glorious visions and both have made their visions into practical realities.

We like to think that the atmosphere which Ford breathed during his early connection with the electrical industry helped to confirm his natural taste for honesty as the only policy and the square deal as the only deal in human relations, as these are the ideals which he has followed in the development of his vast business—ideals which he calls "nothing but common sense."

Ford insists that his success is not to be measured in terms of wealth, no matter how fabulous, but rather by the quality of service which he has rendered humanity. A grateful world acknowledges the debt and rejoices that the donor has been so handsomely rewarded.

But Henry Ford is more than the world's most successful manufacturer. He is the greatest of dreamers and idealists. The electrical industry is indeed fortunate, and the world is to be congratulated that this modest but amazing genius has taken as a hobby the fascinating and useful idea of preserving for future generations the homely and simple tools which our Edison employed in making his great inventions.

This magnificent dream—the expression of Henry Ford's admiration for Edison—is rapidly becoming a living reality in a remarkable group of buildings at Dearborn, Mich., the Edison School of Technology and the great Museum of Americana. There Ford plans to perpetuate Edison's achievements in tangible form for the benefit of posterity.

And one of the most fascinating exhibits was recently made on the spot. The entrance to the Museum in Dearborn is modeled after Independence Hall in Philadelphia. As there is only one Liberty Bell, Ford decided to erect in place of the Liberty Bell a statue of Edison.

During a recent visit of Edison a concrete walk was being laid to the pedestal of this statue. In order to perpetuate Edison's visit, Ford asked him to walk upon the soft concrete. This Edison did, leaving his footprints in the concrete and his signature upon the pedestal.

Thus has this dreamer, Ford, left for posterity our Master's signature and footprints in solid concrete, instead of trusting to the shifting "sands of time."

There, in Dearborn, on Oct. 21 of this year, the Fiftieth Anniversary of the birth of the incandescent lamp, the celebration of Light's Golden Jubilee, which we are beginning here and now in this great convention, will be concluded with the reenactment of historic scenes of absorbing interest. Edison will then put in operation his same old machinery, in the same old laboratory of Menlo Park, restored by Henry Ford—his monument to his friend, which is destined to become a shrine for the American people.

Ladies and Gentlemen, I present this dreamer of magnificent visions, this friend of Edison's, this benefactor of all the world—Henry Ford.

[The audience arose and applauded.]

A Word From Mr. Ford

MR. HENRY FORD: We build at Dearborn 8000 complete electric light plants every day. This being an electric meeting I just thought I would say that. Thank you. (Applause).

CHAIRMAN EDGAR: To come from the sublime to the ridiculous, I am reminded of a story. Unlike many stories that are told on occasions like this, it is appropriate to the occasion. It has to do with Mr. Ford on the one part and with Mr. John A. Britton, a man whom we loved when he was with us and whom we revere now that he has passed on.

At the time of the San Francisco Exposition there was set aside a day for Mr. Edison. Among other functions there was one given at the University Club where 400 or 500 well-known men came to do honor to Mr. Edison. Mr. Ford was seated at the head table. After the various talks regarding Mr. Edison, the audience tried to get Mr. Ford on his feet. They were not as successful as you people have been today.

After the applause had lasted for perhaps five minutes, Mr. Britton got up from his chair, walked over to Mr. Ford's chair, and whispered something. Of course the audience was quieted. He then walked back to his seat (with my apologies to Mr. Ford) and said that Mr. Ford did not feel he would like to speak, but that he had an announcement which he wished Mr. Britton would make, and that is that next year he proposed to paint his cars yellow and sell them in bunches like bananas. That brought down the house. (Laughter).

The next in order is the third of the series of talking movies which were explained to you yesterday and the day before. As you know, Mr. Edison is not with us today. He and Mrs. Edison are both in Florida, and having this in mind he has taken part in a movie-talking picture which will now be shown.

GREETINGS TO THE CONVENTION*

By THOMAS A. EDISON

Before starting experiments on the incandescent electric light system, many memorandums were drawn up as to a general system that would permit of the subdivision of the lights into small units analogous to gas jets and with commercial economy superior to the prevailing gas system. The result was that if it was to be successful all the units must be worked in multiple arc. This necessitated the creation of lamps of very high resistance to diminish the enormous investment in copper necessary if low resistance lamps were to be used. This necessitated a very fine hair-like filament of high resistance material.

On Oct. 21, 1871, numerous experiments resulted in the production of a small unit lamp of comparatively enormous resistance. The filament being under conditions of great stability, after the result I knew the problem approached a commercial solution.

While these lamp experiments continued, other parts of the general system were actively experimented upon.

The dynamo as then in vogue was extremely inefficient, the loss approaching 50 per cent, due to some misunderstanding among electricians which I never comprehended. However, these experiments produced a dynamo of which 90 per cent of the energy was useful. Then meters for measuring the current used by thousands of customers, and also a host of accessories, like underground conduits, switches, sockets, etc., were necessary to make a complete system of distribution, all of which was accomplished.

After the installation of the first station in New York other improvements were added, such as the three wire system which reduced the copper conductor requirements more than 50 per cent. After this many central distribution stations were introduced. In those days I had a high opinion of this system, but I did not realize the stupendous electrical industry of today.

Naturally I am gratified to feel that I have been privileged to play a part in this achievement. I am proud of the electrical industry, of its vision, courage, zeal and devotion to the public service, and I suspect every American feels the same way about it.

It is a great reward for me and my colleagues and co-workers, many of them still living, that we have survived to see the fruit of our labors.

The record is wonderful, but fine as it is, it can be made still better, and I have a feeling that in your hands it will be.

CHAIRMAN EDGAR: I do not know just how to introduce the next gentleman. Ordinarily, I would call him the next speaker, but knowing something about him and his history, I have a feeling that that does not quite give the correct impression. He is a writer and a poet. There is hardly a phase of life in which he has not been engaged, not for the purpose of getting a story, but for the purpose of his livelihood.

In his early days he was a newspaper man in the Far West. It has been said of him that as a poet he sang of common people and common things, but the range of his poetic work was far wider than this. He sang and sings of whirring dynamos, of sweating workers, of office drudgers, stenographers, Babbitts and Main Streeters, but also of moonlight on the South Sea Beach, high adventure at home and afar, life and laughter in a world that he finds full of dreams and gallantries. Such is the man who will tell us of Aladdin and his lamp.

I take great pleasure in presenting to you Mr. Berton Braley.

THE LAMP OF ALADDIN

By BERTON BRALEY

Fifty years ago, Thomas Aladdin Edison rubbed a lamp. And not one genie, but thousands; not one slave of the lamp, but millions, answered to the magic thus evoked.

Where the Slave of Aladdin's lamp might move a palace a thousand miles, the Slaves of Edison's lamp have moved civilization forward a thousand years. Where the Slave of Aladdin's lamp could heap a hoard of gold and jewels before Aladdin's wondering eyes, the Slaves of Edison's lamp have created new wealth beyond the wildest dreams of Oriental magnificence, and made of the very earth itself a vast jewel coruscating with multicolored radiance.

What enchantment imaginable by the ancient sorcerers of East or West could approximate the glamorous spectacle that nightly thrills and dazzles our eyes along this sweep of golden sand?

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*Presented as a "Talking-Movie."

And yet most of our poets, our painters, our writers, bewail the humdrum and monotony of this machine-age and sigh for the lost days of Romance. And the very dirge they chant for the deceased is broadcast over the impalpable ether on waves of wizardry; their words are cast into type by a machine swifter and more cunning than the fingers of any prestidigitator, and printed in hundreds of thousands by uncanny mechanisms that no old-time magician would dare to conceive.

This lament for vanished Romance is transported by couriers swift as seven-league boots and far smoother in action, or flung through the skies on wings of reality that outspeed the flight of any magic carpet of myth.

And at last the funeral sermon on Romance is read—as it was probably written—under the glow of a lamp whose light is fed by a terrific and intangible power no man knows, but which man has learned to control and direct.

The Song of the Dynamo

Some day, perhaps, those who try to sing the songs of a nation will tune in on the hum and purr of dynamos, the drone of planes in the infinite blue above us, the happy rhythm of motors that tirelessly serve by sea and land.

But today, it is the engineer, the scientist, the inventor and the businessman who concern themselves with Romance, who carry it on as their daily job, and who are too busy making sagas to sing them.

Fifty years ago, Thomas Aladdin Edison rubbed a lamp.

But unlike the Arabian Nights' Aladdin it was no fortuitous rubbing. It was not a magic that responded at the first touch. Miracles of modernity do not happen that way. Before Edison rubbed his lamp, he had to imagine his lamp, he had to create his lamp. And before he could either imagine or create he had to have the equipment of mind, of spirit and of body—the patience, the industry, the vision and the persistence that are back of any valid success. He had to have character—and further and beyond all that, he had to possess that unaccountable, elusive but inescapable quality that is known as Genius.

For with due credit and honor to the extraordinary capacity for concentration, the tireless courage and the patient application of Thomas Edison, with every emphasis upon the significance of these in what he has accomplished, the power that drives the whole is Genius.

And so he made his lamp. Created it literally out of a vacuum. And since there were no vacuums sufficiently empty for his purpose, he created his own vacuums.

The light of the world was to hang by a thread. Indeed, by the ashes of a thread. Wherefore all the world must be ransacked for a fiber that would glow and continue to glow after it had been burned.

The quest for the Golden Fleece was a mere jaunt by comparison to the search for this single filament. Finding a needle in a haystack was as easy as finding Cleopatra's Needle in Central Park when put beside this job of discovering the fibre for the incandescent lamp. If you can imagine a haystack composed of about every possible sort of fibrous material, and then patiently testing each separate strand, you have an approximation to the job that preceded the rubbing of the lamp.

But that story is known to most of this audience and to most of the world that now works and plays under the illumination resulting from that search for a thread. The thread is now a tungsten filament that gleams with greater brightness and lesser cost than when Edison first found the fiber he sought, but none the less practically the whole economic and industrial structure and mechanism of today can be said to hang by that single burnt thread which first successfully glowed in the vacuum Edison had himself created.

Fifty years ago Thomas Aladdin Edison rubbed a lamp.

Not immediately did a set of genii leap to serve it. Before modern genii can work their enchantments, they have to be equipped with tools and backed with money. But a plant in New York and a plant in Appleton, Wis., began to function—the New York station financed from the inventor's own purse, and a few homes knew for the first time, the luxury of light that is summoned and dismissed by the push of a button or the turn of a switch.

A new era was begun. What may be a new civilization was inaugurated. For seven thousand years or more of recorded history, there had been practically no progress in the utilization of the forces of nature in the service of man. Then Watt invented the steam engine, about 150 years ago. But though steam lifted a little of the burden from man's back and speeded his transportation greatly, the transportation of power itself was possible only for a few feet—and with huge waste.

Despite the improvements in steam engines, they were only improvements. For a hundred years, nothing—or practically nothing—developed to make possible the distribution of power. It could be concentrated in factories, it could be applied to move trains, and ships, but it could not be made available in small units for the home or the small shop.

The New Era of Power Distribution

The invention of the incandescent light heralded the beginning of the era of power distribution. The need of and the demand for this new, cleanly efficient and dependable form of illumination brought a need of and a demand for its wide use. And Edison himself, and hundreds of other brilliant Slaves and Masters of the Lamp, proceeded to fulfill the need the lamp had created. The central generating stations multiplied, alternating current and high tension transmission evolved in response to the country's necessities.

Greater grew the size of generators and wider the web of transmission lines. Perhaps the steam turbine might have come anyhow, but its invention and perfection were hastened by the demand of the electric industry for more efficient driving mechanism.

With the distribution of power in the form of light came the call for the localized use of the power itself. And thus there grew swiftly a phenomenon new in the world—the application of power in small units to the labor of household and of shop.

In nineteen million homes in America this localized power from central stations gives the light which makes naught of night. In these homes this distributed power purrs over tasks that once made housewives drudges. On thousands of farms this power runs the churns, milks the cows, does the washing, hums merrily as it does the cleaning that once made the farm wife a slave.

Out of the vacuum and the charred thread of the incandescent light has come ten billion dollars of new wealth—wealth that is added to the sum of things and subtracted only from the infinite and exhaustless forces of Nature. It is a kind of wealth that economists scarcely knew a hundred years ago—a kind of wealth that Russia, for example, denies—and starves by denying.

And this ten billions is only the material, tangible, touchable sum of these new riches. What the Lamp of Aladdin Edison and the electrification of America which followed it—and which has only begun—mean in terms of human comfort, human happiness, release from drudgery, increase in productiveness with larger leisure and broader opportunities are things beyond estimate—their full significance is imponderable and incalculable.

More Produced With Less Labor

Philosophers and economists who are still under the domination of economic shibboleths of a "golden era" that existed only in their imaginations may rail at mass production, but the mass that benefits by it knows that life is better, broader and kindlier because we produce more with less labor. That mass production creates millionaires is true, that it enables ordinary folk to live as no millionaire could have lived even a hundred years ago is less emphasized, but far more important.

All is not yet for the best in the best of all possible worlds, but the clear-eyed reporter of Things as They Are knows that this much-damned "remorseless mechanistic civilization" has made it a much more possible world for the average man than he ever knew before.

An operator at a lever
Doing a thousand men's endeavor;
A crane-man, sitting aloft, who runs
A titan, lifting a thousand tons;
A switchboard tender, bossing forces,
Stronger than a half a million horses;
These be spectacles characteristic
Of matters "grossly materialistic."

Of course, if you think of the sweat that's saved
Of the one-time drudges un-enslaved,
Of the way man's strength is multiplied,
And his dream-horizon amplified;
Of the larger scope of the human brain
When the body's free from its dreary strain—
If you think of these—then the dull machine
Might possibly, somehow, seem to mean
A little more than a mass of steel,
Might even distantly reveal
A sort of a soul whose patient might
Is lifting men upward to the light.
—But, of course, in this sordid, commercial day,
No Realist ever could think that way!

For the mechanism by which mass production is accomplished the Lamp of Aladdin Edison is basically responsible. Until that first crude but successful bulb glowed in his laboratory electricity was mostly something that coursed through arc-lights which sputtered and gathered bugs. From the date of his invention, electricity became the greatest single factor in the industrial progress of America and the world. It is because this country is electrified beyond any other that it excels in production and in industrial efficiency beyond any other. The incandescent lights the path of progress.

Mechanical Slaves Work Harder

And remember that this accelerating pace of industry, this high speed process is an acceleration of machines, not of men. It is the mechanical Slaves of the Lamp, not the human workmen that work harder and faster. It was in those good old days of hand labor that men were driven for twelve and fourteen hours a day, that men fell exhausted into bed at the end of a shift and woke only in time to begin another. Philosophers may hanker for those halcyon times, but the workingman cherishes no such illusions.

Fifty years ago Thomas Aladdin Edison rubbed a lamp.

Genii of the lamp answered the summons, and their magic was no mean necromancy. But being practical genii, scientific genii, far-seeing genii, they were not satisfied merely to serve the Master of the Lamp. They, like Aladdin Edison, dreamed dreams and saw visions—and made them real. They wasted no energy by appearing on thunderbolts, they harnessed the lightning instead. The lamp of Aladdin demanded power—the genii of the lamp made power available. They put the waterfalls to work, they taught steam to labor more efficiently, they changed chemistry from a compounding of drugs to a compounding of industrial forces. And they taught other genii to carry on and amplify their work.

So the magic of Aladdin Edison and those who follow him has multiplied and will multiply beyond our broadest imaginings. Around us here at Atlantic City is visible enchantment of light, of color and of beauty, that the genii have created for us. Perhaps the conventionally clad individual sitting next you is one of these genii—perhaps you're one of them yourself.

But the gorgeous show put on here is only the more obvious of the miracles that have resulted from the rubbing of Edison's Lamp. Magic and romance that would have dazzled Arthur and Launcelot and dumbfounded Merlin and Cagliostro surround us wherever we turn. When we click an electric switch, when we revolve a knob on a radio, when we lift a telephone receiver, when we watch and hear a movie, when we shoot skyward in an elevator, we are utilizing or summoning forces that those old-time romancers couldn't have conceived.

Romance at Every Turn

And less obvious wonders touch us at every turn. What we wear, what we eat, the house we live in, the office we work in, are tinged with the hues of romance and luminous with the St. Elmo's fire of wizardry. For our clothes are woven on fairy looms, our food is packed and shipped by mechanical magicians, our houses are heated, lighted, equipped with wonders and manifestations, our offices are laboratories of alchemy. We not only need not search for romance, but we must blind our eyes to escape it. It is not only in the earth below, the heavens above and the waters under the earth, it is in the packets of paper matches in our pockets and in the cigarettes that we light with those matches.

Fifty years ago Thomas Aladdin Edison rubbed a lamp and the electrical industry as we know it now was born. Its social, material, industrial and spiritual ramifications the historian of 3000 A. D. may possibly be able to estimate, but we cannot. We can count—by mathematics such as only an Einstein might understand—the physical wealth that hangs by that burnt fiber in a vacuum, but even with the aid of calculating machines that think and ledgers that talk we are probably shy several billions of dollars. Of the other values created by the Lamp of Aladdin we can have no approximation. We are in the realm of the infinite where, as Kipling says, the "blindest bluffs hold good, dear lass, and the wildest tales are true!"

Let the bards turn to yesterday for Romance; we know she is with us today and leading us into the bright and brave promise of tomorrow. We recognize her not only when she flashes across the sky with the air-mail, but when she perches in the grimy cab of the coal dumper beside the sooty-faced operator whose levers do the work of a thousand sweating men. She rides on the radio waves, and she runs the washing machine. Her glamor is no less now that she has gone to work than when she sang songs among the sirens as Ulysses passed, bound to his mast. And where once only a few adventurers might follow her fleeting footsteps, the Lamp of Aladdin now lights her trail for us all.

Invention Is Design

In this extension of the frontiers of achievement we have all had a part. Knowingly or unknowingly, we further the vision. But the vision itself must be that of Genius. Invention is not accident, but design. It is the application of mind to the problems of Matter that makes true magic—and the Wizard of Menlo Park is that kind of an enchanter.

Fifty years ago Thomas Aladdin Edison rubbed a lamp. And the magic of that lamp was the magic of thought.

Back of the beating hammer
By which the steel is wrought.
Back of the workshop's clamor
The seeker may find the Thought.
The Thought that is ever master
Of iron and steam and steel.
That rises above disaster
And tramples it under heel!

Back of the motors humming,
Back of the belts that sing,
Back of the forges drumming,
Back of the cranes that swing,
There is the eye which scans them
Watching through stress and strain,
There is the Mind which plans them—
Back of the brawn, the Brain!

The drudge may fret and tinker
Or Labor with lusty blows,
But back of him stands the Thinker,
The clear-eyed man who Knows;
For into each plow or saber,
Each piece and part and whole
Must go the Brains of Labor,
Which gives the work a soul!

Might of the roaring boiler,
Force of the engine's thrust,
Strength of the sweating toiler,
Greatly in these we trust.
But back of them stands the Schemer,
Putting the vision through
Back of the Job—the Dreamer
Who's making the dream come true!

CHAIRMAN EDGAR: The meeting now stands adjourned.

[The meeting adjourned at 12.50 p.m.]

FOURTH GENERAL SESSION

FRIDAY, JUNE 7, 1929

[The meeting convened at 10.05 a. m., President P. S. Arkwright presiding.]

PRESIDENT ARKWRIGHT: It is hardly necessary to ask you to come to order. Those who are so diligent and faithful are always in order.

Personally, I like a small audience. We get closer to each other and think along the same lines and understand what the other is thinking, with sympathetic appreciation of the other's viewpoint. So far as I am concerned I want to say to you that I appreciate your being here.

The first part of the meeting will be presided over by Vice-President Sampsell.

[Marshall E. Sampsell, Vice-President, assumed the Chair.]

CHAIRMAN SAMPSELL: Our President should indeed be happy today, for another Golden Jubilee shines from the skies. Each year we are vividly reminded that in the midst of life there is death. Mr. W. H. Onken, Jr., Chairman of the Memorials Committee, will now address you.

REPORT OF MEMORIALS COMMITTEE

By WILLIAM H. ONKEN, JR., *Chairman*

"An electric sign gone dark." That was the title chosen by the American poet, Carl Sandburg, for some obituary verses on the closing by death of the career of a queen of the stage. Is it not a title that without too great fancifulness might be written as an epitaph over the grave of every member of our great industry who realized its greatness and its beneficence and did what in him lay to make it greater and more beneficent yet?

To such men electricity is not merely an art, not merely a material achievement; it is a gospel, and they are its evangelists. When they are called hence it is as when lamps that spell words of comfort or encouragement are turned off, or the flood lighting that beautifies dark structures dies away. And this applies not only to the departed veterans who grew up with Edison, but to the younger men who seem to die before their work is finished.

In the words of that master painter in words, Robert Louis Stevenson, "All who have meant good work with their whole hearts have done good work, although they may die before they have the time to sign it. Every heart that has beat strong and cheerfully has left a hopeful impulse behind it in the world and bettered the tradition of mankind. . . . When the Greeks made their fine saying that those whom the Gods love die young, I cannot help believing they had this sort of death in their eye. For surely at whatever age it overtake the man this is to die young. Death has not been suffered to take so much as an illusion from his heart. In the hot-fit of life, a tiptoe on the highest point of being, he passes at a bound on to the other side. The noise of the mallet and chisel is scarcely quenched, the trumpets are hardly done blowing, when trailing with him clouds of glory, this happy starred, full-blooded spirit shoots into the spiritual land."

Among the members of this Association who have embarked to meet their pilot face to face were the following:

John W. Robb, of Clinton, Ind., past-president of the Indiana Electric Light Association, and one of the organizers of the Clinton Electric Company.

Herbert Lloyd, president of the Electric Storage Battery Company of Philadelphia.

Frank A. Gavagan, superintendent of distribution for the Consumers Power Company, Saginaw, Mich.

Robert I. Todd, prominently identified with public utility interests in Indianapolis, and a past-president of the American Electric Railway Association.

Arthur L. Freyer, of the Northern Indiana Public Service Company, Hammond, Ind.

J. T. Blacknall, general manager, Virginia Electric & Power Company, at Williamsburg, Va.

George L. Sadlers, manager of the Nashua District of the Public Service Company of New Hampshire.

Charles A. Sears, who at the time of his death was in charge of the erection of the mechanical equipment at Conowingo for Stone & Webster.

Frank N. Savage, superintendent of conduit construction of the Commonwealth Edison Company, Chicago, Ill.

William B. Wilkinson, district manager of the Ohio Power Company, Mount Vernon, Ohio.

Robert E. Brown, manager of the Mankato (Minn.) Division of the Northern States Power Company.

Walter N. Gordanier, superintendent of the Elektron Station of the Puget Sound Power & Light Company, Seattle, Wash.

Isaac Krall, an Edison Pioneer, for many years associated with the New York Edison Company.

Robert V. Prather, secretary of the Great Lakes Division of this Association, and secretary-treasurer of the Illinois State Electric Association, the Illinois Electric Association, and the Illinois State Gas Association.

Bernard J. Crahan, for many years connected with the American Electric Light & Power Company.

James M. Eglin, superintendent of the Underground System of the Philadelphia Electric Company.

Louis C. Laube, superintendent of the Ohio Power Company, Logan, Ohio.

Samuel G. Rhodes, general superintendent of the distribution and installation department of the New

York Edison Company. For a number of years Mr. Rhodes served on various technical committees of this and other national associations, and in addition conducted a considerable amount of original investigation for the New York Edison Company on street and park illumination. Mr. Rhodes had been a member of the engineering staff of the New York Edison Company since 1891.

Miss Harriet Billings, for many years assistant secretary of this Association, who died suddenly at the Martha Washington Hotel, New York, on Nov. 3. Miss Billings became identified with the National Electric Light Association in 1891 in the capacity of assistant secretary and treasurer. This position she filled until 1906, when she retired because of ill health. She took active charge of all the work of the committees, prepared all advance notices of the papers for the conventions, and for many years edited the Proceedings of the Association.

Col. Robert H. Timmons, assistant to the vice-president of the Kansas Gas & Electric Company, Wichita, and for more than a decade a figure of prominence in the electrical industry in the Middle West.

Nelson J. Young, assistant electrical engineer with the Rochester (N. Y.) Gas & Electric Corporation.

Lincoln Beerbower, manager of the Northern Division of the Oklahoma Gas & Electric Company at Enid.

Edwin W. Robertson of Columbia, S. C., at one time head of the Columbia Railway Gas & Electric Company, and of the Parr Shoals Power Company.

Andrew J. DeCamp, for more than forty years general manager of the Philadelphia Electric Company, and at the time of his death at the ripe age of 86 years, the oldest employee of the Philadelphia utility.

James A. Leroy, assistant to the superintendent of the Central Division of the Public Service Electric & Gas Company, Newark, N. J.

Oscar F. Lackey, at one time vice-president and general manager of the Colorado Springs Light, Heat & Power Company.

Benjamin N. Duke, who, with his brother, the late James B. Duke, was deeply interested in water power development in the South; was a director of the Duke Power Company, one of the subsidiaries of which is the Southern Power Company, operating in North and South Carolina.

H. A. Clarke, vice-president of the Penn-Ohio Edison Company.

Edward A. Batwell, public relations director of the Puget Sound Power & Light Company, Seattle.

Harold B. Whiteman, assistant to the vice-president, Allied Power & Light Corporation, New York.

Robert A. Speed, at one time president of the Memphis Gas & Electric Company, predecessor of the present Memphis Power & Light Company.

Leo H. Susman, general attorney for the Pacific Gas & Electric Company, San Francisco.

Harry L. Murdock, auditor of the Niagara Falls Power Company.

Henry W. Withers, head of the legal and claim department, Houston Lighting & Power Company, Texas.

Benjamin K. Howard, commercial manager of the Texas Power & Light Company.

George L. Estabrook, secretary and treasurer of the Portland (Ore.) Electric Power Company.

Andrew A. Cavanaugh, treasurer of the Wisconsin properties of the Northern States Power Company.

P. L. Griffith, formerly connected with the Pearson organization, an engineer of the Electric Bond & Share Company on most of its work in foreign countries.

Paul W. Barnes, distribution engineer of the Ohio Power Co., Coshocton.

W. H. Jones, president of the Atkins (Ark.) Light & Power Company.

William G. Kerckhoff, one of California's pioneers in hydro-electrical development and a leader and organizer of public utilities, who, with the late Henry E. Huntington, formed the Pacific Light & Power Company, now a part of the Southern California Edison Company, and later, with associates, acquired the San Joaquin Light & Power Corporation, now part of the Great Western Power Company.

John Wolff, for many years mechanical engineer of the Cleveland Electric Illuminating Company.

Paul L. Morgan, at one time general manager of the Jersey Central Power & Light Company and vice-president and general manager of A. E. Fitkin & Company.

Thomas S. Henderson, sales manager of the West Penn Power Company.

Charles L. Kurtz, formerly president of the Columbus (Ohio) Railway Power & Light Company.

William H. Detlefsen, chief engineer for the Alabama Power Company, at Mobile.

William S. Barker, controller of the Public Service Corporation of New Jersey.

George S. Carson, president of the Iowa City Gas & Electric Company prior to its absorption into the United Light & Power Co., and also president of the Iowa Gas & Electric Company before it was taken over by the Iowa Southern Utilities Company.

S. H. Brownlee, of the engineering department of the Niagara Falls Power Company.

Thomas F. Quigly, superintendent of the Yuma Utilities Co., Riverside, Cal., and an executive of the Southern Sierras Power Company of Mexico.

Frederick R. Slater, vice-president in charge of public relations of the Queensboro Gas & Electric Company at Far Rockaway, N. Y.

Wray L. Cole, an official of the old Rochester Railway & Light Company.

Fred B. Pitney, advertising manager of the Brooklyn Edison Company.

H. D. Seavey, United Electric Light Company, Springfield, Mass., who died suddenly June 6, here in Atlantic City.

Here ends this halting attempt to pay a debt by word of mouth to our associates who during the year have crossed the border of life into the impenetrable vastness of death. With all their weaknesses, it is comforting to feel that underneath are the everlasting arms. We shall think of them like sunset in the sky bequeathing to us the splendor of their prime.

CHAIRMAN SAMPSELL: Let us stand for a moment in silent reverence for those who have passed beyond.

[The audience arose and observed a moment of silence.]

CHAIRMAN SAMPSELL: Under the leadership of its Chairman, Mr. J. F. Ford, of the Philadelphia Electric Company, the Accounting Section has this year made further conspicuous progress along practical lines. In standardizing and simplifying our intricate accounting system they make it easy for us to know in which direction our operations are tending. Indeed, they constitute a dependable compass upon which, if we rely—and we will rely if we are wise—we can successfully chart our course.

It is a pleasure for me to introduce Mr. J. F. Ford. (Applause).

REPORT ON ACCOUNTING NATIONAL SECTION

By J. F. FORD, *Chairman*

We have been passing through one of the most strenuous years in the history of the electric light and power industry. In the many problems which have confronted us I feel that the Accounting Section has not been found wanting, and that we have gallantly and with fortitude met all the demands made upon us from our executives, the regulatory bodies, the Geographic Divisions and the National Association.

There has been marvelous progress in the past few years in our industry, and I feel the Accounting Section is entitled to some credit for keeping pace with all the advancements.

Persistent study and research by the several committees of the Section fully demonstrate that we are not lagging in the constructive and instructive work of the Association. This year, in my work as chairman of the Accounting National Section, I am more convinced than ever as to the importance of the accounting department of a public utility organization.

The Accounting Section—The Steering Wheel

From the organization of a public utility through consolidations and mergers and all the many ramifications of financing, the accounting department functions as the only recording channel of all its activities, and is the steering wheel which guides the executive in his contructive thinking.

The accounting section must be alert and on its toes continually, to meet the constantly changing conditions in the march of progress of the industry.

This association and the industry at large owe a debt of gratitude to the members of the several committees who have given so much time and energy in the preparation of the reports produced by the Section this year. When men of intelligence and ability, recruited from the National and Geographic Divisions, give their time and effort and are supported by their company executives, nothing but constructive results must be obtained.

The Accounting Section gives to those who take an active part therein a broader vision and an enthusiasm that is essential in the development of ideas. For this reason alone executives of member companies should encourage and see that members of their staffs serve on these committees. Executives are strongly urged to allow their accountants to serve on committees, attend meetings and perform geographic and national association work. It is not only a distinct advantage to each individual company, but a great educator to its accounting staff.

Permit me to ask what better means has this great industry of ours for developing and improving its accounting systems than through the medium of the accounting section, where the interchange of ideas is a constant source of improvement, which otherwise probably would remain undeveloped.

Closer Affiliation of Sections

I have endeavored during my administration to establish a closer cooperation with all the other national sections. I have found that there are an infinite number of questions arising in the commercial, engineering and public relations sections which need our assistance, and we need their assistance, so by closer affiliation we can be of infinite value to each other, to the association and to the member companies.

The accountant today stands in a different light. He is beginning to be recognized as one of the essential parts of a public utility enterprise. The accountant today tells you where we have been, where we are now and where we are going. The accountants are the compass for executives to steer their course toward the harbor of successful and financial results.

It had not been my intention to make any mention of the meetings of the Accounting Section during the year, but I feel that I can point with pride to the two very successful group meetings, at both of which the active interest and enthusiasm displayed by those in attendance were most remarkable. An innovation was adopted at these meetings in the form of general luncheon meetings—something new for the Accounting Section. These meetings were addressed by men prominent in the industry, who gave of their time to leave with those in attendance a message and an inspiration that was helpful to them in their daily tasks.

The serial reports that have been prepared by the various committees are a matter of record. They prove conclusively the valuable research work which has been done and are of unquestionable value to the industry as a whole.

An Outstanding Accomplishment

One of the most outstanding accomplishments of the Accounting Section in the past few years has been the establishing of a closer contact with the various sections of the Association and the Geographic Divisions and the benefits derived through these closer contacts undoubtedly accrue to the member companies.

I have been connected with the Accounting Section in many capacities for the past ten years and finally reached the goal of Chairman of the Accounting National Section. My administration and activities in past years have led me more forcibly to the idea that men in the industry must work up to their opportunities and work faithfully and conscientiously toward this goal, as it is an honor to be classed as a Chairman of the National Accounting Section and as Past Accounting Chairman. It is an honor to which every accountant should aspire, and executives of member companies should assist in seeing that their chief accounting officers have this ambition.

I have endeavored within my régime to meet all the conditions which have confronted this Section, have carefully selected assistants and outlined the work which was expected of them, and in every instance they have not been found wanting. I want now to thank in an humble way my able assistants, vice-chairmen, members-at-large, and the chairmen of the several committees for their most loyal support and untiring efforts in making this administration the success it may merit.

In closing my administration as chairman of the Accounting National Section I want to pass on to my successor that he continue those principles of expansion and development so ably carried on by my predecessors and which I have tried in my humble way to expand dependent upon them for further expansion and to carry on this good work to a successful and inspiring fruition.

In closing this report I want to express my personal appreciation of the splendid support and hearty cooperation I have received from headquarters; to Mr. Paul Clapp, who has shown by his personal attendance and talks before this Section his loyal and helpful support and suggestions; to Mr. A. Jackson Marshall, Secretary, who has given us every helpful suggestion and cooperation in our arrangement of meetings and programs; to Fred W. Herbert, Director of the Accounting Section, that untiring individual who is a stimulus for every chairman to put forth his best efforts and about whom too much cannot be said of his capabilities and willingness to serve, and to President Arkwright, who has taken a personal interest in our Section, devoting his time and energy toward stimulating interest in the Section.

In retiring as Chairman of the Accounting National Section I am not retiring in loyalty and further assistance, and hope I may long continue as an active member of this Section and give what service, experience and advice I can to help toward further accomplishments.

I have given my time and services most willingly to this work the past year, and if I have given anything constructive I am most grateful, but I feel I have been fully repaid by the experience I have had and the most pleasant acquaintances which I have made. My best wishes for my successor are that he may get the same pleasure out of this work as I have, and I know he will get the same cooperation and assistance which has been accorded me during my administration. (Applause).

CHAIRMAN SAMPSELL: When one approaches his work in the spirit just announced by Mr. Ford, nothing but success can follow.

At the request of President Arkwright, we will vary the program and now hear from Vice-President Owens, and the Vice-Chairman of the Constitutional Revision Committee.

REPORT OF CONSTITUTIONAL REVISION COMMITTEE

MR. J. F. OWENS: Your Constitutional Revision Committee elected at the first General Session on the morning of Tuesday, June 4, has reviewed the report of the Constitution and By-Laws Committee, and recommends that the annual dues of Class "F" members as now listed in the Constitution be changed from fixed to percentage dues, and that Section 6 be amended to provide that the rate of dues for Class "F" membership shall be 1/100 of 1 per cent of the gross sales for the preceding calendar year, and that the minimum dues of Class "F" members shall be $25 per annum.

Also, that the words "Electrical Jobbers" be changed to "Electrical Wholesalers" in Section 7 of Article 3.

Also, that the dues of Class "H" members shall be $50 instead of $20, as now set forth in the Constitution.

Your Constitutional Revision Committee recommends the adoption of these proposed amendments to the Constitution, and I so move you, Mr. Chairman.

[The motion was seconded, put to a vote and carried.]

CHAIRMAN SAMPSELL: Those of us who have spent our lives in congested districts, amid towers of stone and brick, little realize to what degree we are indebted to the American farmer who toils alone in open spaces. He has the same hopes and the same ambitions, the same desire for the good things of life that we have, and he is entitled to them. He needs, he wants and he is entitled to electric service. In cooperation with the Federal Government, State agencies, agricultural agencies, manufacturers of machinery of all kinds, and others, this Association, through its light and power members, has worked unceasingly to the end that the farmer may have electric service for all purposes.

The next speaker, Mr. J. R. Howard, of Clemens, Iowa, was the first president of the American Farm Bureau Federation. That Federation now has a membership of over 1,000,000. Mr. Howard was president of that organization for a number of years, and it was during his term of office that the Committee on Relation of Electricity to Agriculture was formed. He was indeed one of the five men who developed the idea of organized cooperation to solve the problems of carrying electric service to every farm in this country.

It is indeed a great pleasure to me to introduce Mr. Howard, and I know it will be to you to hear what he has to say to us this morning.

RURAL ELECTRIFICATION

BY J. R. HOWARD

Past President, American Farm Bureau Federation

I come before you today as an Iowa farmer who has no other interest than that of the farm on which I live and work. I am not here as a technician. I am here because the farm people are vitally interested in the practical applications of your industry. I feel the burden of the occasion today since I note that in a five-day program you are devoting about twenty-five minutes to the farm field where your immediate large expansion lies, and where a third of the people of the nation live. I sincerely hope your interest is not limited by your program allotment of time. More than 5,000,000 rural homes are your potential markets for power and light, and there are more miles of highway which some day will be illuminated than there are miles of city streets. This rural field is your field of immediate large expansion.

Other Kinds of Farm Relief

It would appear from press reports and political discussions that the farmer is wholly interested in political farm relief. We can perhaps agree that there have been, are and always will be acute farm problems, and that legislative relief must ultimately consist in the establishment of equality of opportunity between agriculture and other occupations, nothing more. But not all farm relief is political, and while Congress has been legislating and politicians palavering, the farmer has become increasingly active in other kinds of relief.

One of these is electric service. A survey of 22 of the principal agricultural states made by the Committee on Relation to Agriculture, shows that since 1923 rural electric service has rapidly increased as much as thirty-two-fold in some states. Today more than 15 per cent of our farms have electrical service, and the expansion is gaining momentum. More farmers today can intelligently discuss amperes and watts, and kilowatt-hours than can define debentures, or the principles of other various relief bills. This does not minimize the importance of the latter.

Economic Factors

There are certain factors of economics affecting agriculture that we are interested in today. The farmer must operate on much the same business system as do our public utilities. We on the farms have our fixed charges of taxes and interest which must be met. These are inflexible and quite uniform from year to year. Hence, easily determined but not easily voided. In addition to these, the farmer has his operating costs, consisting principally of labor, living expenses, machinery, fertilizer, seeds and many sundry articles. These operating charges vary from year to year, and some of them are capable of material reductions. Both operating costs and fixed charges must be met before the farmer can count profit which shall enable him to expand his operations and improve his plant. You have exactly similar problems, likewise your production and distribution present some striking parallels to that of the farmer.

It is obvious that profits may be created or increased either by increasing the prices of the product produced, or by decreasing production costs. In the past the principal gain has come from decreased production cost, and rural electrification holds the largest hope for future reductions. The farmer has made notable progress in efficiency of production. Products from the farms of the United States, measured in tons, bushels or gallons, have increased faster than population for several decades. If we consumed our own product without importing or exporting, 100 people would have had as much to eat and wear in 1925 as 105 had in 1890. If, however, we should take the year 1910, we would find that 100 people had as much as the people had in 1890.

This indicates there is some basis for thinking that in some future time we may find ourselves under the necessity of increased production, or the importation of foodstuffs, rather than be burdened with surpluses as we now are.

But the percentage of rural population compared to urban has steadily decreased since 1890. Dividing the total farm population by the rural population as given by the Census Bureau, we find the average production per worker on the farm has increased 38½ per cent within the 30 years. The new census will doubtless show much wider margins, and if those classed as rural only were actually engaged in farming, the increased per capita of productiveness would be still larger.

This increased productiveness is due to two causes: One is the improvement in the method of technique of operation, better varieties of both grain crops and live stock—agricultural education, if you please. The other general cause is summed up by saying that the use of farm power has greatly increased in 30 years—and you are interested in power. Indeed, that is almost a span of transition from the walking power to the tractor gang, and measures a change from the five and six-foot binder to the newly developed combine.

We must illustrate this power increase by stating that 30 years ago the farm power was largely in small type horses, a mixture of draft and road-bred crossed, in order to produce a general purpose animal. The 1400-pound horse is considered too heavy for general farm work. The 1200-pound horses were about the limit of draft power for most purposes. The horse team averaging 1600 or 1800 pounds would have no place in the machinery scheme of the earlier day, while the 1530 tractor was not even a dream.

One evening less than 30 days ago a man working for me came in a little early from the field with a tractor. He had disked twice and harrowed 40 acres of ground that day. It would have taken 5 men each with a 4-horse team to have accomplished this same result. The farmer has thus become a large user of power, and there is every reason to believe that the application of power to the business of farming is yet in the early stages of its development.

You need no statistics to prove that power is the coefficient of agricultural income and efficiency, whether that power be horse power or mechanical power. Of the three types of mechanical power as applied to farming, steam is practically obsolete. The internal-combustion engine, with its liquid fuel, has proven an efficient, adaptable economizer for many kinds of work, and will continue as a principal source of power until superseded by new discoveries and inventions.

Uses of the Electric Motor

The third power agency, like electricity, is more adaptable and efficient in doing every conceivable job about buildings and yards, and in every other place where high lines can be run. The desirability of the electric motor for running the milking machine and separating the shell from the feed grains, for pumping water and a multitude of other chores, is only fully appreciated by the man who must daily crank a gasoline engine on a below-zero morning. These kinds of work, too, are jobs where the greatest profit lies, and they will be better done by electricity than by hand because irksomeness and drudgery are removed.

Let me bring you this thought further. The uses of electric power are such as to stimulate a larger and better live stock and poultry production because they help the farmer to convert on his own farm the raw production from the field into production more finished and more valuable, and this in turn means added fertility, not depleted fields. In most sections of the United States the successful farmer has been an animal user. That has been particularly true during the past five years. More chores, better done, spells profit, and that is where electricity comes in.

A member of this convention remarked that states with large farms far between, like the Dakotas, could not well be electrified. True, if you are thinking of rural electricity in terms of lighter and small appliances only; but if you consider electricity from its power possibilities as applied to a well-diversified agriculture, you reach a solution of agricultural distress in those and other sections of the country similarly located.

Paying the Bills

It is useless to dwell upon so evident a thing as the desirability of electricity on the farm. The problem is paying the bills. When the high line comes it means the farm budget (too often already strained) must be stretched to meet monthly payments. To do this, electricity must be made to produce enough profit to pay its own bills. That is why I am dwelling largely upon its power functions. If it were a matter of farm lighting only, the 32-volt plant would in many cases prove adequate. In my own community it is the owner of the farm plant who, having had a little taste of electrical service, becomes the first signer for the high line.

That power is an economy is shown by the rapid increase of current on farms where high voltage is available. With this in mind, let me observe that when the farmer can be convinced that the rate which he must pay for this power is sufficiently low to materially decrease his production costs, it will be only a short time until high tension lines are as commonplace throughout the farming regions as our rural telephone lines. It is a mighty poor salesman today who cannot with a fair contract sell electrical service to the farmer, providing the farmer has confidence in the company with which he is dealing and is made to fully understand the terms of his contract.

Much, of course, depends upon the rate at which the current is sold to the farmer. So far as I know, there is every disposition on the part of the utility companies to make this rate a reasonable one. It is to be hoped that the companies may get and keep the good-will of the farmer in this respect. Rates determined by mutual agreement will in the end prove more satisfactory than those arbitrarily set by State or Federal commissions.

Progress for Agriculture

Just how an increased production through the use of cheaper power will affect the agricultural solution when there is already a burdensome surplus in some commodities, is problematic. Lower costs of production or higher prices for the commodity inevitably lead to increased production. This matter, in my opinion, will eventually take care of itself. Electricity means progress for agriculture. Nothing can stop its coming. The farmer is going to have it just the same as he has had his automobile, radio and every other thing which goes for increased living standards.

Much is said in discussing the farm situation about the large number of farmers who are forced to leave the soil because of economic conditions. I have already referred to the fact that a decreasing farm population has maintained a fair level of national per capita production. There are approximately 300,000 people who now annually are compelled to leave the farm because of the increasing efficiency of farmers as a whole. I am told that approximately 400,000 people are likewise compelled to seek new industrial connections for the same reason. It is no worse for a farmer to be forced from the soil because of mechanical progress than it is for the coal miner or the textile worker to be forced into other channels of employment. Indeed, to maintain the same relative proportion of rural and urban population that pertained 50 or even 30 years ago, would mean to remove as economic factors all such things as automobiles, self-binders, telephones, rural delivery and other things. The farmer himself would be the first man to object to this.

The farm problem is not to place a premium on inefficient production. It is ready to so improve processes of production, lower costs of production, and raise levels of rural standards that permanent farm prosperity and a contented farm people may always hold their rightful place in our national life.

I do not believe in a national farm policy, or a national industrial policy, or a national utilities policy. What we need is a national policy in which opinions and experience of the agricultural industry in all of its realms are properly timed and fully measured, so that all may move forward as a perfect working machine.

The Social Problem

We have been discussing the relationship of electricity to agriculture almost wholly from the power side. I recently noted an account of some social survey service which enumerated the number of homes in the country without light other than kerosene lamps. Without depreciation of the well-intentioned social worker, I call your attention to the fact that electricity on the farm is both a social and an economic problem. The farmer does not need to be educated as to his needs. He knows all about them now. Give him a price which will enable him to buy your commodity and he will demonstrate to you quickly that he can pick out his own motor needs, and his wife will demonstrate in short order that she knows as much about lighting fixtures and percolators, and electric curling irons, as does her city sister. (Applause). Indeed, from the household point of view electricity is of much greater importance on the farm than in the city. Electricity in the city home is in comparison with the farm home a luxury. It is non-productive in the city and productive on the farm. The farm woman can use the time saved from cleaning kerosene lamps in garden and poultry yards.

I know an Iowa banker who, on leaving college a quarter of a century ago, resolved he would never own a foot of land, but that he would keep his earnings so liquid that he could change from one hand to the other overnight. His first savings were invested in securities of electric railroads because he felt that they were supplying the great economic need of the country. Of course we all know those same roads are now strips of rust. This banker tells me that in 25 years he has had to change from hand to hand almost overnight, continually, in order to keep ahead of mechanical and scientific progress, which is continually making seemingly fundamental things obsolete. It may be the lines your companies are building now or planning to build, will be reduced to the junk value of copper almost before they are builded because of radio or other means of distribution. Be that as it may, these high lines along our highways denote real agricultural advancement. Power always spells progress. A farm on one of these lines is worth more than a similar farm a mile away. In building them you are doing more than distributing current, you are building communities —and communities make the nation. (Applause).

CHAIRMAN SAMPSELL: You will all agree with me that Mr. Howard has made a notable contribution to the subject he so ably discussed in his paper, a subject every one of our light and power companies is intensely interested in. I want to thank you, Mr. Howard, for your paper.

[President Arkwright assumed the Chair.]

PRESIDENT ARKWRIGHT: There will be a little change in the program of the morning. It has become necessary to wait a little while for the talking motion picture, so we have placed it immediately after the installation of the new officers to be elected. While that is not done by design, it is very fortunate that it is necessary to make the change. For one thing, it hastens your getting a new President. For the same reason, it hastens your getting rid of one you already have. I recommend to you that you do not fail to see this talking motion picture. You have seen the other three. You will agree with me I know that they cannot be surpassed in excellence, but that is because you haven't seen this one. It is by Sir Kengo Mori, in Japanese costume, Japanese scenery, spoken in broken English, and will entertain, interest, and instruct you. After the motion picture is over you can go if you feel like it, because you know the runner is going to be put out at the home plate whether you are here or not. There will be no surprise after the picture, except we are going to present to you the one event in the year which will be the happiest one for you, the present President who has been here for the year fades out with the picture. You might stay for the happiness that that will give you.

I take pleasure in presenting Mr. W. A. Jones, Vice-President of the Association, who will preside over the next few numbers.

I hope you won't think it amiss for me to suggest that you do not save your applause for the time when you get rid of your President, but use a little of it as you go along because it creates enthusiasm and expresses your own feelings. Don't be timid about it or too reserved. Come out and evidence what I know you feel.

Mr. W. A. Jones, Vice-President!

[Mr. Jones assumed the Chair.]

CHAIRMAN JONES: If I can add one word to what the President has told you, there will be a surprise following the motion picture listed on the program, and I hope that none of you will leave until you know what it is. I am not going to tell you.

Mr. Howard paid the light and power industry a tribute when he said that in electrifying the farm we were building industry. That is something worth while when it comes from a man who knows and appreciates very much industry building.

The light and power business has always tried to be, as President Arkwright has aptly said, good citizens wherever they serve. As a part of this program in 1927, President Arkwright headed a committee on Industrial Development in the United States, and carried on as Chairman of that Committee a very important piece of work. It is far reaching, the surface has only been scratched, and we expect to see as time goes on very important products of this piece of development work. There is no sectionalism in it. It does not mean that this association will attempt to take from one community and build in another, but it has to do with the real constructive type of industrial building in this country, which helps industry help itself.

I think perhaps the idea of the association doing this work sprang from the feeling that as an industry becomes larger its responsibility to society becomes greater; it becomes more and more incumbent upon that industry that it play its part in the stabilization of business. In undertaking this work it was realized that much help could be obtained from other industries and we are fortunate to have had the assistance of one of the largest of America's business institutions—the Metropolitan Life Insurance Company. We have here today the Vice-President of that institution, who will present to us the report of the industrial development work in the United States.

It is now my pleasure to present Mr. James L. Madden, Vice-President of the Metropolitan Life Insurance Company of New York. (Applause).

INDUSTRIAL DEVELOPMENT IN THE UNITED STATES AND CANADA

By JAMES L. MADDEN

Third Vice-President, Metropolitan Life Insurance Company, New York

The competition among cities for new industries has been called "The Battle of Smokestacks." Apparently many communities and local associations have been under the impression that their real industrial growth depended upon attracting industries from other cities. This gave rise to the preparation of organized plans to accomplish this purpose. We are living in a fact-finding age and the progressive businessman demands facts prior to the formulation of conclusions. When he turned toward the field of industrial development he found that the facts were clouded by the emphasis being put upon the migration or shifting of industry. No comprehensive, factual survey had been made which isolated the migration of industry from the other fundamental elements in industrial development and took stock of their collective effect upon economic growth. Yet all of these elements vitally affected the social and economic progress of American communities and geographical areas.

The absence of this factual information was responsible for the National Electric Light Association through its Civic Development Committee, determining to get at the fundamental industrial development situation in the United States during 1926 and 1927. The Metropolitan Life Insurance Company was invited by the Association to undertake this fact-finding enterprise in cooperation with it. Through the assistance of numerous public utility companies, railroads, chambers of commerce, and other associations, as well as governmental agencies, 2084 cities contributed their experience with the migration of industry as well as the other factors which entered into industrial development. These represented the experience of over 16,000 industrial firms. These cities also were representative of three-fourths of the urban population of the United States, and about two-thirds of the corresponding Canadian population. It is the purpose of this paper to set forth some observations based upon the compilation of this factual information.

Industrial Growth of Communities

First, let us give some attention to the industrial growth of communities. The various cities reported gains during 1926 and 1927 of over 10,000 plants which employed more than 371,000 employees. The migration of industry which has heretofore assumed so much importance in the matter of industrial development, is relegated to a much smaller role in our economic growth than was expected, for relocations, or the shifting of industry, accounted for only a little more than 9 per cent of the total plants gained by the various communities. The real industrial development came from new industries which were started within the communities themselves. These represented over 81 per cent of the plants gained. Branch plants were responsible for the remainder of the gains, and represented a little more than 8 per cent of total plants and 25 per cent of total employees gained. The experience in Canada is essentially the same in regard to these three sources of industrial development as that of the United States.

Measuring the size of the plants gained in terms of employees, we find the average branch plant had 102, the average relocated, or migrated industry, 71, and the average new local plant 25. While these figures are for the United States as a whole, the average size of plants gained when measured in terms of employees, varied with the geographical areas. In the South Atlantic States, for example, the average size of plants gained was 75, or more than twice the size of the national average. New England's average number of new employees was 47, and the Middle Atlantic States was 26.

Let us see which geographical areas profited most from each of the three sources of industrial gains. The Middle Atlantic States consisting of New York, New Jersey and Pennsylvania, showed the greatest gain due to the migration or relocation of industry. The New England States comprising Maine, New Hampshire, Vermont, Massachusetts, Rhode Island and Connecticut, rank second, and the East North Central States which consist of Ohio, Indiana, Illinois, Michigan and Wisconsin, rank third.

Again we find the Middle Atlantic States receiving a bigger gain from the establishment of branches than the other territories; the East North Central territory stands second, while the South Atlantic States, consisting of Delaware, Maryland, Virginia, West Virginia, North Carolina, South Carolina, Georgia and Florida, are third. As to the last source of industrial development, the establishment of local plants, the Middle Atlantic States again ran very substantially ahead of the other territories throughout the United States, New England taking second place, and the East North Central States third. If the South Atlantic territory, though, were combined with the East South Central territory, consisting of Kentucky, Tennessee, Alabama and Mississippi, their record would be extremely close to that of the East North Central territory.

Again using the nine geographical areas into which the Federal Census Bureau has divided the United States, let us see to what extent the three sources of industrial growth have been responsible for the gains in each of the various areas:

		Relocations Per cent.	Branches Per cent.	New Industries Per cent.
NEW ENGLAND	Plants	18.0	6.5	75.5
	Employees	28.3	16.0	55.7
MIDDLE ATLANTIC	Plants	5.7	4.3	90.0
	Employees	15.9	16.0	68.1
EAST NORTH CENTRAL	Plants	18.8	11.1	70.1
	Employees	28.7	26.9	44.4
WEST NORTH CENTRAL	Plants	9.6	17.6	72.8
	Employees	12.9	42.1	45.0
SOUTH ATLANTIC	Plants	13.4	19.2	67.4
	Employees	17.2	36.8	46.0
EAST SOUTH CENTRAL	Plants	6.2	20.1	73.7
	Employees	10.6	30.7	58.7
WEST SOUTH CENTRAL	Plants	8.1	16.0	75.9
	Employees	12.2	33.7	54.1
MOUNTAIN	Plants	4.0	28.3	67.7
	Employees	2.0	77.2	20.8
PACIFIC	Plants	6.4	16.9	76.7
	Employees	4.8	50.4	44.8

Reasons Underlying Location of Plants

You are naturally interested in the reasons underlying this industrial development. Markets are advanced most frequently as the reason for the location of plants. This is not surprising when one reviews the economic situation in the United States. While it is as important as ever to manufacture as cheaply and as well as possible, the primary problem confronting the manufacturers of today is to sell their products. The business man who has tuned in his sales practices to the high demands of his consumers is naturally going to consider the location of plants in relation to his marketing program. The closer his plant is to his markets the smaller will be his transportation costs, the quicker and better his service to consumers.

In many industries, though, labor is regarded as of most importance in the selection of plant sites. The survey indicates, in fact, that labor ranks second to markets as the predominating factor in the location of plants. Some manufacturers were primarily impressed with the general labor supply available in particular communities, while others were interested principally in the skilled or nonskilled supply of labor. The reasons advanced by some executives centered around the opportunity to secure steady, dependable types of labor. The prevailing wage scales in the communities selected for new plants were the predominating factors in the decision of many industries.

Importance of Transportation

When we realize the intimate relationship between marketing and transportation, it is not surprising that the latter, transportation, ranks in third place in point of importance in the selection of plant locations. The increased efficiency of the railroads under private enterprise has been a potent factor in the economic prosperity which the country as a whole has enjoyed. The extent to which improved railroad service has released capital for industrial purposes, through the elimination or reduction of inventories, the quicker delivery of raw materials to the plant, and the faster service from the plant to the consumer, cannot be over-emphasized.

We have mentioned the three main reasons underlying the gains of plants by the cities throughout the United States and Canada. It is significant that bonuses, free taxes, free land, or free factory buildings, which inducements at one time were frequently offered, and occasionally still are, do not appear among these reasons. Then, of course, there are many other reasons which the final report tabulates. There is one thing which is significant, and that is the increased thought which manufacturers are taking prior to the location of plant sites. Many of them are seeking the advice of engineers; others are going about the selection of their plant sites in just as thorough a manner as they do in selecting their mechanical equipment.

On the other hand, personal reasons creep in from time to time. For example, in one big city in the State of New York, a big plant decided to move away. Every effort was made to keep that plant, and when in disgust one of the city fathers went to a friend of the president and said, "Well, I have done everything I could to save the plant," the friend replied, "There is nothing you could have done to have saved that plant because the president's wife has decided that she wants to mix in the social circles in a big city on the Atlantic Coast."

Now then, personal reasons of that type often do creep in, but they do not account for any substantial part of the migration of industry or the location of plants, or the development of local plants.

Then, too, the local chambers of commerce have thrown a great deal of light upon the reasons underlying the location of plants, and I have brought with me just one letter which, if you will bear with me, I will read, taking excerpts to drive home the fundamental ideas which this Chamber Secretary has so well expressed:

"We are very glad a definite effort is being made to find out why industry is moving because we believe that when this information is made public it will have a tendency to discourage the ruinous competition between cities for factories. A number of cities in our state have had some sad experiences lately with bonus factories. Blank City is one of the outstanding examples. The people of that city raised a fund of $125,000 for a shoe company of another city in spite of the fact that they were warned the company was not in sound financial condition. A very fine factory was erected, but has never been operated, and nobody knows just when it will be in view of the fact that the X Shoe Company is now trying to effect a settlement of 15 cents on the dollar. The X plant is only one of eight factories presented to that company by small cities.

Many Offers Received

"For several years we have been kept busy offsetting the efforts made by commercial organizations in other cities to steal our factories. Our manufacturers receive offers almost daily, and some of them are so attractive that it is hard for the manufacturers to turn them down, especially if they happen to be having any kind of difficulty here. During the last twelve months two of our large factories suffered fires, and it took our very best efforts to keep these plants here because of the extravagant offers the owners received from the outside. It was largely due to the fact that the principal owners were active members of the local chamber that we were able to appeal to their civic pride in an effective way.

"Every fire, labor dispute, or any other condition that gets outside publicity, brings bonus committees here like a flock of vultures."

That is a straightforward letter from a chamber of commerce official. Fortunately, the survey was so broad that we were able to decide to our own satisfaction that after all conditions like that, while undoubtedly prevalent in certain localities, looking at the situation from a national viewpoint the manufacturers are showing a great deal of common sense in the scientific approach to the selection of their plant sites.

Just as the requirements of industries vary, so it is natural that the specific reasons underlying their selection of different geographical areas would not be the same. The food industry places most importance upon markets as the reason for the selection of plant sites. The textile group puts a greater stress upon labor in locating new plants. The machinery group gives primary emphasis to markets. The location of leather plants has been decided principally as a result of labor. The chemical group ranks markets as of most importance.

Industrial Losses in Communities

In order to get a more complete picture, let us for a moment think of the industrial losses in communities. During the period of investigation about 6000 plants were lost to American cities. That is quite a number. About 18 per cent of these moved away, while the remaining 82 per cent went out of business. The total number of plants lost was about 60 per cent of the plants gained. The information about the causes underlying these losses has not been nearly so complete as for the gains. In many cases the communities did not have this information, whereas in others they were not enthusiastic about releasing the available material.

There is one observation which stands out after reviewing the causes of plants lost. Many of them which have moved away have been influenced by reasons which might readily have been corrected if the local community had taken sufficient interest in the new industry not only to help it in becoming adjusted to the local conditions, but to continue this interest thereafter. The community which does not keep in close contact with its new industries might reasonably expect to lose some of those which have come from outside of the city. Certainly, whatever is done to help these outsiders likewise should be contributive toward the happiness and prosperity of the local industries which spring up within its borders. While there are numerous organized efforts supported with substantial sums of money to attract new industries from outside of their respective communities, we did not learn of one case during the survey where a community was placing equal emphasis upon aiding its own new industries.

If a community is really going to keep an accurate picture of its net gains it must record not only the number of lost plants, but more important, the reasons therefor. The latter will undoubtedly present suggestions for improvements from time to time. Then, too, the intimate contact which such an effort necessitates, will often result, as evidence disclosed by the investigation proves, in disgruntled industries being made happy and retained.

Large Versus Small Cities

Let us turn the searchlight of facts upon the industrial development of the large versus small cities. If we arbitrarily take a population of 50,000 as a dividing line between the larger and smaller cities, we find that the branches and relocations were divided nearly equally between these two types of cities, but that approximately three-fourths of the new local plants were established in the larger cities. All types of plants established in the larger cities accounted for only 58 per cent of the total gains in employment reported in the survey. There are various reasons for this continued industrial growth of the larger cities, one of which is the large number of satellite industries which are established around existing industries located therein, and another is the development of style industries, such as clothing and allied lines, which are usually located in metropolitan areas.

The extent to which the smaller cities have gained through relocations and branches is worthy of special note. Of all gains made by these cities, it is particularly important to observe that about one-fourth of the branches are located in cities of under 10,000 population, and about one-sixth of the relocations likewise went to these cities of less than 10,000 in population.

The foregoing statistical survey indicates that cities of 50,000 and over received about 73 per cent of all plant gains. The record of the smaller cities is undoubtedly better than this figure would indicate, because approximately 90 per cent of all cities in the United States with a population exceeding 10,000 made reports, whereas only 33 per cent of the cities between 2500 and 10,000 submitted their experience and a still smaller percentage of the cities under 2500. If we were to make an allowance for this unequal representation of the larger cities, the percentage of all plant gains by the cities under 50,000 would be increased to approximately 35 per cent.

The losses experienced by the different sized cities must be analyzed before the net gain can be determined. The larger cities experience a greater percentage of losses than the smaller ones. Thus the cities with a population of 50,000 or over, reported 83 per cent of the total losses in the number of plants and 70 per cent of the total losses in the number of employees included within the whole survey. When you deduct the losses from the gains you will find the cities of 50,000 or over showed a net increase in plants gained of about 60 per cent, whereas the smaller cities showed a net gain of about 40 per cent.

Another Channel of Approach

There is another way of considering this large versus small cities, and that is, to find out the extent to which each is receiving the larger plants, say plants of over 100 employees, and when this test is applied we will find that the larger cities, those over 50,000 population, received during that period 54 per cent of these larger plants, which means that the cities of under 50,000 obviously had the other 46 per cent, more than one-half of which located in cities of less than 10,000 population.

As to the reasons underlying the industrial growth of the smaller cities, those most frequently reported might directly or indirectly be related to lower manufacturing costs. The improvement in railway and power service, though, has undoubtedly been a factor in the development of these cities. Electrical power, for example, has become available within the last five years for the first time to 4000 towns and small cities formerly without service. These small towns now have the same quality of 24-hour electric service formerly enjoyed only by large cities. They also have unlimited electric power supplies available to them to meet the expanding demands incidental to the growth of their communities. Factories can now locate in a small town supplied with electric power from an interconnected system, confident that they can have dependable electric service.

While the larger cities are still getting most of the new plants of all kinds, a tendency in favor of the smaller cities is rather pronounced. Growth of the industrial suburban towns around the larger cities is a reminder of these trends. One very significant fact, for example, is that in the South Atlantic Territory 40 per cent of all plants gained went to towns of under 10,000 population. Another significant trend is that an analysis of migrations, or the relocations in the nine geographical areas into which the census bureau has divided the United States, shows that the preponderant movement was from the larger to the smaller cities, with the exception of three territories, the West North Central, the West South Central and the Pacific Coast, and in all of these three territories the reasons for the reverse movement assigned by those making the movement was the market factor.

Industrial Development by Industries

We might think of this industrial development in another way, and that is, by the specific industries themselves. There are, for example, more relocations—or putting it in another way, there is more migration of industries in the textiles and allied products than in any other industry. Machinery ranks second; lumber and allied lines third, and leather and associated products fourth. Now let us think in terms of branches, and then we find that food and kindred products, during the two-year period investigated, established more of them than any other line of business endeavor; textiles ran second; chemicals third, and machinery fourth. In regard to the third source of industrial development, the record for establishing the greatest number of new local plants was made by the textile industry; the paper and printing industry ranked second; food and kindred products, third, and lumber and allied lines, fourth.

Summing up all gains, we find that the textile industry and allied products are responsible for a little more than 22 per cent of the total plants established in the United States during the period under observation; food and kindred products were second with over 10 per cent; paper and printing was third, with over 9 per cent; while lumber and allied products ranked fourth, with over 7 per cent, the machinery group being slightly below this.

You are probably wondering why the Metropolitan Life Insurance Company accepted the invitation of your Civic Development Committee to undertake this cooperative survey. The Metropolitan has approximately one out of every five men, women and children in the United States and Canada insured with it for over sixteen and one-quarter billion dollars of life insurance. The company has two definite interests in these policyholders. It wants them to keep well and, therefore, maintains an extensive health service, and it is interested in their stability of employment and consequently maintains a broad, economic service. If the Metropolitan can contribute through its economic services toward the stabilization of industry through better management, its policyholders will benefit through greater stability of employment. The company believes in the interdependence of business and the importance of team-play between the component parts of our economic structure, looking toward their mutual prosperity.

It has been a very real pleasure to cooperate with your Civic Development Committee and the officers of your Association in this investigation. The executives of your public utility companies, as well as those of railroads, banks, chambers of commerce, the United States Chamber of Commerce and other organizations throughout the United States and Canada, have cooperated in a whole-hearted manner. Without such assistance the undertaking would have been an impossible one, and it is, therefore, my privilege to express to you our very real appreciation of this enthusiastic aid.

Definite Tendencies

Let us review some of the definite tendencies which the survey has developed. The migration, or the physical shifting of industry, is not the factor in industrial development which many thought. The real development has come from the establishment of new local industries and the setting up of branches in order to tune in with the marketing situation.

No data were developed during the survey about the expansion of existing industries, yet from the standpoint of economic growth this represents just as real an increase in community wealth and opportunity for additional employment as relocations, branches or new local industries. The reason for the failure to get these data was that the communities in the main did not collect them.

Enough emphasis has not been placed upon the analysis of losses of plants, and comparatively little is being done in a definite, organized way to make the new local and already existing industries in a community so happy and prosperous that they want to stay. Yet substantial sums of money very frequently have been raised and definitely organized movements initiated for the purpose of attracting industries from other cities. The real prosperity of a community depends upon stabilization, and the losses of industries tend to upset this condition. The large cities still receive most of the plants, but there is a strong tendency toward the establishment of relocated industries and branches in the smaller cities. About 40 per cent of the net gains of all plants has been in the smaller cities.

There is a definite need for the present pioneering effort to be continued on a systematic basis. The development and movement of industry so affects our social and economic growth, nationally and territorially, that some machinery is necessary to record what is taking place. Yet no such machinery exists. It would seem that a neutral agency, such as the United States Department of Commerce, would be the logical body to carry on continuously this effort to know at all times how, why and where industry is growing or moving.

There is one observation which stands above all others in the survey; the greatest industrial development comes from SELF-development rather than from attempting to attract industries from other communities. (Applause).

CHAIRMAN JONES: I believe you will agree with me that this industry is indebted to Mr. Madden and the Metropolitan Life Insurance Company for their valuable services in connection with this work in civic development. If we are assisting in any way in stopping the economic waste which has been increasing yearly in chasing industries from one section of the country to another, we are doing a good job.

I think it is interesting that this Association is big enough to take that national view as against the view of sectionalism, and if this Association has done any one thing that justifies its existence I think that alone might stand out, the elimination of the sectionalism that disregards economics, for what is more unsound than the dragging of one industry from New England to the South, or from the South to the West Coast, or anywhere else, if that industry is already properly located. So if we can help point the way to sound economics in industrial development, we are playing a part and being good citizens where we serve.

This industry, unlike some others, is not only regulated by competition—I think perhaps some people still feel that there is no such thing as competition in this business—but in addition we are regulated by municipal and State bodies, who supervise our rules of conduct, tell us what we shall charge for our service, and discipline us in many other ways. As to whether regulation is good or bad for us, it is still a matter of some doubt in the minds of the leaders of business, but it is with us and it is perhaps here to stay in some form. If the character of our business changes, no doubt regulation will change with it.

Our next speaker is a man who has made a close study of regulation from its beginning. It is my pleasure now to present Mr. W. J. Hagenah, Vice-President of the Byllesby Engineering & Management Corporation, who will speak to us on the subject of Regulation.

PUBLIC UTILITY REGULATION AND ITS ACCOMPLISHMENTS

By WILLIAM J. HAGENAH
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There are perhaps few people today who are not familiar in a general way at least with the extent and workings of public utility commissions. Looking over the record of twenty years of State regulation, the question may now be asked, What has regulation accomplished? The answer is that State regulation laid the foundation for the remarkable improvement of this industry in service-rendering capacity, reduction of rates and public investment support. It has substituted scientific rate-making for the hodge-podge that unregulated competition and political trafficking had produced; it made clear to the public how wasteful utility competition was; it developed the indeterminate permit in place of the rigid long-term franchise that so often defeated real progress in service development and reductions in rates; it showed the impracticability of "home rule" for cities because the electric industry was not a local institution; and it exposed the misrepresentations and accounting irregularities of municipally-owned electric plants.

When 47 States prescribe by statute for the regulation of public service corporations, when 43 through specially created commissions restrict earnings to a reasonable return on the fair value of the property devoted to the public service, when 23 States supervise the issuance of utility securities—all with the approval of the highest courts of the land—it is obvious that new business fundamentals have here been established.

The adoption of this public policy came on the eve of a great technical advancement in electricity, in chemistry and in the mechanical sciences. This awakening, together with the World War, stimulated industrial production as never before, and opened the door to better standards of living. The resulting demands for electricity doubled and redoubled. The greatly expanded properties and increased production made lower rates possible, and with each reduction new fields for business development were opened. Public confidence was won as no other industry in America has succeeded in doing, and with the proof of political square-dealing capital flowed to the utilities in increased volume and at steadily lower costs.

With the greatly improved technical processes, largely based on utility service, the productive power of the American people and their output per person employed in industry increased so largely that in some industries the labor cost per unit of production has reached the lowest point in history, and this in spite of an approximate doubling of wage scales. Under this condition we have developed a mechanical power per man employed that is from two to three times as large as our European competitors, and our production and consumption per capita have now reached the highest point in the history of any country.

Yet in the midst of the widespread prosperity that we have witnessed, to which regulation has been a large contributing factor, the electric utility industry is today being subjected to attack. There are those who tell the public that great wrongs are being committted and that legislative bodies must assert themselves to protect the people against the encroachments of the power corporations. There were more utility bills introduced during the last sessions of the State legislatures than in any year since the beginning of regulation. Finally, the Federal Trade Commission is conducting an exhaustive investigation into all phases of this business. It is not surprising, therefore, that some people are beginning to wonder whether there may not be something wrong in this industry that calls for corrective legislation.

That there are individual and corporate abuses in the utility situation no well-informed person will question. They are regrettable, and they will be corrected as similar abuses have been corrected in every rapidly growing industry. It will, however, not be conceded that these conditions are serious, or that they call for legislative action. In many instances these attacks are mere exaggerations, unsupported by facts, and made with a selfish personal motive. Nevertheless they are unfair and disturbing to every conscientious electric utility executive, but there is comfort in the fact that these charges can be met by a frank statement of the facts which the excellent public records accumulated under public utility regulation now make available to the industry and to the public.

Reviewing the Facts

Time will not permit a review of all the accomplishments of regulation, but the facts concerning three subjects in respect to which the electric utilities are now being subjected to criticism can be stated definitely:

1. Every economy resulting from the progress of the electric art, or increased efficiency in the electric utility industry, has been transmitted to the public through lower rates.
2. The earnings of the electric utilities are among the lowest of the major industries in America.
3. There is no inflation in the securities of the operating electric utilities nor in the securities of the larger and older holding companies.

Let me discuss these briefly. First, as to the reduction of rates in the face of advancing costs. During the last fifteen years, which include the period of the World War, the post-war deflation, and the recent period of great industrial activity, practically every item of cost entering into the construction and operation of electric utilities has greatly increased. Nevertheless, electric rates have tended steadily downward. Electric service is today one of the few items entering into the family budget that can be obtained at substantially lower cost than in 1913, and State regulation has been a major factor in bringing about this distinct public gain.

Because the residence lighting service affects the largest number of customers and is also the least competitive and, therefore, more easily exploited in the absence of effective regulation, were such attempt seriously made, the rates for this class of service can best be made the basis for such a comparison and study. It is to these rates that public agitation is almost exclusively directed and where the test of the results of regulation must be applied.

Principal Items of Cost

The principal items of cost with which the electric utility, just as well as every other class of business, must contend are wages, material prices, taxes and the cost of money. Fortunately data covering each of these items are obtainable from official and semi-official sources, and may be reduced to index numbers for comparative purposes. According to these records, the index number of wholesale commodity prices as determined by the United States Bureau of Labor reached a peak of over 220 in 1920, as compared with 100 for 1913, and following the reaction in 1921 has become fairly stabilized on a basis that is now approximately 50 per cent higher than the pre-war level.

As this index number deals mostly with raw materials priced at wholesale, and in which labor is but a minor factor, it by no means reflects the conditions with which the utilities were confronted. Because of the large amount of skilled labor present in construction undertakings, the index numbers of electric utility construction costs have been separately computed, and these indicated a peak of 196 in 1920, with a later stabilized condition, but gradually declining costs, now reaching a level nearly 70 per cent above the pre-war level.

Factory skilled labor, an important item of cost in all the materials and supplies purchased for construction and operation, today stands 120 per cent above the pre-war level. Union labor, which is a large factor in the construction and operation of electric utilities, has continued strongly upward ever since 1913, and today stands at a level 140 per cent above pre-war wages, the highest point that wages have reached in the history of civilization. Interest rates covering utility financing, while reaching an almost prohibitive figure immediately after the war, have declined, but are still higher than in 1913. State and local taxes, which each year take an increasing percentage of the gross and net earnings of utilities, are today occasioning grave concern in the electric industry. They have increased violently and without interruption since 1913, and give no indication of a stabilizing tendency, much less a decline. Yet with all those items entering into the cost of supplying electricity to the rate payers, residential rates have tended steadily downward since the beginning of the war, and today show for the United States an average of over 25 per cent below the 1913 level.

It is interesting at this time, when both the electric industry and the work of the regulatory commissions are being subjected to criticism, to note how quickly private industry and individuals adjusted themselves to these conditions by rapidly advancing prices, wages and interest. It is also interesting to note the large increases in the cost of government, which increases are continuing to this day. From a per capita State and local tax burden of $15.81 in 1913, there was a quick advance to $28.24 in 1919. This increase was explained, and everyone accepted the explanation, as due to the war and the social changes which followed the war. Since the close of the war, however, this tax burden has continued to grow more rapidly than ever before in American history, reaching in 1927 the disturbing total of $48.39 per capita, or over three times the cost of conducting our State and local governments before the war.

Such tax increases are explained by government ownership advocates as due to the higher cost of labor and material and the ever-expanding activities of the State and local governments. Even the casual observer, however, will note that the principles of regulation, and the economies which were enforced by the commissions among the utilities, were never employed in the departments of the government themselves. When mounting costs and the declining purchasing power of the dollar of income destroyed their pre-war rate basis, the utilities were compelled to ask for some relief, but never did the total increases granted by the commissions bring the residence rates back to the level that obtained in 1913. Even by 1920, when the peak of wages and prices generally was reached in the United States, the entire increase granted in residence rates had been wiped out by reductions ordered by the commissions or voluntarily granted by the utilities.

Constant Downward Revision of Rates

What has made possible the continuing reduction of electric rates in the face of this disturbing economic condition and advancing wage and price levels? The answer is to be found in the remarkable progress made by the electrical industry itself and the reduced cost of producing and distributing energy. This was brought about by larger and more efficient units of production, the greater productivity of labor, the interconnection of utilities, and the increased economy of operation and efficiency of management made possible by the development of the holding companies. These great savings that resulted from inventions, improvements in technical processes and efficiency in management have been transmitted to the public through the constant downward revision of rates.

The profits have not been retained by the utilities, for at no time have the commissions permitted the utilities to earn rates that would yield more than a reasonable return on the fair value of their properties. The influence of the State commissions has always been present, both in formal and informal negotiations, in carrying out the spirit of the utility laws and the economic concept of a public utility.

Every saving by the utilities almost as soon as it was accomplished has been passed on through lower rates to the public. During this same period private industries, limited only by the restraints of competitive business, not only advanced prices violently, but generally maintained them at a level far in excess of pre-war prices, and with high profit to themselves.

Let me turn now to the second major accomplishment of regulation. Commission regulation has maintained electric rates at such a level that the earnings of the power companies yield no more than a fair return. The income of different companies naturally varies, but the earnings of the industry as a whole are not excessive and are far below those found in other fields of endeavor. A comparison of the earnings of private industries with those of the electric utilities provides a sufficient answer to any contention that the public is being exploited by the power industry. It also provides a convincing reply to the charge that the utility commissions, because of court decisions, are no longer able to function for the protection of the public. Statistics have recently been compiled by the National City Bank of New York, covering 772 business establishments, representing 31 different industries. These computations set forth the relative net profits in 1928 expressed in terms of per cent of the net worth of each industrial group at the beginning of that year. The net worth for these industries was computed by taking the capital stock outstanding and the surplus account for each individual company for which the data were available. To show the extent of this survey, let me say that the 772 establishments had a gross income in 1928 of nearly $2,800,000,000, and represented a net worth of $19,943,000,000, or more than twice the total investment in the operating electric industry.

Net Profits of Private Industries

The net profits for only a few of these industries can in this limited time be referred to. The automobile industry in the United States earned 28 per cent; drugs and sundries, 24 per cent; printing and publishing, 23 per cent; milling flour and baking, 21 per cent; household equipment, 18 per cent; industrial chemical lines, 17 per cent; merchandising, 16 per cent; food products, electrical equipment, and office equipment, 16 per cent; copper mining, 13 per cent; tobacco manufacture, 13 per cent; machinery, 11 per cent, and agricultural implements, 12 per cent. I might go through the entire list of 31 industries if time permitted. The average earnings shown by this great cross section of America's unregulated business was 14 per cent on the net worth, after paying all operating expenses, depreciation, taxes and interest.

Compare these earnings with the returns computed on the same basis for the leading electrical companies under State regulation in 1927, the latest year for which the data are available. Such a study covering 30 properties with an aggregate book cost of over $4,143,000,000, showed profits on the combined capital stock and surplus, not the value of the property, of 9.1 per cent, after taking care of depreciation and taxes, and bond interest. This percentage, however, is misleading because the capital structures and fixed charges of the different industries differ materially. Further, private industry sets aside reserves not allowable to electric utilities under State regulation, and in the private industries embraced in the study mentioned were many companies having little or no funded debt. The average earnings of 14 per cent in private industry, therefore, represent the return on a much larger proportion of the total investment than is true for electric utilities.

Comparison of Returns

Were the industrial net profits related to a smaller share capital, such as we find in the electric industry capital structure, the returns of private industry for comparative purposes become approximately 20 per cent. The measure of return for the electric utilities, however, can only be correctly expressed when the 9.1 per cent earned on the capital stock and surplus is related to the entire property, because that is the lawful basis of value under regulation.

The capital structure of the electric utilities now shows an almost equal division between bonded indebtedness and capital stock. When the cost of capital for these different forms of securities is applied to such capital structure, the net return after depreciation, taxes, and bond interest of 9.1 per cent on only the capital stock and surplus, discloses a considerably lower return on the fair value of the property on which the returns to electric utilities must be computed. An analysis has been made of all the electric bond issues listed on American exchanges where the amount involved in each case is over $500,000, and where there have been open market sales from which true value quotations are obtainable. This study covered $2,091,000,000 of bonds having the four highest investment ratings. It developed that the cost of money to the public utilities under these four high grades of bond issues, including amortization of discounts, commissions, brokerage fees and legal opinions pertaining thereto, was 6.1 per cent.

Applying now these two percentages, that is, 6.1 per cent to a 50 per cent bond structure, and 9.1 per cent to a 50 per cent capital stock structure, it develops that the 30 largest operating electric utilities in the United States in 1927 averaged 7.63 per cent on the value of their property as determined by the laws of regulation. These 30 companies, however, operate in the larger cities where the profits naturally are higher than for the companies that serve the smaller cities, and that reach out into the rural communities. When the average earnings of the most favorably situated and the most prosperous companies do not exceed 7.63 on the fair value of their properties, while those for the industry as a whole are considerably less, it follows that the commissions have permitted only such earnings as are necessary to attract sufficient capital to make possible the expansion of the electric industry, while transmitting to the public through reduced rates all earnings beyond the measure of a fair return as indicated by the decisions of the United States Supreme Court.

Thirdly, State regulation has prevented capital inflation in this industry. How can there be overcapitalization, let me ask, when the commissions fix rates on bases that yield no more than a reasonable return on the fair value of the property dedicated to the public use, when the commissions supervise the issuance of securities, and when they prescribe accounting systems and see that the books are properly kept? This assuredly enforces conservative capitalization and gives protection to the investments in the hands of the public. Is this not an explanation for the great investment movement among people of small means and by trust institutions to buy the securities of the electric industry? In no other field is there so close a relationship between the fair value of the property assets and the securities outstanding against them. This conclusion is supported both by the accounts of the electric utilities and by the decisions of the commissions.

Property Costs and Securities Outstanding

It is possible to ascertain the relationship between the property costs and the securities outstanding for a sufficient number of individual companies, making up in the aggregate a large percentage of the total industry, and thereby establish the fact that there is no capital inflation in either the electric utility operating field or among the older and larger holding companies.

This study can be made by analyzing the balance sheet accounts of the operating companies and the holding companies, and grouping them according to their character, as follows: First, operating electric companies deriving over 95 per cent of their gross income from electric operations. Second, operating companies associated with gas or railway companies, but obtaining between 60 and 95 per cent of their total income from electric operations. Third, holding companies which publish sufficiently detailed balance sheet data of their own operations distinct from consolidated balance sheets of their subsidiaries.

Such a study has been made for the industry covering the year 1927. Let me refer first to the group having earnings from electric operations exceeding 95 per cent of their total gross revenues. This group embraces 195 electric companies which comprise approximately 50 per cent of the total investment in the electric operating properties.

According to an analysis of their balance sheets, the book cost of these properties was $4,772,781,000, while their capitalization is but $4,491,861,000, or less than the invested capital by $280,920,000. There is consequently an excess of assets over securities outstanding of 6 per cent. This, however, does not reflect the true relationship, for in utility regulation it is the fair value of the property on which earnings are computed. Neither does the par value of the securities necessarily measure the total amount that the utilities received from such securities and invested in their property and plants. Certain adjustments are therefore necessary before the true relationship can be expressed. The earning power under regulation determines what is in the last analysis the true asset value of a utility property, offset against its outstanding securities. Consideration must therefore be given to what extent the book cost reflects the fair present value under regulation.

Cost studies indicate that for many large electric utilities approximately 70 per cent of the total property now in service has been constructed since the beginning of high prices in 1917, and that much of the property that was acquired prior to that date has since 1917 been reconstructed and replaced with high-priced material and equipment. For this reason there is little to choose at this time between the original cost of many electric properties and their replacement cost, and controversy on the subject as to the relative weight to be attached to these two factors becomes merely academic. Hence the book cost of the electric utilities may be accepted as fairly reflecting the present value of the physical plants, especially since practically all of these capital expenditures have been made according to the commissions' prescribed classifications of accounts, and the capital charges have been approved by the commissions themselves.

The decisions of public service commissions indicate what additional factors must ordinarily be added to the book cost of the properties to more nearly reflect fair values. An analysis of the decisions, of which there are a great many in the official records, shows that the average allowance for working capital is equal to approximately 3 per cent of the investment in the physical property, and capital securities may be issued for this purpose. Likewise, The United States Supreme Court has long since held that the existence of going concern value in an assembled and established utility property is self-evident, and constitutes a property right on which the owner has a right to earn a fair return when the same is dedicated to public use. This language has often been restated with approval, and in one of the most recent decisions of that court it was further said that the amount generally included by commissions and courts to cover this intangible item in the appraisal of a utility property was equal to approximately 10 per cent of the value of the physical elements.

The Protective Factor

Restating now the property investment of the operating companies in terms of fair present value as defined by the United States Supreme Court, the reconciliation of the asset value and the outstanding securities becomes more interesting. The total book cost of the property of this first group, after deducting the average depreciation that exists in well maintained properties and making allowance for working capital and going concern value according to the findings of commissions and the decisions of the United States Supreme Court, the asset value of over 50 per cent of the electric industry is $4,854,000,000 as defined for rate base regulation purposes, against outstanding securities at par of but $4,492,-

000,000. In other words, these securities have a protective factor of $362,000,000.

Even this does not tell the full story. The securities of corporations are generally, in the first instance, sold at less than par, and in addition to absorbing this discount the borrower must pay the banker's commissions, brokerage, the cost of engraving and printing securities, legal opinions, etc. The question of necessary past discounts and similar expenses may have no place in a discussion of the burdensomeness of present capitalization, but it is interesting at this point to know what such costs aggregate in ordinary utility financing and that under commission regulation these costs represent a much more modest charge than they do in private industry generally.

Sale of Electric Utility Securities Analyzed

An analysis has been made of the electric utility securities that have been sold in the United States as listed in the *Commercial and Financial Chronicle* for the last seven years, and they disclose a discount below par to the purchaser of 3¼ per cent.

A study of bankers' commissions and brokerage charges in connection with the sale of many hundred million dollars of public utility securities indicated that such items cost an additional 5½ per cent, making a total burden on the financing of utility properties of 8.75 per cent. If such cost is taken into consideration in studying the present outstanding securities, it appears that but $4,098,000,000 was realized from the securities outstanding for over 50 per cent of the operating electric utilities, and over $750,000,000 less than the valuation findings supported by the United States Supreme Court decisions and the rulings of the commissions.

These facts taken together show first, that there is no overcapitalization in this group of electric utilities and, second, that their financing has been conducted on an exceedingly economical and conservative basis.

Let me next take up the second group of utilities analyzed in this study. They embrace the electric operating properties associated with gas or street railway utilities, but still deriving from 60 to 95 per cent of their total gross income from electric services. This group comprises 74 companies, the book cost of which properties is $3,714,000,000 against outstanding capital of $3,735,000,000. Here we see on the first examination a slight margin of outstanding securities in excess of the cost of the properties as disclosed by the books. When, however, we apply to the total book cost the principles laid down by the decisions of the public service commissions and the United States Supreme Court as to the proper value for rate-making purposes, such book costs, less depreciation, but including working capital and going concern value for the second group, becomes $3,778,000,000, against $3,735,000,000, or a property value greater than the amount of the securities outstanding. There is thus no evidence of overcapitalization in this group.

If now we deduct 0.7 per cent of the book cost of the utility property included in the first group, and 30 per cent of the property included in the second group to cover the non-electric property operations included therein, the purely electric investment here analyzed and covering 269 companies aggregates $7,339,696,000. Comparing this sum with semi-official estimates of $9,000,000,000 as the total amount invested in operating electric properties today, it follows that for nearly 82 per cent of the total industry, there is no justification for the charge of overcapitalization. "But," say the critics of the industry, "your figures are not convincing. Just leave it to the accountants to make your balance sheet balance. A shrewd accountant and a smart lawyer can arrange that." Such a view is interesting and also important, but here again the facts of regulation as laid down in official reports squarely meet this issue and justify the reliance placed on the books and records of the electric utilities. The utility laws require that commissions ascertain the fair value of utility properties. In arriving at such value they must give consideration not only to the book cost of the properties but also to their replacement cost, existing depreciation, and such other evidences of value as are present in each individual case. Since these decisions definitely establish the true value of such properties through the right to earn a fair return thereon, it follows that the relationship between the valuation findings by the authorities and the capitalization provides an official answer to any inflation charge.

Analyses of commission decisions covering fair value findings of entire electric properties, and setting forth also the related outstanding capitalization, show valuation findings of over $292,000,000 against a total capitalization of $309,000,000. In this comparison the securities exceed the earning value by 5 per cent. However, the combined rate base included in these decisions reflects in a number of the early cases some exceedingly heavy deductions for depreciation, and no allowance was made in the capitalization for the cost of financing. These latter costs, as already explained, aggregate on the securities in question, over $27,000,000. After making this deduction, the proceeds realized from such securities and invested in the properties appraised, were perhaps not in excess of $282,000,000, or well below the total of the rate bases found by the authorities.

Data Are a Matter of Record

In the decisions referred to, the commission rate bases exceeded the capitalization in nearly half of the instances. In only six cases did the capitalization exceed the rate base by over 10 per cent, and 85 per cent of such excess capitalization was accomplished before the adoption of public utility laws in those states where these particular properties were located. These data are all a matter of record in the files of the State commissions and are open to examination by any interested party. It may be that the advocates of municipal ownership of electric properties sincerely believe that there is overcapitalization or inflation in the electric industry, but it is only fair to suggest that before making such charges they should first acquaint themselves with the facts.

There is also no inflation in the capital structures of the older holding companies. Thirteen of such companies publish detailed reports of their own balance sheet data, disclosing the cost of the securities which they hold and have taken out of the market and the cost of the securities which they themselves have issued. The cost of the securities acquired and held by them, that is, the 13 companies giving detailed balance sheets, aggregate $1,878,643,000, and the par value of the securities which they have issued against these properties is $1,733,000,000, showing an excess book cost of the property in the treasury of these companies of $145,000,000 over the par value of the securities outstanding. The magnitude of the operations of these 13 holding companies is indicated by the fact that the book cost of their subsidiaries is almost $6,000,000,000, or 65 per cent of the total investment in electric utilities.

While the securities held by the holding companies constitute the assets against which their own capital has in turn been issued, these bonds and shares are no part of the capitalization of the operating companies. They are in no sense an addition to the securities or the capitalization of the operating companies. When this fact is understood the holding company assumes a different aspect in the investment field, for so long as it removes from the market and holds in its own treasury the securities of other companies, and against these puts out its own securities and in no greater amount, there is no pyramiding or weakening of the capital structure of either the operating company or the holding company. Since the holding company can ordinarily acquire no securities from its subsidiaries except as their issuance is approved by the regulatory commissions of the States in which such properties are located, there is little danger of overcapitalization. There is no contact between the holding company and its operating subsidiaries that is not subject to the closest scrutiny of the regulatory commissions, and any abuse of the power control can be arrested by the commissions at its inception.

A word in conclusion. Commission regulation has successfully met every test of the soundness of its policies. The utility laws have proved strong enough to protect the public, and their administration has been sufficiently flexible to adapt them to violent economic changes. Regulation, when the occasion required, has restrained tendencies leading to wrongs and abuses, and it has been found equally competent to protect the investment of the utilities and the public they serve. Although not perfect, it has nevertheless met every problem in a manner that has justified public confidence.

It is the hope of the friends of good government and of sound business generally, that this record of achievement in public administration will be maintained. Serious problems affecting the ownership and management of public utilities are on the horizon. They can best be met through a presentation of the facts, a statement of the truths that regulation has disclosed, and the beneficial results it has accomplished. Should the influence which the commissions exercise be removed, or the workings of these bodies become influenced by political considerations, both the utilities and the public will suffer. The accomplishments of commission regulation furnish the best reason for not disturbing the workings of this branch of our State governments.

I thank you. (Applause).

CHAIRMAN JONES: I am sure that paper is a bright spot on the program of this convention. It is one of the most valuable contributions to regulation and rate discussions that I have ever heard.

MR. MARTIN J. INSULL: I would like to propose that that paper be printed in pamphlet form for distribution to our membership, providing Mr. Hagenah will give his consent.

CHAIRMAN JONES: I think that is a splendid suggestion, Mr. Insull, and I am sure the incoming President will carry out that recommendation.

Mr. Hagenah referred in the course of his remarks to the fact that this industry is now being subjected to an investigation by the Federal Trade Commission. We have with us this morning a gentleman who has been representing this Association as Special Counsel before the Commission in the presentation of its case. This gentleman is an experienced public utility man, knows our problems, and I believe knows how to present them in a proper and intelligent way.

It is now my pleasure to present to you Mr. Bernard F. Weadock, Special Counsel before the Federal Trade Commission. (Applause).

FEDERAL TRADE COMMISSION'S INVESTIGATION

By BERNARD F. WEADOCK

Special Counsel

This is a day of investigations. The present investigation of the electrical industry was instituted by a member of the minority party in the year immediately preceding the presidential election. That, however, should not in any way affect the completion of that investigation by the administrative body to whom it was referred.

It has been my pleasure to consider the Federal Trade Commission in its work as a quasi-judicial body, and I have accorded to it that position. The commission, I believe, is endeavoring to execute the command of the Senate thoroughly. The public hearings have been running for a year and a quarter. They have been presided over by the Chairman, Judge Edgar McCullough, faithfully and with some patience. The matter has been presented by

Mr. Healy, the Chief Counsel, a good lawyer and a splendid gentleman, bent upon fulfilling his duty as he views it, in the order of the Senate.

The Commission has consented to give the utilities an opportunity to present their side of this matter. The exact time is uncertain, but pending that time I would rather refrain from discussing what we propose to show out of deference to the commission itself. It would be rather unique for a lawyer to discuss the character of the evidence or the testimony that he proposes to present in a case in advance of the actual hearing.

I can say to you only this: That this investigation, it will be my hope, when it is completed, will set at rest forever the insinuations, the innuendoes and the accusations in regard to this industry. It is my hope that when it is concluded you gentlemen can devote your time to the expansion of your business and your community in your usual orderly procedure, rather than to the matter of this investigation.

I said that this was a day of investigations, and so it is. The same gentleman who introduced the resolution which brought on our investigation has but recently introduced into the Senate of the United States a resolution to investigate every industrial and commercial consolidation and merger occurring within the last five years wherein the capital involved was in excess of $20,000,000. The scope of that resolution is broad enough to include practically every commercial enterprise in the nation. It is broad enough to include all sizeable business.

I think the American people today are not gravely concerned with the magnitude of an enterprise. They realize the necessity that if this nation is to continue to go forward and the industries of it are to be successful, it must be done by a large organization because of the economies resulting therefrom, which are always beneficial to the consumer.

As usual, the electrical industry is in the fore. Our investigation comes first and the others follow. I feel that when we do present our facts to the Commission that the Commission itself, the American people and the Congress of the United States will view this industry as it properly should, and that is an industry in the fore of the progress of the nation, operated by skilled men trained in the business for the good of the country.

I thank you. (Applause).

CHAIRMAN JONES: For the information of those who were not here earlier in the session, I would like to say that the report of the Constitutional Revision Committee has already been presented and acted upon. The talkie-movie for the day has been postponed until immediately after the installation of the newly elected officers. Please stay for the picture. It is on a par with the others you have seen. Therefore, I need not urge you to remain to see this one.

We will now have the report of the Nominating Committee of the officers for the ensuing year. Mr. W. W. Freeman, Chairman, will present it.

REPORT OF NOMINATING COMMITTEE

MR. W. W. FREEMAN: Your Nominating Committee takes pleasure in submitting the following nominations:

PRESIDENT, M. S. Sloan, The New York Edison Co., New York.

VICE-PRESIDENT, W. A. Jones, Cities Service Co., New York.

VICE-PRESIDENT, J. F. Owens, Oklahoma Gas & Electric Co., Oklahama City, Okla.

VICE-PRESIDENT, Marshall E. Sampsell, Central Illinois Public Service Co., Chicago, Ill.

VICE-PRESIDENT, Edwin Gruhl, North American Co., New York.

TREASURER, P. S. Young, Public Service Electric & Gas Co., Newark, N. J.

MEMBERS-AT-LARGE, National Executive Committee, to fill expiring terms of office:

P. S. Arkwright, *ex-officio,* Georgia Power Co., Atlanta, Ga. (Class "A").

Representatives of Class "A" Member Companies for Three Years

E. W. Lloyd, Commonwealth Edison Co., Chicago, Ill.

Harry Reid, National Electric Power Co., New York.

Representative of Class "D" Member Companies for Three Years

G. E. Cullinan, Graybar Electric Co., New York.

Representatives of Class "F" Member Companies for One Year

C. L. Collens, Reliance Electric & Manufacturing Co., Cleveland, Ohio.

James R. Strong, Tucker Electrical Construction Co., New York.

Respectfully submitted,

R. J. GRAF
FRANKLIN T. GRIFFITH
C. E. GROESBECK
MARTIN J. INSULL
W. W. FREEMAN
Chairman.

CHAIRMAN JONES: You have heard the report of the Nominating Committee. Nominations are in order from the floor if you care to make any.

[A motion was made, seconded and carried that nominations be closed.]

[President Arkwright assumed the chair.]

PRESIDENT ARKWRIGHT: All those in favor of adopting the report of the Nominating Committee say "aye"; contrary "no." The report is unanimously adopted.

I hereby instruct the Secretary, Mr. Marshall, to cast one ballot for the officers named in the report of the Nominating Committee.

The Secretary has cast a ballot for the election of the officers named in the report, and they are declared unanimously elected.

I would like to ask former Presidents Martin J. Insull, J. E. Davidson and Frank Smith to escort the newly elected President to the rostrum.

[The newly elected President, Matthew S. Sloan, was escorted to the platform, the audience rising and applauding.]

PRESIDENT ARKWRIGHT: Matt, the Presidency of the National Electric Light Association is one of great distinction. Its symbol of office is a badge of honor. It has been bestowed upon you by the unanimous choice of the representatives of the electric light and power industry throughout the United States. They have known you for years, observed you, and watched you. They could not have made any mistake. They have all been looking forward to the time when you would be President of this Association. They are confident that its affairs will be handled with ability and skill and tact under your leadership.

In addition to that they get gratification and satisfaction in the feeling that, not only will their Association be well conducted under your administration, but the handling of it by you will reflect pride and credit upon each one of them.

It is a peculiar pleasure and pride to me to transfer to you the office of this Association, because the same soil from which you drew your inspiration furnished the clay out of which I am made. Your traditions are my traditions. Our people are intensely proud of your accomplishments. You are entering into this office with knowledge of the business, the head of the largest single electricity company in the world, the chief executive of the first-born among us in whom we have great pride. You take with you our best wishes for your unqualified success in this position.

You have also, as I can tell you, an amazingly pleasant and inspiring experience ahead of you when you go over the country to visit the people in this industry in the various sections everywhere, and receive from them a glowing welcome from warm hearts, and you begin to appreciate what your industry means and the kind of people that run it.

I congratulate you on having the very great distinction, the very great privilege and the very great pleasure of serving this Association as its President.

Ladies and Gentlemen, I present to you our new President, Mr. Matthew S. Sloan. (Applause).

PRESIDENT-ELECT SLOAN: I want to thank President Arkwright for the fine compliment he has given me. I am deeply conscious of the honor you have done me in electing me to the presidency of our great Association. It might perhaps have been well if some other man had been chosen, for it is no small task to assume, and I have a job in New York with heavy duties and responsibilities. However, I have been chosen and subject to those duties and responsibilities I pledge you my interest, my energy and my devotion to the affairs of our Association and our industry.

Thank you very much for electing me. (Applause).

PRESIDENT ARKWRIGHT: We will now have the feature which has attracted so much interest during the week every day. I will let the man who is responsible for having it made tell you about it. I said the first day of the session that if we had nothing else in the convention but these talking motion pictures, we would have had a convention, and we owe that in large part to Mr. Onken, who went to Europe to secure them. Before going he had an agreement from the people who would take part, but after arriving there he was disappointed in not getting any of them. With his initiative he overcame his discouragement and brought us back better ones than we sent him to get.

In addition to our obligation to Mr. Onken, I want to again express our obligation to the Western Electric Company, through whose generosity all of these pictures were provided for our interest and our entertainment.

Mr. Onken will himself present this feature.

After it is over you need not remain if you do not care to. As I said earlier, there is no surprise after it is over. It will be the last half of the ninth inning, with two out and one on the bases. You know in advance that the game is going to end, by the runner being thrown out at the home plate.

JAPAN'S TRIBUTE TO LIGHT*

BY SIR KEMGO MORI, TOKYO, JAPAN

Chairman, Japanese Committee of Experts to Reparations Conference

The event we are celebrating today is not something which can be celebrated one day and forgotten the next. You will remember it every day and forever.

An invention whose advantage can be enjoyed by only one section of the community, or the people of one country, cannot be termed a true blessing. But the electric lamp is a true blessing in the sense that its beneficence extends to every man, every woman, the world over.

I am one of those who was not so blessed in his youth. My studies were made under the oil lamp. I like to think that that time is not very long back, and it is certainly a very short time for the electric lamp to have made such remarkable progress considering that, according to the statistics I have, my country was lighted at the rate of one lamp for every two people in 1927.

No later figures are available, which fact throws into a relief, as clear as the illumination I am talking about, the rapidity of the expansion this public utility is making. Official statistics cannot keep pace with its progress.

The electric lamp has a sister, equally admired, more vocal; but less enlightened. I refer to the telephone. This lady, however, is less fortunate and is often seduced in government hands. Her virtue is not, therefore, always irreproachable.

There are three virtues which are rarely possessed combined by mortals—beauty, cool head and a warm heart. The only thing I know which possesses them is a mountain in Japan. Its name, which must surely be known almost as universally, is Fujiyama. It is beautiful in form. Its head is cool in perpetual snows, and its heart is warm with internal fires. But it has its peer in the electric lamp, which is a happy mixture of these three virtues.

Let us hope that this wonderful creation may make still further progress in the days that are to come, and in its gathering strength bring light upon the questions which trouble mankind, and in the solution of which the West and the East must join hands.

PRESIDENT ARKWRIGHT: It is appropriate that this convention should fade out with the picture, and with it fade the one who has had the honor to preside over your deliberations. I thought that I would run toward the end of it, but as the end comes I find I am approaching it with reluctant feet. I have had a wonderful experience. I have been all over the country meeting all the people in the industry everywhere. With wide open arms of welcome, with cordiality that proceeds only from the warmest of hearts, I have gained a new inspiration from them, a new appreciation of them.

I appreciate more than I can say the honor you have bestowed upon me. It has been a year to me of receiving. I have received from everybody, everywhere, and I want to express to you my very great appreciation. I will remember the experience. I will cherish it always. (Applause). I think, I think, I think it's a feeling of affection I have for you.

MR. W. W. FREEMAN: Mr. President, may I have the platform for a moment?

My excuse for asking the courtesy of the platform of Mr. Arkwright for a moment is because I am acting under instructions from the management of the Association which at this time, however, is acting without the knowledge, much less the approval, of the President. I am sure we have all been profoundly impressed during this convention with the untiring zeal and the versatility of our President, Mr. Arkwright, and the Executive Committee desires to do something this year, to present a diploma which no Past-President has ever had the privilege of receiving.

I am asked by the members of the Executive Committee and given the honor, to present to Mr. Arkwright this engraved diploma, which with your permission I will read:

"National Electric Light Association, Organized 1885, *to advance the art and science of the production, distribution and use of electrical energy for light, heat and power, for public service, hereby attests and expresses its appreciation to Preston S. Arkwright, President of the Georgia Power Company, Atlanta, Georgia, who faithfully and successfully served the electric light and power industry through this Association as its Forty-second President, July* 1, 1928—*June* 30, 1929."

The diploma is signed by the Managing Director and the Secretary of the Association, and also by a representative of the Public Policy Committee.

It gives me very great pleasure, under instructions from the members of the Executive Committee, to present in your presence this very well merited diploma to your retiring President, Mr. Arkwright. (Applause).

[The audience arose and applauded.]

PRESIDENT ARKWRIGHT: Well, I have graduated. I think I would like to take a post graduate course.

Before leaving, please let me say that I do not think I have done the Association any harm, and if I get a diploma it probably means you think maybe I might have done it a little good. If I have, then being President of the National Electric Light Association is a pretty easy job. It ought to be. I don't think I have ever experienced anywhere the consciousness that came to me from association with this industry, that each seemed to be willing to give of his best in order that all might benefit. That quality and that attitude of mind exist to a most emphatic degree in the industry. Our administration has had the united support of all the industry, in addition to which I beg to repeat that you provided before I entered the office the most excellent administrative headquarters' staff. Your Managing Director is outstanding in intelligence, in character, in high-mindedness, in purity of conduct, in tactfulness, in sincerity, in initiative, and in devotion to the industry.

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* Presented as a "Talking-Movie."

The Secretary, Mr. Marshall, is untiring in his work. No possible detail escapes him. You can go to sleep and have a convention. You know it will be all right. You can sleep at night soundly without worrying at all. Always you will find things provided for even if you didn't think of them.

So it goes with all the heads of the departments, Mr. Oxley, Mr. Herbert, Mr. Greenwood, Major Bennion, and all the others.

If you will just let me say it, I would also like to acknowledge my personal debt of obligation to Miss M. B. Woods, Secretary to Mr. Marshall. In addition to her very extensive and active duties, she is assigned the duty of training, guiding and directing the President. She not only does that, but she makes his work a pleasure.

Goodby to you. May all prosperity come to you; all clouds of suspicion be blown away from you, and your real sincerity of purpose be manifest and believed in by the people you serve so faithfully. Goodby. (Applause).

The meeting adjourned at 1.05 p.m.

ACCOUNTING NATIONAL SECTION SESSION

ACCOUNTING NATIONAL SECTION SESSION

TUESDAY, JUNE 4, 1929

[The meeting convened at 3:15 p.m. in Westminster Hall, Hotel Chelsea, Atlantic City, N. J., Mr. J. F. Ford, Chairman of the Section, presiding.]

CHAIRMAN FORD: In arranging a program for a session such as this we are having this afternoon, I had hoped to be able to call upon the various chairmen of our Standing Committees to report in person their activities and accomplishments of their committees during the year, but since time is limited and your chairman is supposed to give an accounting of his stewardship, I will endeavor to briefly summarize the activities and accomplishments of the various committees and the Section as a whole.

The Accounting National Section year 1928-29 is gradually drawing to a close. During the year many problems have confronted us and I feel that this Section has not been found wanting and has met the demands made from the many sources.

I feel that the secret of what success the Section has had has been due principally to the chairmen and the personnel of the various standing committees. I do not believe that any of my predecessors have had any more active or enthusiastic committee workers than has been my good fortune to have.

Some idea of the outstanding accomplishments may be gleaned from the following brief summarization of the activities of the various committees.

The first of which is the Classification of Accounts Committee, Mr. H. C. Hasbrouck, Chairman. I am going to ask Mr. Hasbrouck if he will stand up so everybody knows him.

[Mr. Hasbrouck arose. Applause.]

While this committee cannot point definitely to the adoption of the Standard Classification by any State regulatory commission which had not adopted it prior to the current year, however, very definite progress has been made. Two States have gone into the subject to considerable extent, one of the States having held a hearing, and indications are that it will only be a matter of time before the Standard Classification is adopted by the regulatory commissions of these two States.

The committee has been called upon to answer a number of questions throughout the administrative year, many of which have been on interpretation and undoubtedly have been of real service to member companies.

The committee has had two special problems on which they have been working, namely, Accounting for Merchandise and Jobbing activities, and Interconnection Accounting. Progress has been made and completed reports will be published in the near future.

Our next committee is that of the Customers' Records Committee, Mr. Douglas Brown, Chairman. Mr. Brown, will you stand up?

[Mr. Brown arose. Applause.]

This committee, always one of the most active of the Section due principally to the large field in which they have to work, as usual has been extremely busy.

Particular attention has been devoted to three subjects: Machine Appliances in connection with Customers' Records and Accounts; What the Customers' Departments of Some Companies Have Done to Promote Good Will, and Final Bill Procedure.

Several serial reports have been published; two more are in the stage of completion and ready for publication within the next month.

Fixed Capital Committee, of which Mr. J. A. Rockwood of the Pacific Coast is chairman, and he was unfortunately unable to be with us, and I am going to ask the Vice-Chairman, Mr. T. M. Ford, if he will stand up.

[Mr. Ford arose. Applause.]

Here again we have a committee that has been extremely active. Four serial reports are ready for publication and three others will be published in the near future.

The work of the committee for the past year has been largely devoted to the study of practical questions involved in carrying out a system of Fixed Capital Records. These studies have been summarized in a group of serial reports which have been authorized for publication as follows:

Fixed Capital Records for Insurance and Taxation Purposes
The Practical Application of Fixed Capital Records for Fire Insurance
Turbo-Generator Units, Steam
Accounting for Fixed Capital Under Joint Pole Agreement.

Further study of detailed methods of Fixed Capital Accounting with the thought in mind that eventually all classes of property have been suitably covered.

General Records Committee, Mr. K. B. Crumb, Chairman. Mr. Crumb, will you stand up?

[Mr. Crumb arose. Applause.]

This Committee, while comparatively new in the Section, has accomplished wonderful results. Two serial reports have been prepared, namely, "Filing Corporate Documents and Automotive Equipment," "Accounting Practices and Records, Suitable for Smaller Companies." The first was published in May.

A study is also being made to determine the extent to which machine systems and methods for general books and records have been developed. Information as to systems now in use was requested from a number of member companies and a tentative report has been prepared on the statistics thus obtained. This report when published will be entitled "Statistics of Machine Accounting Systems for General Books and Records."

Statistics Committee, of which Mr. Harry A. Snow is Chairman. Mr. Snow was unable to be here today and I am going to ask the Vice-Chairman, Mr. E. J. Fowler, if he will stand up. Evidently he is not here either. However, the work of the Statistics Committee for the fiscal year of 1928-29 has been centered on improving, extending and accelerating the collection of data by the Statistical Department of the N. E. L. A. Headquarters and in supervising the publication of the compiled results.

Upon assuming its duties at the start of the year the Committee found that there were a number of important companies which were not reporting regularly to the Statistical Department. They also found that many of the member companies were very slow in sending in their reports, and that certain items called for by the report forms were not being supplied by the reporting companies, particularly the data requested on the Sale of Energy to Farms.

The Committee at once undertook to improve this situation. Securing the appointment of the chairmen of the several Geographic Statistics Committees, the National Committee forwarded to them lists of delinquent companies, soliciting their cooperation in securing or hurrying up reports from the delinquents. Pressure was also brought to bear through the personal acquaintance of the members of the Committee with officers of the delinquent companies.

During the year, the Statistical Department at Headquarters, with the advice and the assistance of the Statistics Committee, inaugurated the publication of National Statistics for the Industry in the N. E. L. A. BULLETIN, which is issued regularly each month. The Committee plans to continue the monthly publication of Statistics for the Industry, and it has hopes that these statistics will assume rank with other important economic indices such as the regular reports of railroad car loadings, and of unfilled orders of the U. S. Steel Corporation, which form so important a part of the current information on economic conditions.

Budget Committee, of which Mr. B. S. Rodey, Jr., is Chairman. Mr. Rodey, will you kindly stand up?

[Mr. Rodey arose. Applause.]

For a number of years the Budget Committee was a Committee of the Accounting National Section. Several years ago, due to the varied nature of the work, it was decided to make this a National General Committee. It was felt advisable, during the past year, for the Accounting Section to again take over this Committee, and with the approval of the National Executive Committee work was started and while the year was well under way before the Committee was organized, they have nevertheless been very active and studies are being made on the following:

1. a. The functions of budgetary control in modern electric utility management.
   b. Outline of procedure for development of long term forecasts.
2. Study of the National Budget System and suggested plans and its possible application to budgets in electric utilities.
3. Relative purpose and use of budget period in electric utilities.

At this time two serial reports are in process of preparation and it is expected that they will be ready for publication within the next six or eight weeks.

Corporate Finance Committee, of which Mr. Oliver McCormick is Chairman. Mr. McCormick, will you kindly stand up?

[Mr. McCormick arose. Applause.]

For policy reasons and for question of jurisdiction, it was decided that this Committee act as a standby Committee to take up subjects as may be submitted and approved from time to time.

The next Committee is that of Purchasing and Storeroom. Mr. Wilbur G. Young, Chairman. Mr. Young, will you kindly stand up?

[Mr. Young arose. Applause.]

Here again is one of our unusually active Committees. To date, the following serial reports are complete:

A Review of Public Utility Salvage Methods
Receiving and Inspection of Material in the Stores Department.

Considerable work has been done on several other subjects, none of which, however, are ready to be released by the present committee. They have, however, recommended that the subjects be considered and finished by the succeeding committee. These subjects are:

1. A Revision of Existing Classification of Materials and Supplies
2. Unit Piling
3. Storeroom Statistics
4. Allocation of Cartage charges on Stock Material and Supervision of Employees and Equipment Engaged in Such Work.

Another, and not by any means the least active Committee, is that known as the Exhibit Committee, of which Mr. E. S. Brock is Chairman. Mr. Brock, will you stand up?

[Mr. Brock arose. Applause.]

Two years ago it was decided to hold an exhibit in connection with the Accounting Section at the Convention. The idea was advanced just shortly before the Convention which did not permit any too much time for preparation.

The purpose of this exhibit is to display forms used for various accounting functions and to have in attendance members of the various Committees for the purpose of round table discussions and for answering questions of the delegates. The results undoubtedly warranted the time and effort put forth so much so that this Committee was organized again at the beginning of this administrative year with the thought in mind that they would be in a position to collect information and data throughout the entire year. The work which has been accomplished has been most remarkable.

At one of the group meetings of the Section in Chicago, this Committee arranged for an exhibit of mechanical office appliances which was of untold value and of interest to everyone in attendance. The Committee has prepared, as most of you know, an exhibit here at the Convention and no one can afford to leave the Convention without having paid a visit to this exhibit.

They have also arranged through the courtesy of the Atlantic City Electric Co. for a practical demonstration of a machine accounting system. This demonstration will take place at the office of the Atlantic City Electric Co. at Baltic and Kentucky Avenues, on Thursday afternoon, June 6, between the hours of 2 and 5 p.m. Cards of admission will be necessary and can be secured at the Accounting Section Booth at the Convention Hall.

From time to time there has been some criticism that too much time was being devoted to work on Committees and the question asked just what is accomplished. I believe that everyone gets out of his or her work on Committees many times more than they put in it and the benefits that are derived from Committee activities accrue to the companies as well as to the individuals, otherwise member companies would not sanction the time and expense involved, and I am sure that our Section and the committees give to those who take an active part therein a broader vision and an enthusiasm that is essential in the development of ideas.

I want to take this opportunity of publicly thanking the officers, members at large, chairmen and personnel of Committees, as well as the Geographic Division Members, for the loyal and hearty support accorded me during my administration which is nearing its close.

In conclusion permit me to ask what better means has this great industry of ours for developing and improving its accounting systems than through the medium of the Accounting Section where the interchange of ideas is a constant source of improvement which otherwise would probably remain undeveloped.

That is all you will have to hear from the Chairman of the Section. (Applause).

According to the Constitution, Section 6, it is the duty of the Chairman of the Section to appoint at the first session or the beginning of the first session, a Nominating Committee, and the duty of this Nominating Committee is to select the names of 15 members of the Section or Association and report later at the Session just prior to the adjournment. This Committee that I have appointed is as follows:

Mr. C. M. Breitinger; Mr. E. A. Davis, Mr. W. Paxton Little; Mr. W. C. Lang.

Mr. W. B. S. Winants, Chairman.

This Committee will report just prior to the adjournment of this meeting.

We will now hear from one of our speakers on a subject which I am sure will be of interest to everyone in attendance here today and would also be of interest I believe to every delegate attending this Convention. His subject is "The Professional Motive in Public Utility Management." I don't know of anyone who would be better able or more qualified to talk on this subject than our speaker who is Assistant Dean of the Harvard School of Business Administration. He is also co-author of a text book on Problems in Utility Management. It is my pleasure and privilege at this time to present to you Assistant Dean of the Harvard School, Deane Malott. Mr. Malott. (Applause).

THE PROFESSIONAL MOTIVE IN PUBLIC UTILITY MANAGEMENT

By DEANE W. MALOTT

Assistant Dean, Graduate School of Business Administration, Harvard University

I ask you in the next few minutes to back away from the accounting and administrative problems with which your profession must abound—to retreat so far that the figures of your operating statements and balance sheets fade into oblivion—in order that we may take stock of the direction of your progress and examine the far horizons toward which this great electric industry, in common with all American business, is heading.

The newspapers today are filled with criticisms and suspicions, and a certain amount of fear, that the electric light and power companies have become a species of diabolical octopus, which will get out of control and choke the very life of our nation. There are charges of corruption and propaganda, of enormous profits, inflated security prices, and selfish manipulations.

Yet I lay aside my evening paper to switch on the radio, bringing entertainment from distant cities. I note the convenience, the luxury of electric refrigeration, the electric cooker, washer and ironer, which bring to my family the opportunity of a richer life—and all at a price which I must be willing to pay, or I would not have these conveniences. I am not forced to have them, for with the exception of electric lighting, there are substitutes in direct competition for all these services.

From the telephone at my elbow, I can reach any one of millions of individuals, for I am told something like 80 per cent of the entire world's telephones are at my immediate service. I ride through the country late at night and see the twinkling windows of isolated farmhouses where inside are the comforts of electric lights and other domestic appliances, where the families are served by electric motors for pumping water and doing a dozen other tasks which provide the farmer with greater comforts and easier living. There must be something peculiarly dynamic in these utility industries, something of lasting worth which gives prophecy of even greater service in years to come. Somewhere in the industry constructive imagination of a high order has been at work.

Corruption and Business Ethics

I do not say that there has not been corruption, unhealthy propaganda and short-sighted self-interest. Undoubtedly there has been, for I have observed that these elements are an inseparable part of every rapidly growing and prosperous industry. But it seems unlikely that an industry of such size could have arisen with these as the dominating motives. Largely the development of public utilities has been through the corporation, a type of organization which, contrary to popular conception, inevitably tends toward higher ethical standards, with more of a feeling of trusteeship for the public which it serves as well as for the employee and the security-holder. The big corporation stands for stability and permanence rather than for rapid and immediate profits. It is easy for one man, in a little shop around the corner, to engage in sharp practices. It is far different in a corporation where the individual executive is surrounded by associates whose respect and trust are necessary to his existence. For these corporations are no longer controlled by a few men, nor by bankers. The ownership shares are scattered throughout the land, just like autos or electric lights.

In spite of this, considerable uncertainty seems to exist as to the motives of this industry. A part of the uncertainty is the result of a mistaken idea. prevalent both in and outside of the field, that there is essential antagonism between the public on the one hand and the utility operators on the other. A wall has been reared between the two, over which the two sides are making faces at each other. This feeling has tended to aggravate itself in the attempt occasionally made by the utilities to extort a monopoly profit by charging a high unit price for their services. Enlightened economic study, however, has shown that the ideal should be not a high price with resulting high unit profit, which restricts the business, but a low unit profit, which will result in a high aggregate profit. Your business is subject to two definite economic laws. One is the law of diminishing costs; the other of elasticity. The first indicates that unit cost decreases as volume increases. The second indicates that volume increases with a decrease in unit prices. Sound practice, therefore, calls for abandonment of the attempt to collect a monopoly profit, which results in a high unit price on a restricted output, because your aggregate profit will be greater if your prices are cut to the limit. You may have seen instances within your own experience of this sort—where price reductions have led to increased consumption and increased profits —but the courage to follow this policy has been all too rare. The Hartford Electric Light Company has recognized these facts with notable success. And, after all, there is nothing in the world more obstinate than a fact.

Barrier Wall Disappears

With these economic concepts clearly understood, the barrier wall between utilities and the public largely disappears, and what is good for one is also good for the other. If the utilities' profits result from decreasing price, it is inevitable that the public, as well, receives a profit through the revision.

Europeans tell us that Americans are materialistic, money-mad, ruthless. Hence we have developed sordid tendencies toward the aggregation of wealth which have precluded any finer sensitiveness, and our foreign critics say as a result we have developed no great artists. But are the great business leaders so far removed from the great artists? The artist is one who visualizes the unseen, then through his ability turns vision into reality—on canvas, the printed page, in marble or in music. Great business men likewise bring dreams to reality. James J. Hill as a boy, sitting on a packing case on the muddy banks of the Missouri River, dreamed of a great Northwest, and he made his dream come true. Theodore N. Vail dreamed of a universal telephone service, and the dream which he projected is reaching fulfillment. Are not these the qualities of the artist—to see things which no one has ever seen before, and then with rare force and vitality to convert the vision into reality? Undoubtedly these business leaders—and you have them within your own industry—have the same powers as the artist, though they apply them to a more obstinate material.

Evolution Is Supreme Law

But you say these business leaders have now "arrived"; they have succeeded. Why worry about them at all, for life can hold for them no more. No, that cannot be, for evolution is our supreme law. We live in a dynamic, not a static, world; there must be continual change. A professional motive must be found, is being found, I think, to carry these leaders onward. No victorious army ever went into camp, with never another campaign to fight, that it did not at once begin to disintegrate. Under these conditions leadership is impossible.

American business today is at the crossroads. We have mastered the technique of it, developed mass production and mass distribution beyond the point where they have ever been developed in the history of mankind. The development of business with a material aim—the aim of mere size and for a mere profit—cannot go much further. And when the aim of business becomes merely to hold on to what we have, the end is in sight. In the early stages of individual leadership, there comes the desire for individual wealth. It is easily satisfied, and a surfeit of money does not bring satisfaction. In "Dodsworth," Sinclair Lewis' latest book, this is portrayed forcibly—almost tragically. Then comes the desire to build up a big business, to dominate through sheer size, and still there is no lasting satisfaction. There must come forth, not a materialistic aim, for that has been attained, but a new, an ideal aim to serve as the objective of progress.

Already we are beginning here and there to see some signs of it. Let me quote from the annual report for 1927 of the American Telephone & Telegraph Co., a company which has certainly reached nearly the zenith of materialistic progress and which dominates the field in its own industry:

"The American Telephone & Telegraph Co. accepts its responsibility for a nation-wide service as a public trust. Its duty is to provide the American public with adequate, dependable and satisfactory telephone service at a reasonable cost.

"Earnings must, of course, be sufficient to permit the best possible telephone service at all times and to provide a reasonable payment to stockholders with an adequate margin to insure financial safety. Earnings in excess of these requirements will either be spent for the enlargement and improvement of the service furnished, or the rates charged for the service reduced. This is fundamental in the policy of the management."

Ideals of Business

Certainly this is the beginning of a publicly announced ideal aim, which will continue the telephone industry's development and prevent a "victorious army" from going into camp.

With this sort of attitude there will develop in this country a body of business men held together by a professional *esprit de corps*. This professional motive is not new—it has dominated many of the older professions for centuries. In the early ages we find it fiercely alive in the religious leaders—Francis of Assisi, Loyola, St. Dominic. There was a considerable measure of it in the early military leaders, such as Charlemagne and Frederick the Great. The old-time conquerors were nearly all constructive statesmen. It is new only in application to business which has developed from a means of livelihood to stand for service to the community.

Among men who have vigorous, adventurous lives we have always found a strong tradition, an idealism, which has carried them to their objectives with irresistible force. The men who have followed the sea have been held together by strength of tradition, by an idealism which makes the captain the acknowledged leader. He tolds his place by respect rather than force. The great men who followed the sea built up the tradition, which in turn served to bolster up the weaker men—a phenomenon no less true in the business world.

In the novels of Joseph Conrad we see the domination of the captain's honor—more important to him by far than his life. In the story called "Typhoon" we see the traditional professional motive, which never presents alternatives, but drives straight for its objective.

Captain MacWhirr, in appearance an insignificant little runt, is on the deck with Jukes, his mate, in a storm at night which shakes the crazy old steamer from stem to stern. As Conrad tells it, "While Jukes was exchanging explanatory yells with his Captain, a sudden lowering of the darkness came upon the night, falling before their vision like something palpable. It was as if the masked lights of the world had been turned down. Jukes was uncritically glad to have his Captain at hand. It relieved him, as though that man had, by simply coming on deck, taken most of the gale's weight upon his shoulders. Such is the prestige, the privilege and the burden of command.

"Captain MacWhirr could expect no comfort of that sort from anyone on earth—such is the loneliness of command."

Later on, and the ship "was being looted with a senseless, destructive fury; trysails torn out from the extra gaskets, double-lashed awnings blown away, bridge swept clean, weather-cloths burst, rails twisted, light-screens smashed—and two of the boats had gone already. They had gone unheard and unseen, melting, as it were, in the shock and smother of the wave. It was only later, when, upon the white flash of another high sea hurling itself amidships, Jukes had a rapid vision of two pairs of davits leaping black and empty out of the solid blackness, with one overhauled fall flying and an iron-bound block thrashing in the wind, that he became aware of what had happened within about three yards of his back.

"He poked his head forward, groping for the ear of his commander. His lips touched it—big, fleshy, very wet. He cried in an agitated tone: 'The boats are going now, sir.'

"And again he heard that voice, distinct and faint, forced and ringing feebly, but with a penetrating effect of quietness in the enormous discord of noises, as if sent out from some remote spot of peace beyond the black wastes of the gale; again he heard a man's voice—the frail and indomitable sound that can be made to carry an infinity of thought, resolution and purpose that shall be pronouncing confident words on the last day, when heavens fall and justice is done—and it was crying to him as if from very, very far: 'All right'."

Behind those two words was the leader of men, impregnable in his duty. Apart from the ego-centric fears which break the weaker men, MacWhirr sees his duty, so clearly bound up in the tradition of the sea—and no danger of the physical universe can daunt him.

The Sporting Instinct

But, you say, that is not real, that is only a blind tradition, the sporting instinct. It may be a blind faith, a creed, but there are parallels. The doctor with his professional ideals, the business man, urged far beyond the point of perishable financial success, keeps on. Mr. Ford started as a tinker. He made a car, which became successful, dominated the market, and he became tremendously wealthy. Did he stop? No, because his ideal was unattainable, infinite. He visioned a cheap and a respectable car within the reach of everyone. That dominating motive drives him on.

Men everywhere, who are in positions of leadership, have come to make their ideal greater than themselves. It is a question with them of what is right, what will contribute most to the permanent welfare of the community. There are exceptions, of course, but if you look at the truly great leaders you will find their goal has absorbed even their interest in themselves. Thomas Edison, another whom you honor at this convention, long ago forgot himself in the pioneering efforts which absorbed his life. With perhaps unattainable ideals of what may be done, Mr. Edison keeps on.

Great problems confront these leaders and press for solution on every hand. An individual may want to contribute the maximum service, to do what is right, but the decision calls for rare judgment. Owen D. Young, in discussing the Golden Rule in business, says: "When you discuss what is right in business, the difficulty lies not in determining what is right in principle. It is rather in the application of the principles to the vast, complex problems of our modern business. If you ask me with reference to business what is right in principle, I answer that the Golden Rule supplies all that a man of business needs. Yet if you ask me to apply the Golden Rule to bank rates I find it amazingly difficult to do. It is like telling me to apply the multiplication table to the design and manufacture of a steam turbine. I know that principles of mathematics underlie the building of that great machine, but it is a highly difficult problem to step from the multiplication table to the steam turbine.

"What is right in business requires, in highly complicated situations, that the Golden Rule be applied by men of great understanding and knowledge, as well as conscience."

And along with the trusteeship for business itself, our leaders are faced with a great social responsibility. In the midst of materialistic surroundings such as the world has never known, clear-sighted vision and tremendous effort are required, if we are to avoid becoming so highly geared in our physical activities that we lose our sense of poise, our sense of spiritual values. Business leadership must very nearly assume responsibility for our civilization itself if our upward evolution is to continue. Loss of these values, of a necessary perspective, has caused civilizations in the past to disappear. Who will assume the responsibilities of leadership, so greatly needed to maintain the balance? When we look to our ministers, our standard bearers through the centuries, we find them top-heavy with dogma, the issues often obscured with a resulting loss of faith on the part of men and women everywhere. The lawyer, formerly the leading citizen, has devoted his abilities so largely to business interests that he is often no longer the leader of affairs—a position which he occupied back in the days of the village squire. The doctor is involved with the great problems of physical ills; the teacher is too often a lonely man, in an air-tight compartment, who fails to get a universal picture of the world's problems.

Responsibility of Business Men

Who is left? Only a large group of business men, run-of-the-mine and unimaginative, with here and there a great leader. So often the business man has not been urged by professional motives. Self-interest has been his only aim; and he leads his life, busy as a toad under a harrow, agile, but unwitting and ineffective.

Not all men, indeed, are fitted for this new leadership. Some never get into the ephemeral realm of values, which cannot be measured any more than one can define a beautiful sunset, or a human emotion. One man would drive the horses of the sun. Another is happy driving a push-cart. I have heard of a Harvard graduate who tried many occupations without success, and who finally found happiness as a street car conductor. Some think they have found their ideal, when they are merely chasing butterflies.

The very intangibleness of leadership and the professional motives which dominate it keep many from entering its realm. To him who does, however, that same intangibleness gives a thrust to his activity, which drives over mere tangible obstructions; for the professional motive is dominated by an almost mystical faith, where the end of the road is hidden; yet progress is the compass by which the journey is known and charted.

The Professional Motive

The professional motive is something bigger than the individual who possesses it, something outside of him, which takes possession of him and absorbs him in its inspiration. He acts freely, not under compulsion as a slave or a man with a vicious habit. He willingly and gladly stakes his property and his comfort. It caused a brilliant medical man to spend his life among the Kentucky mountaineers in comparative poverty; it caused a business man to give up a splendid position to become a college administrator; it caused a man like Munsey at the end of his life to give his millions to art; and it has caused many a man so to devote himself to his business, so to apply his energies, as to fulfill his dream of a business of maximum service to the community. The sporting element is always present. The professional motive does not calculate, does not weigh chances and risks like a bookmaker at a race or a cockfight. The professional man plants his feet upon a law of the universe, a great ideal, and defies chance, accident and fate.

Charles W. Eliot, one of America's keenest observers of human nature, once wrote: "The gypsy in Asia Minor makes iron nails one at a time with hammer on an anvil, much as his ancestors did before him for hundreds of years. I have seen him doing it; but I also observed that his small children were stark naked and that his larger ones had only one garment. . . . In industry and commerce all things are become new."

The one tradition, therefore, which we should hold inviolable, is the tradition of constant change. It will inevitably lead in the great industry which you represent, to the adoption of a professional motive on the part of your leaders—a motive which will still further develop your service and aid in raising the level of our nation. (Applause).

CHAIRMAN FORD: I have thought many times in the past year that we have had every reason for having a most successful Accounting Section year, with the enthusiasm and hard work of our chairmen and members of the committees, and the loyal support of my predecessors. In addition to that we have had as President of our Association this year a man who has always been a very staunch rooter and a loyal supporter of the Accountant. He has in his talks throughout the country stimulated interest in our Accounting Section activities. I refer to President Arkwright. He is here with us today, and I am sure we will all feel honored in having a few words from President Arkwright at this time. (Applause).

PRESIDENT ARKWRIGHT: Ladies and Gentlemen: I am very much pleased to see such a large meeting of the Accounting Section. It verifies what we believed to be true: that if an opportunity were given people to attend the sectional meetings they would come. If they have been smaller in the past it has not been because of a lack of interest in the subject, but because of a lack of opportunity to come.

I think we are going to have, and we are having, a very wonderful convention. I have had so many of my friends meet me on the boardwalk and say, "Arkwright, you certainly are getting the breaks." I guess they think that the President likes to have a good convention. Certainly, he does. So they say, "I think you are getting a wonderful lot of breaks."

"Breaks—what are you talking about?" I say.

"Well, the Hall down yonder."

"Well, what else?"

"The Fiftieth Anniversary of the 'Lamp.'"

"What else?"

"Well, the fine weather you are having."

You don't call those accidents, do you?

Why, they have been building that Hall down here for three or four years, and we got it ready just in time for this convention as the first one. You don't call that an accident. That was designed, and if you don't believe it was designed, how do you account for its being located on Georgia Avenue? (Laughter and applause).

And then about the light. You know the Lord knew that I was going to be President of this Association in 1929. If He knew anything—and He knows everything—He knew that (laughter), and He had Edison invent the lamp in 1879 so we would have a Golden Jubilee when I got to be President. (Laughter.) No accident about that. That was planned, predestined. The Lord takes care of His own. (Laughter).

They say, "Well, about the weather."

I say, "That is not an accident, either. If it doesn't rain, if it holds like this the balance of the week it will be the first week in the year 1929 that it didn't rain all week long." (Laughter.) I know the rain falls on the just and the unjust alike, but I tell you, the bright, clear sunshine for a whole solid week shines only on the just. (Laughter.) So it is sort of cherished up at the end of the year to make up for the troubles we imagine we have, to sort of take out the worries and the wrinkles and dissolve the cobwebs. To let us feel that there is hope and there is reward in good work no matter what people may happen to say about us.

Records Are Essential

I saw it stated by some accounting firm that there couldn't be a decent, successful business executive that didn't have an understanding of accounts. I think that is so. He can't control one of these businesses. They have grown too big. You can't know them all. You can't keep all of the revenues in your own pocket and count up what you have got left at the end of the day and tell how the business is going. It can't be done that way. They are too big. You have got to keep records. You have got to know what the expenditures are. You have got to know what the history of the business is, if you are going to forecast what you have got to have in order to meet the demands on you to keep your business growing.

"I Can't Understand Figures"

I had a rate case once. I pulled a bone in it. It went to the Supreme Court of the United States. It was decided at the same time as the Bluefields Water Works, at the same time as the Southwest Bell case. Justice Brandeis rendered the decision, it is true, but if you can distinguish it between these other cases I will give you this badge, as much as I prize it. It is indistinguishable, directly contrary to them. I want to tell you why we lost it. We had a fine lawyer, a big-brained fellow, forceful, sound fundamentally, a fine speaker and advocate with deep understanding.

He argued that case, and I went to him and tried to explain it to him, and had a lot of figures that somebody had explained to me, and he said, "Oh, I can't understand figures, I can't understand figures."

I said, "If you can't understand figures you can't understand rates. If you can't understand accounts, you can't conduct business. It can't be done."

I talk so much about this business, myself, the wonderful steam stations, beautiful water power plants and fine public relations, interesting the public. I want to render them a useful service, but do you know we are not in business to build magnificent water power plants or fine steam stations. That is a part of our business, yes, a part of it. That isn't the object of this business, to have stations we can brag about. We are not in business to lay out fine transmission lines. That isn't the motive that got us into this affair.

Why, I have seen treasury departments who think the purpose of the business is not to take any risks, so they never will have an uncollected account. (Laughter). That is very nice, but that isn't what we are in business for, to keep from losing money, I mean a little money sometimes. Of course, we can't lose it on the average, but that isn't the primary purpose of this business. We are not in business to be loved by the public, as much as we need their help and support. We want to render a useful service. We want to give value received and brimming over for what we get. It is a great delight and pleasure and a function of our business, a stimulant to it, but it isn't our motive. We are in business to get net earnings (applause) and we have got to get net earnings in order to render the service. We have got to have net earnings in order to raise the new capital to make the necessary extensions, to give the additional service necessary to the growth of the territory. We have got to do it. We have got to have net earnings in order to build nice-looking power plants, modern, efficient and economical. We have got to have net earnings to get the capital to build the interconnected transmission systems that take our service everywhere, the little town, the big farm and crossroad settlements. It is as much in the public interest that we should have adequate net earnings as it is in our own.

We can't get net earnings in a slipshod-run concern. We can't get net earnings with our moneys wasted. We can't get net earnings ignorant of what things cost us. We can't get net earnings or fulfill our commercial possibilities without knowing what the territory will yield to us or whether the business can be run at a profit, and we can't run the business and get net earnings or build plants or render good service until we have accountants and accounting systems. So I say accountants are fundamental to the business.

I don't think that we fulfill our duty if we run a business wastefully, we run it shiftlessly, we run it without proper control, we let the people waste our money here and there and spend it without proper records—why, that business would die and fulfill no longer any useful function. Of course, anybody that is interested in the success of this business and interested in making the business able to meet the need for its service, is bound to be interested in accountancy so there can be no possible question about it.

You know, we are growing rather large in our various communities. Most of us are the largest institutions in our respective territories, outside of the very largest city, perhaps. There is a danger in it to some of us if our companies are so big that we think we can do what we want to. I say that no company can ever grow big enough to impose on anybody. I don't care how much apparent power it may seem to have, that mere size may give in other businesses, it doesn't and cannot in this business give power to impose. It is regulated. It is run by permission, by public sentiment, because our very life is dependent upon the continued confidence of the public, so that we may never impose, we may never grow large enough to abuse the power of size, and therefore there isn't the same danger in our size that there may be in the others, but there is to the individual who thinks he has a powerful company behind him so that he can trespass and run over somebody else.

I didn't come here to make a speech. I came merely to bring the badge of the office of President of the Association to the Accountants' Meeting, to let you know the regard in which the whole industry holds its accountants, and to convey to you the appreciation we have for the work you have done in past years, and for the work particularly that you have done this year. (Applause).

CHAIRMAN FORD: The Convention or the Program Committee that has to make the plans and arrange for a meeting such as we have here today are so often confronted with many disappointments. That has been true of our committee. I believe that if we had been able to secure all of the speakers we endeavored to secure we would have an audience or an attendance that would more than have filled the auditorium in the Convention Hall, where the exhibits are now. These disappointments happen up to the last minute, so this is true of our next speaker. While he is here at the convention, he is, unfortunately, not in the best of health today. However, our disappointment sometimes brings us good fortune. I think that is true today. Fortunately, our next speaker had prepared his talk, and he has sent in his place a substitute, one of his very able assistants, and one of our most loyal workers and a past chairman of this Section. I am now going to call on Mr. W. B. S. Winans to present the next talk. Mr. Winans. (Applause).

MR. W. B. S. WINANS: When I left my home to come to this Convention I congratulated myself that I would have no official duties. Instead, I find myself trying to act as a substitute for Babe Ruth, Mr. W. A. Jones.

In talking to Mr. Jones this morning he asked me to convey to you his regrets at not being able to be present, and to tell you that he still retained his interest in this Accounting Section's work. You will remember that he was at one time the Chairman of this Section. He also asked me to tell you that the only thing that prevented him from getting out of bed and attending this meeting was the stubbornness of two doctors and one wife. (Laughter).

Fortunately, Babe Ruth left his bat with me, the speech which had already been prepared. I will read it to you.

THE ACCOUNT AND MODERN BUSINESS

BY W. ALTON JONES,

First Vice-President, Cities Service Company, New York

There was recently published in the city of Madrid an accountant's report of the cost of the discovery of America. This accounting, which was taken from documents discovered in Genoa, disclosed that Columbus spent a total sum of $6,000 in his first voyage across the Atlantic. A prominent American newspaper in commenting on this accountant's report concludes that the return on the investment has been "pretty fair," and I think that most of us here would be inclined to agree with this conclusion.

It is interesting to note, however, that a resident of Philadelphia has raised a question as to the wisdom of the venture and the amount of profit, if any, which has resulted. This Philadelphian points out that, had the $6,000 been placed out at interest in the year 1492 and the interest compounded at fair rates, the present value of the $6,000 would be $500,000,000,000. He further observes that, from what he believes to be reliable records, he finds the estimated wealth of the Americas is something like $400,000,000,000. We might, therefore, conclude that from a dollars and cents viewpoint, Columbus' voyage was not a success, and the resultant accretion of capital has not adequately compensated for the great hazards of the undertaking.

I would not suggest that this Accounting Section undertake now to settle any controversy with respect to the wisdom of Columbus' voyage to America, for I am sure the controversy would be long drawn out, and, even if it were finally decided beyond a reasonable doubt, I would question the value of such determination to the light and power industry. The fact is that 437 years ago Columbus did prevail upon Queen Isabella to finance this expedition, and according to the records he spent $6,000 in his undertaking. Whether this money was wisely spent or not is "water over the dam."

Accountants Busy 500 Years Ago

It is, of course, of some historical interest to accountants to learn that 500 years ago accountants were employed and careful records kept of business undertakings. If we delve into the pages of history, we find that even before the time of Columbus the accountant had a place of more or less importance in the scheme of things. Almost from the dawn of civilization accountants were used, and, while in the early days their methods were crude, they did exist and served a useful purpose. Long before the time when there was a business institution in the modern sense of the word and, in that period when men engaged in only two lines of endeavor, agriculture and war, there was need for accountants to reckon the number of men and the amount of property so necessary to the propagation of war.

It is a far cry from the duties and functions of the accountant or keeper of records of ancient times to the skilled student of accountants and economics so necessary to the conduct of modern business.

This 20th century in which we live is the high-speed age of history. Each new day sees a new record established in the speed with which we may travel from place to place, the speed with which our mail is carried from one point to another, the speed with which the human voice is transmitted from one country to another, and, above all else, the speed with which a business transaction may be conceived, financed and consummated. Sometimes we look upon these new speed records in the abstract, with little thought of how they will directly affect our business. But sooner or later we must gear ourselves up to these modern speed trends, or we fall behind in the march of progress.

The Speed of Modern Business

Time was when a business man went about his business in a leisurely fashion, weighing and deliberating, considering and debating, calculating and reconsidering as to how his proposed business venture could be brought to fruition without the loss of his original capital outlay. This day in which we live, however, is one of quick decisions, for we often see a business venture conceived, financed and consummated in one-tenth the time which a business man of other days took to weigh such an undertaking. This speed in modern business is not always accompanied by carelessness or increased business hazards for in most industries worthy of the name of a business organization the machinery is "tuned in phase," and with the new tools we have to work with it is possible for business executives to give thoughtful and careful consideration to problems in a shorter period of time than was dreamed of a hundred years ago.

These new tools of modern business are numerous, and each has its respective value. Among these tools might be enumerated modern office machinery, highly trained specialists, carefully trained research departments and certainly as not the least important of all, I would list the modern accounting methods.

I use the word "accounting" here in its broadest sense. A limited definition of the term, such as "keeper of records," has no place in this discussion, for I believe the time has long since passed when the successful business executive can afford to spend much time in a lengthy perusal of the accomplishments of past years. I agree that the accomplishments of the last decade, the last year or the last month are of interest to the executive, but not of primary importance in the conduct of his business.

We in the light and power industry may be interested to know that not so many years ago electrical energy was sold for 15 cents, 20 cents or even 25 cents a kilowatt-hour, and that not so long ago it required 5, 6 or even 10 pounds of coal to generate a kilowatt-hour of electrical energy, but these facts are not of primary importance to a light and power executive. He is vastly more interested in knowing what it will cost him to serve his customers next year and the year after, and at what rates he can hope to meet competition, hold his present customers and attach new business.

A Pertinent Question

If you agree with me that the modern business executive is more interested in the determination of future costs than in the perusal of old records of performance, I would like to invite your attention to the consideration of a question, the answer to which I believe in a large measure rests in your hands and which, in my opinion, is of the greatest importance to light and power executives everywhere. This question is: How can the accountant better serve the light and power industry?

I have said that the answer to this question rests in your hands, which is another way of saying that I am not going to attempt to answer it here, but with your permission I will leave with you some suggestions which may assist in arriving at the answer. These suggestions have to do with the current problems confronting our industry, a better understanding of which is needed both within and without our industry.

An agency of the Federal Government is now conducting a searching investigation of the light and power business. This investigation was prompted by questions raised on the floor of the United States Senate by men who contended, among other things, that the light and power business has reached that stage in its development when it should be controlled or regulated by some agency of the Federal Government; and the Federal Trade Commission has been directed to make such investigation as may be necessary to determine whether or not Federal legislation to that end should be enacted.

Whether Federal regulation of the light and power industry would be good or bad for the public is a broad question of public policy, on which there is a wide difference of opinion; and I have my own decided views, as have most of you, on this subject.

The facts are that this industry is confronted with an examination; and before this examination is finished light and power companies everywhere will be required to answer many questions about their business.

So far as I know, there is no disposition on the part of the light and power companies anywhere to refuse to disclose pertinent facts about their business to bodies duly authorized to examine into the facts. But I am sure there is concern in many places that incomplete facts gathered here and there about certain phases of our business may lead to erroneous conclusions and may have a far-reaching effect on the minds of those men charged with determining whether or not there should be Federal legislation looking to the regulation of our business.

Therefore, in my opinion there is confronting the accountants of this industry the grave responsibility of seeing to it that in the course of this Federal investigation such facts as are required of us be presented in such a manner as not to lead to hasty or improper conclusions on the part of those who will be called upon to consider them, and who may be less familiar with our business than they should be.

It is well to bear in mind here that whatever may become of this present investigation, because of the quasi-public nature of our business, the light and power industry will always be subjected to some form of regulation by municipality or state. Fair regulation without intelligent information is impossible. I realize that through your Committee on Uniform Classification of Accounts much effective work has been done toward standardizing report forms for various state commissions, but the work of this Committee is far from complete. I believe you should consider the reorganization of the committee along broader lines to the end that the member companies of this Association may be able to get better advice from your Committee on this subject.

Accounting Aspects to Interconnection

The interconnection of large power systems throughout the country has now reached the point where it touches hundreds of communities and involves the purchase and sale of electrical energy between various companies. Each year will see more and more of these interconnection agreements in the interest of greater economies and better service to the public.

I believe this work would move forward much more rapidly if the accountants of this industry were more conversant with this problem. Here is a case where the engineer and the accountant should work very closely together and often failure to interconnect one system with another, or an isolated plant with a large power line, is due to improper allocation of costs. I would commend this question for your consideration, as one of very great importance.

Proper Accounting and Competition

There are still some people who hold to the opinion that the public utility business is non-competitive. This was never true of the light and power business, although I regret to say that some light and power men still seem to think so.

Approximately 61 per cent of the electrical energy sold in this country is sold for power purposes. Much of this energy is sold in direct competition with other forms of power, such as steam, Diesel engine, natural gas, etc. Many of the individual power customers of our electric companies are so large they are fully able to finance the cost of a private power plant when they are unable to get better service at lower costs from the light and power companies.

Only the great economies effected by the installation of large and highly efficient generating units have made it possible for our companies to hold some of their most valuable business and with the advent of improved Diesel engines, power companies everywhere are further threatened with the loss of business.

In many instances the determining factor in holding a power customer is the proper determination of his own over all costs of manufacturing power. The accountants of this industry could render a very valuable service, if they would give further attention to the matter of the proper determination of service costs for isolated plants. Some people may hold that this takes the light and power accountant outside of his own sphere, but I feel that any study of this kind that will throw additional light on this important subject is the public utility accountant's job.

Better Cost Records

America is known the world over for mass production and with this mass production in recent years has come lower unit production costs. No other industry has shown greater improvement in production efficiency than has the light and power industry. In fact, the point has been reached in some cases where the production cost of our product is negligible. Much of this improved efficiency has come about through new inventions and new and improved processes and equipment.

It is to be regretted, however, that little or no progress has been made in reducing the cost of distribution. We do not differ from other industries in this respect and, if we carefully analyze the family budget of the average American home, we will find that a large part of the cost of living is made up of distribution costs. All industry is directing its attention to a more careful scrutiny of this problem.

It is of vital importance that the light and power companies give this matter more serious consideration. In order that we may intelligently approach this problem, a more careful analysis of distribution costs is necessary. This problem is decidedly one for our light and power accountants to handle.

There are also large savings to be effected in what we term in this business "customer's expense." which for the most part falls under the direct supervision of the accounting executives of the various companies.

The Accountant and Proper Rate Structures

There was a time when the public utilities had a reputation for charging "all the traffic would bear." It may be that the industry earned that reputation, but few public utility executives are interested in this question today. They are more often interested in the question of how cheaply they can sell their service and still make a reasonable return. The most progressive light and power executive today realizes that our greatest ultimate success depends upon the widest economic use of our service.

In the intensive development of business, the light and power companies in many parts of the country are introducing promotional rates, rates for off-peak load, preferential rates for high load factor business, etc. All of these departures in the development of business require the most careful cost analysis. If our commercial departments are to be properly guided in attaching to our lines business that can be economically served, we must know more about the cost of various classes of service. This again is an accounting job and, while it needs engineering interpretation, you are the men who will have to marshal most of the facts with which to solve the problem.

The Accounting Problem of the Government in Business

In spite of the fact that this country has made the greatest progress of any nation in the world under the rule of private initiative in business, there are still many people to be found in this country who believe that we would have made even greater progress under government ownership. And, what is more to the point, many people throughout the country are openly advocating the political ownership of the light and power business.

Some able men who have studied this problem contend that back of this movement are the leaders of communistic thought, other people hold that many of our Socialists are responsible for this doctrine of the "government in business." But, I am satisfied that there are some people, who listening to these doctrines and being sincerely impressed by them, would immediately desert such doctrines if they had a better understanding of the economics involved in government ownership.

Many successful politicians are gifted orators, and often unhampered by facts, they are able to sway public opinion in favor of unsound doctrines. In the end, however, one who pleads at the bar of public opinion in this country must use facts and not fancies.

I am of the opinion that there is enough factual information available to prove to almost any open-minded American citizen that the Government should keep out of all lines of business, but I am equally certain that far too little real factual information about this subject has been presented to the American public. Too many of the people who oppose government ownership deal in glowing generalities and do not marshal the most effective arguments against it. As I see it, here is another problem which may properly commend itself to your attention.

I have offered here several suggestions for the consideration of the Accounting Section. Some of you may say that much of what I have said has more to do with economics, engineering and management than with accounting. But, to those I would answer with an expression which I shall borrow from that baby of industry in America, Aviation, which has adopted as its slogan "Lift up Your Eyes." for as I see it the accountant who wishes to best serve his industry must do that very thing in order that he may better view the problems which confront us to the end that he may aid in their solution.

CHAIRMAN FORD: Mr. Brock, Chairman of the Exhibit Committee, has asked me to call your attention to these little cards, a schedule of meetings or the times at which the various committees will be on duty, to furnish you with any information or answer your questions. They will be on duty at various times at the Accounting Section booth at the Convention Hall. You can secure these cards at the rear of the hall as you pass out after the meeting is over.

In trying to find out what to say about the speaker in introducing him, I endeavored to find out some things about our next speaker, not knowing at the time that I had already had the pleasure of meeting him. One of the things I found out about him, which must be good, is that he was born the same year I was. I don't know whether that is a handicap to him or not. However, many of you have had the pleasure of hearing our next speaker, you as his unseen audience. He has talked many times over the radio. His subject to day will be "The Trend of the Times." I know of no one more capable of talking to you on this subject than would be the President of the *United States Daily*. It is my privilege and pleasure to present to you Mr. David Lawrence. (Applause).

THE TREND OF THE TIMES

By David Lawrence

President, The United States Daily

I was wondering, as I came into the hall, what I could say to accountants, but there came instantly to me the refreshing thought of the many hours that I have spent in the last several years in studying phases of accounting that relate to the National Government, and I thought perhaps I might impart to you the wholesome respect that I have come to feel for those who are engaged in the accounting business in this country.

You naturally have a feeling of what I might call detachment toward government nowadays, and perhaps you are not as ready to see the good in some of the things that are happening. And perhaps, too, you feel that you are in the middle of a controversy and you are not willing to pass judgment upon the merits thereof. But when the income tax was first imposed it was viewed as a matter of great irritation, and I dare say since that time American business has come to understand that there is an affirmative value in a real system of taxation. And I doubt whether any single force, any single influence in educating the American business man has been as potent as proper accounting, which has been taught involuntarily through the income tax.

You are a group of men interested primarily in the financial side of the industry, and not in its public relations, and as the preceding speaker indicated, you are the ones from whom the facts will be sought when the time comes to pass judgment upon the merits of your policies. I have my own ideas as to the stage through which we are passing now, and perhaps I am an insufferable optimist, but I think that when all is said and done, and all the inquiries have been made, you will yourselves view what has happened as very largely constructive.

Education Requires Time

I go on the theory that it takes time to educate the people who are unfamiliar with the facts, but if the facts are legitimate it doesn't matter how long the time; they are their own reward. So I say to you that while your attitude at the moment may be one of hesitancy with respect to the operations of a Government that inquires minutely into your affairs, this is, nevertheless, a great cooperative influence which we may attribute to government, and the significance of which we cannot possibly escape in this modern age of ours.

We are passing through a stage, an economic stage, which is not easy to understand. We are given to temperamental attitudes, perhaps, because no one year is like the other. The American business man is so inclined to view his own affairs in the light of 90 days, especially if he is dealing with a bank, or in the light of a year, if he is dealing with an annual balance sheet, that he sometimes forgets we are a part of an epoch, part of a decade, part of an era, and that no one year is necessarily illustrative of the particular epoch. And you must take the whole in order to get a fair understanding of what is happening.

We need only to look back ten years to recognize how fleeting are our impressions of the future and how wrong might be our prophesies, and how easily they are unfulfilled.

Ten years ago we were talking in terms of prewar standards. The war had ended and the whole trend of thought was that we must return instantly to the base year, 1913. The economists were talking of everything in relation to 1913. We rarely hear about that now, because we have searched and we are groping for a norm which has no relationship to 1913. And, broadly speaking, we thought at that time that we had reached the peak in our industrial development. The great war machinery, the facilities for expansion, we regarded as merely the episode of the war. We thought it had no relation to our future. Perhaps mass production would have come anyhow. It was accelerated by the war. But we faced a large expansion of industry and we thought that the only way we could make ends meet was to deflate labor. We talked about Europe as if Europe was done for, and as if for generations to come, certainly within our lifetime, we would see chaos over there.

World Has Been Linked Up

We had the idea, too, that peoples would be distant; that this reconciliation might follow after 25 or 30 years, that it certainly was far off. We had no idea that the world would be linked up as quickly as it has since been linked up.

You know we had the opinion that the Allies wouldn't pay their debts, that the Germans would default, and we had one or two experiences which rather corroborated that tendency early in the decade. But ten years have passed and none of these things has happened. Instead of a Germany defaulting we have a Germany paying her debts, annually, punctually and in full. We have the Allies definitely on the dotted line, and many of them have already paid us. We are discussing at the moment a revision of the financial plan whereby reparations is being paid. We are discussing the refinancing of Germany, on the basis of an index of prosperity. And it is only fair to say that Europe has made an unprecedented recovery herself. The stabilization of her currencies, the rearrangement of the whole world of finance, has come about in these ten years. And as for ourselves we haven't deflated labor. We have increased the production of the labor dollar instead. We have gone forward to an expansion unheard of. In fact we have at times over-emphasized this expansion, so much so that we have been drawn occasionally into speculative excesses, as a result of that over-emphasis.

But to keep track of the thread that has gone through these last ten years in order that we might better understand the trend of the times that are coming, we must bear in mind that a war of the proportions which we witnessed brings its own unprecedented convolutions in the post-war period. And yet the United States, in these ten years that have passed, having solved the problem of production, and having made real progress toward distribution, now is confronted with the question of getting markets to absorb our immense surpluses.

Our whole politics is colored with economic conflict. We are concerned now in government with a proper balance between government and the economic growth of the country. You are constantly aware of the regulatory power of the Government; you see always the restrictive, the police power, the indirect coercion, you might call it, whereby Government enforces the statutes, or expresses its views on things that are not necessarily statutes.

But, as I see it, in an atmosphere of government from day to day the big thing of the hour is the cooperative side of government. It is the side which is seeking to give to industry its real impetus. It is the side which is searching for the facts. It is the side which is trying to coordinate industry and encourage greater progress.

The most significant movement of our times is the trade association movement. Say what you will, if you are the literary cynic who talks about the Babbitts, we know that the progress of this country is directly related to the trade organizations and the units that have been built up in business for the exchange of ideas. We know, too, that trade associations have become the greatest influence in the elimination of waste, in bringing about better understanding of industry among competitors within industry. We know, too, that government has played a part in bringing together discordant elements within industry.

Government Cooperation

The time will come, in my judgment, when the Government will be able to serve in a cooperative influence even in your industry, and when I utter the word "government," I mean it in its generic sense, because it is not merely the development of government in the federal idea, along cooperative lines, which is coming in America; it is the development of state government and state institutions too, which we are bound to find growing in that direction, because we are leaning on organizations, we are leaning on central institutions, in order that we may coordinate the interests of the public. That may sound vague to you and it probably is nebulous yet, but it is one of the distinct trends of the time, the necessity almost for cooperation between governmental bodies and industries.

I might say, parenthetically, that there will also grow up a definite and a real relationship which is not nebulous and which is not vague as to the proper responsibility of government and industry. There is in this a mutual obligation. In some infant industries in the early history of our Republic we found the Government extending direct aid. We find even today in such an industry as aviation, the Government extending direct aid.

With the last several years the Government has been a great factor in stimulating the growth of an American Merchant Marine. But there arose the desire, the natural desire, of the individual for the possession of that instrumentality which would assist him in realizing his destiny and today we have a policy established whereby the Government slowly relaxes its hold as a possessor, as a competitor of business and acts in a transition sense in order that the merchant marine may be established through private initiative and private ownership. That transition is an interesting one because involuntarily the Government was forced into the shipping business in the war, and yet public opinion has said that where the private industry can do a job effectively, efficiently, that is the function of the individual; that where the Government can cooperate to stimulate an industry to larger growth by contact with its trade associations, by assisting frequently in coordinating discordant elements in an industry, that can be the function of government.

And so, it is quite natural that in many industries where there is not even a suggestion of the regulatory power, this great cooperative influence proceeds and is making a very remarkable record.

The automobile industry is a good example of that. Government cooperation has assisted that industry materially. The gathering of facts from all parts of the world, the establishment really of a clearing house in Washington for the exchange of information relating to the export trade has made it possible for the motor industry to realize the great export market which it has available today and which indirectly is responsible for the continuance of the mass production machinery in the great motor centers, and which in turn has made possible the low-priced American car with the excellent design, within the reach of a great many more people.

It is that particular function of government, the extension of its aid in stimulating an industry and assisting it in reaching out for its markets, which is a proper function, and about which there can be no debate. It is on the question of the regulatory side of government that we have differences of opinion but there, too, as I said at the outset, I think you will find in the long run that the pressure of time will transform that influence into a cooperative influence.

Problems Largely Economic

The problems with which we are dealing in the central government are so largely economic, they are so largely the result of group action, sectional interest, commodity pressure, that sometimes I wonder how the person outside of Washington can get a fair impression of what is really happening in the center. You see these fragments of governmental action and sometimes you are led to judge of all government by these fragments. The most difficult job that we have today is to make the American people thoroughly conscious of what their Government is. So much happens because they are not only unconscious but they are indifferent. Time and again, men are appointed to public office who ought not to be appointed and the people who are affected thereby discover it months and years afterward. And it is not a solution for people to turn up their noses and say the whole thing is wrong, and, "I will have nothing to do with it," just because some of it is irritating and some of it is distasteful.

The attitude of mind of people outside of Washington toward Washington is the only thing that will purify the air and rid us of the inefficiency which we have and bring a true economic mind into government where it belongs, because government is no longer merely a political institution. There isn't a single question today which is strictly political with the possible exception of reapportionment, and even that might be drawn into an economic question, if you really took the time to find out its relationship.

If you are examining a tariff, you are touching an economic question. If it is the question of revision of the tax laws, it is the distribution of the tax burden—primarily an economic problem. If you are touching on railway consolidation, it is an economic question. If you are dealing with these surpluses that have grown up in agriculture, certainly there is nothing more complex than agricultural economics. Even the great subject of prohibition will have as the debate proceeds its economic aspect emphasized in relation to production and it will be decided in the last analysis to a large extent on whether it is beneficial to the large majority or whether it is merely an irritant for a small number.

So as you look over all the questions with which we are dealing in the Federal Government, or as you take the questions with which the States are dealing, you come face to face with that fact: that this is an era of economic emphasis and that government is feeling the pressure of the whole economic age in which we are living.

It means therefore all the more that people who are either in the legislative branch or in the executive branch should know their economics. I think it is partly because people are not interested in what we might call "dry reading" or partly because they don't understand how sensational some of this "dry" material is that we have only a relatively small group of persons interested today in government. That group must enlarge.

Finance Becomes Interesting

I remember when I first was engaged in writing and I had the newspaperman's attitude of aloofness from everything that concerned the industrial side, I had the feeling that all business was something apart, and so far as the Treasury Department was concerned in Washington, that was the department I was inclined least to visit, because it had to do with this complicated question of finance.

Then I went into business for myself and I found I spent all my time with the accountant, with the treasurer, and today it has become to me the most fascinating side of the businesses in which I am engaged, because I have come to realize that the accounting side really gives you a picture of the entire structure and guides you frequently when you are on the wrong track.

So, often things which seem uninteresting become interesting. Often, this question of information from the Government, this matter of the Government's relation to industry seems uninteresting, and we don't take the time to find out how truly sensational it is. Sometimes long after a fact is known we recognize its significance.

I am not a pessimist, and I am not discouraged because a relatively small number of people are vitally interested. I think the number is growing and rather rapidly, too. It will grow in proportion to the way in which this relation between government and business grows, and to the extent that people realize that the regulatory power can become license and that the cooperative influence can really mean progress. Those two separate parts of government, the regulatory power and the cooperative end of it will have to be thoroughly understood in order that government may function at its highest point. And in the period in which we are now living, the period that is coming, the Government's power to influence the situation will not diminish, in my judgment.

Regulation of Credit

No subject for example is more vital to us today than the regulation of credit. Since February we have observed carefully the influence of a governmental body on the credit situation acting, some think, with arbitrary power, others think constructively—certainly, the responsibility is imposed by law upon that body to act prudently and cautiously. And in the several months that have just passed we have witnessed perhaps a transition in this whole seven-year cycle which began in 1921. It may be that we have discovered the proper use of credit in America at this time. It may be that we have restrained the excesses. Time alone will tell. But certainly the responsibility was imposed by law upon a body to see to it that the credit of this great banking system of ours should not be used for wrong purpose. So I say to you, in conclusion, that the Government which just now happens to have its hand in an industry, in a sense, perhaps, regarded by you as an unwarranted intrusion, may in the end prove to you that the exposure of facts is the most enlightening self-help you could have administered.

Thank you. (Applause).

MR. C. M. BREITINGER (The Philadelphia Electric Co., Philadelphia, Pa.): Mr. Chairman, I move a vote of thanks and appreciation of the National Accounting Section be extended the speakers who have given their time and effort to address us this afternoon.

[The motion was seconded.]

CHAIRMAN FORD: It has been moved and seconded that a vote of thanks be extended to the speakers who have given of their time to address us this afternoon. I am going to ask those who will give their consent to kindly rise.

[Carried by a unanimous rising vote.]

CHAIRMAN FORD: The next order of business on our program is the report of the Nominating Committee. I will now call on the Chairman, Mr. W. B. S. Winans.

Nominations

MR. W. B. S. WINANS: The Nominating Committee has had several sessions endeavoring to determine the list of names to be presented. It has waited from time to time for political approaches and felt that here was an opportunity for remuneration for the Accounting Section, but has had no overtures of any kind. Its report, therefore, is rendered to you, as I believe all past reports have been, solely from the viewpoint of availability and desirability. The list is as follows:

W. R. Emerson, Oklahoma Gas & Electric Co., Oklahoma City, Okla.
Franklyn Heydecke, Public Service Electric & Gas Co., Newark, N. J.
J. H. Lobban, The Detroit Edison Co., Detroit, Mich.
J. E. Loiseau, Public Service Co. of Colorado. Denver, Colo.
B. F. Brahaney, H. M. Byllesby & Co., Chicago, Ill.
Oliver E. McCormick, Middle West Utilities Co., Chicago, Ill.
H. C. Hasbrouck, Associated Gas & Electric Co., New York.
E. S. Brock, Public Service Electric & Gas Co., Newark, N. J.
G. U. Stewart, The Philadelphia Electric Co., Philadelphia, Pa.
J. A. Rockwood, Portland Electric Power Co., Portland, Ore.
B. F. McGuire, Commonwealth Edison Co., Chicago, Ill.
C. E. McBride, Electric Bond & Share Co., New York.
Frank C. Gordon, New York & Queens Electric Light & Power Co., Long Island City, N. Y.
Thomas M. Ford, Philadelphia Electric Co., Philadelphia, Pa.
R. O. Launey, Brooklyn Edison Co., Brooklyn, N. Y.

CHAIRMAN FORD: You have heard the report of your Nominating Committee, what is your pleasure?

MR. DOUGLAS BROWN (New York & Queens Electric Light & Power Co., New York): I move, Mr. Chairman, that the report be accepted and the nominations closed.

[The motion was seconded, was put to a vote and carried.]

CHAIRMAN FORD: I hardly need to inform you that the next order of business is adjournment. All those in favor?

[Upon motion regularly made and seconded, it was voted to adjourn, at 5.10 p.m.]

COMMERCIAL NATIONAL SECTION SESSION

COMMERCIAL NATIONAL SECTION SESSION

WEDNESDAY, JUNE 5, 1929

[The meeting convened at 3 p.m., Mr. Marshall E. Sampsell, Chairman of the Section, presiding.]

CHAIRMAN SAMPSELL: The meeting will please come to order.

As provided by our Constitution, our Executive Committee has named as the Nominating Committee the following gentlemen: Mr. E. W. Lloyd, Chairman; Mr. George E. Miller, Mr. M. E. Skinner, Mr. M. C. Huse and Mr. D. Smith. We will have the report of this Committee at the conclusion of our meeting.

At this morning's session the report for the Commercial Section was read, and, therefore, your Chairman in his desire to give each of the Vice-Chairmen full opportunity (at least as full as we can under the circumstances) to present the activities under the Committees in his bureau, will say nothing except to emphasize again the appreciation every one of us in this section has for the work of the other.

We will now hear the report of the Lighting Bureau by Mr. T. O. Kennedy, Vice-Chairman, Ohio Public Service Co., Cleveland, Ohio.

REPORT OF LIGHTING BUREAU

BY T. O. KENNEDY, *Vice-Chairman*

(For Bureau Personnel, See Appendix 4)

Fifteen minutes is just the right amount of time for the report which I am going to make of the Lighting Bureau, because the Lighting Bureau this year has been fortunate in having that kind of personnel constituting its Committees of which it can be truthfully said, "By their works ye shall know them." If, by any chance, there are any in the audience who are not fully conversant with the activities of the Lighting Bureau during the past administrative year, then I will say that the time at my disposal is entirely inadequate for proper halo polishing on my part. Therefore, I shall not attempt it.

I am going to talk now about some of the things that the Lighting Bureau cannot claim credit for as much as it would like to so claim credit. I refer to the permanent lighting exhibition maintained by the lamp manufacturing companies at Cleveland, Harrison, Chicago, and the new and elaborate exhibit at the Grand Central Palace in New York. I refer to the Lighting Festival here at Atlantic City, which is ushering in the celebration of Light's Golden Jubilee, marking the fiftieth anniversary of the development to perfection of the incandescent lamp, by Thomas A. Edison.

Industry Has a Job to Do

The Lighting Bureau believes that the electric light and power industry is away behind in its work when it comes to awakening the public consciousness to the benefits of proper illumination. The Lighting Bureau has hoped and has tried to inspire the member companies of the N. E. L. A. to do in a few years what it has failed to do in the past fifty.

A study of the development of the electric light and power industry in the United States shows a remarkable growth of the use of central station power in manufacturing establishments. Not only have other forms of power been very largely replaced, but new and additional uses of electricity for power and heating purposes have been devised and adopted.

Electric lighting has almost entirely supplanted other forms of illumination in cities, towns and hamlets, and even in rural districts.

To make electric service so universally available, the electric utility companies have invested fourteen billions of dollars in generation, transmission and distribution facilities and, in so doing, have made a material contribution to the prosperity of the nation and to the improvement of living conditions.

The industry has a greater obligation, however, than merely making electric service available. It must promote, encourage and make possible the use of that service by each customer to the maximum extent that the customer can use it for his benefit.

It follows, therefore, that in addition to the highest type of managerial and engineering ability for construction and operation, the industry must have outstanding commercial talent with vision and aggressiveness.

We will have to confess that we have done a poor job of selling our service during the forty-seven years that our industry has been in existence. We can take small credit for the extensive use of electric power in manufacturing. The power users themselves, quick to take advantage of every possible opportunity to increase efficiency, have applied electricity in their production processes. We did not sell our service to them—they bought it.

These industrial users, however, constitute only about 5 per cent of our total customers. The other 95 per cent, more than twenty-two million customers, are yet making but meager use of our service. Here is our opportunity and no less our obligation.

Without question, the most valuable service we have to offer these customers and the service they most lack and need is proper illumination.

The Lighting Bureau has attempted to awaken the interest of the N. E. L. A. member companies in the development of additional lighting business, and has tried to formulate specific plans that could be put into effect by member companies desiring to accomplish this purpose.

Home Lighting Committee

The Home Lighting Committee under its Chairman, Mr. W. T. Blackwell, has done excellent work. One serial report was prepared outlining the organization and duties of a home lighting service department, and it also contains suggestions covering the selection of the personnel of a home lighting service department.

The second serial report of this Committee embodies a critical analysis of various refixturing campaigns carried on by utilities throughout the country, and recommends a suggested form of refixturing activity for the guidance of member companies contemplating such work.

The Committee also arranged for the preparation of literature for distribution to prospects by home lighting specialists connected with member companies. To meet this need a special edition of "Beauty at Home" was prepared by the Bowser Service Corp. This literature is available to any company desiring to use it.

Commercial and Industrial Lighting Committee

The Commercial and Industrial Lighting Committee, under the chairmanship of Mr. J. Daniels, has done most effective work in promoting better contact between architects and lighting service men of the member companies. Two schools have been held, one at Harrison, N. J., and the other at Cleveland, Ohio, in order to acquaint lighting men with the information and methods that they should use in contacting architects. Both of these schools were very well attended.

A list of central station lighting men has been made up and furnished to the American Institute of Architects in order that they may advise their men where authoritative information on lighting and wiring could be obtained.

The Committee also prepared wiring specifications or recommendations that enable an architect to insure the installation of adequate wiring in new buildings. These recommendations, when embodied in the wiring specifications prepared by the architect, will provide for future increases in the standards of illumination.

The American Institute of Architects has accepted the Committee's efforts in this connection most cordially, many of the institute members being in attendance at the two schools above mentioned. Mr. L. E. Kern, Secretary of the American Institute of Architects, has cooperated with our Committee in promoting this work.

The Committee has assisted The Society for Electrical Development in preparing three sets of broadsides covering commercial, industrial and new building lighting. These very effective mailing pieces are available for the use of member companies in opening the prospect's door for their lighting salesmen.

Street and Highway Lighting Committee

The Street and Highway Lighting Committee, under the chairmanship of Mr. R. J. Malcomson, reports that during the year there was a marked tendency toward the use of higher intensity street lights, many cities making complete changes in their street lighting systems to eliminate small candle power lamps. The street lighting of a town reflects the character of commercial lighting and, to a certain extent, residential lighting. Good street lighting is usually accompanied by good window and store lighting, while, as a rule, poor street lighting is accompanied by poor commercial lighting.

The Committee has endeavored to call this fact to the attention of member company executives, so that they would recognize that the development of the street lighting load not only is a service to the public but is a definite step toward building up their entire lighting business. It has been the attempt of the Committee to impress upon member companies that street lighting development is a commercial responsibility and as such should receive the same active and aggressive attention of the commercial manager as do other forms of load development.

The Committee has endeavored to show the economic fallacy of the use of lamps of low intensity. In conjunction with the Illuminating Engineering Society committee on street lighting, definite progress has been made on eliminating lamps of an intensity of less than 250 candle power.

A survey is now under way showing the type of lighting in various cities in this country so that a basis for street lighting measurement can be formulated. It is expected that this survey will be completed before the end of the summer, and recommendations will then be given as to the definition of adequate street lighting and a measure by which every member company can compare its street lighting load.

The Committee is cooperating with the Rural Service Committee in developing highway lighting as an aid to non-congestion of highways at night and as a means of providing rural lines for farm customers.

Work of the Electrical Advertising Committee

The Electrical Advertising Committee, under the chairmanship of Mr. C. J. Eaton, has been most aggressive throughout the year. Considerable work has been done on the formulation of a model sign ordinance, which will be complete at an early date. The need of such an ordinance, which will be fair to the general public and to the lighting industry, is generally recognized.

The Committee has in preparation a number of articles dealing with the subject of sign maintenance, and these articles will be published in the near future in various trade papers and also in the N. E. L. A. *Bulletin*.

Electrical advertising schools have been sponsored by the Committee. These schools were conducted by the Great Lakes, New England and East Central Division with most successful results.

The Metropolitan Section of New York has made definite plans for a school, and at least three other divisions have made tentative plans for similar activities.

As a result of the Committee's activities, the Geographic Divisions are paying particular attention to the subject of electrical advertising, and the Committee Chairman recommends that everything possible be done to maintain this interest through the prompt reappointment of Geographic Division Committee Chairmen.

The Committee has cooperated with the publication, "Signs of the Times," in conduct of a national contest for electrical advertising. As a result of the Committee's activity, the Federal Electric Co. award is being competed for by member companies, the winner for 1928 being announced at today's session.

"The Symposium of Electrical Advertising," in the form of a serial report, has been distributed to member companies. This report covers the three sections: Commercial, technical and accessories, and is very valuable as a ready reference or text book.

The Society for Electrical Development, in cooperation with the Committee, is formulating a plan book dealing with the mechanics of the sign business.

Your special attention is directed to the exhibit of the Electrical Advertising Committee at this convention.

Geographic Division Groups Cooperate

A report for the Lighting Bureau would be decidedly incomplete if specific mention were not made of the valuable cooperation which the Bureau has had from the Geographic Division organizations. The Committee wishes to point out that in its mind the greatest result in the development of public consciousness for better illumination can be better promoted through the activities of the Geographic Sections than through any other means.

Every talking movie should have a theme song. I am not going to sing, but I would like to suggest a theme story dedicated to every member company of the N. E. L. A. that is not making now a sincere effort to develop additional lighting business. Two negro boys were taking a short-cut through a cemetery. This was in the daytime, and in walking along and reading the epitaphs, one of them read from a gravestone, "Not dead, but sleeping." He read it out loud to the other one, who said, "That fellow ain't foolin' nobody but hisself."

Thank you! (Applause).

CHAIRMAN SAMPSELL: The next will be the report of the Power Bureau by the Vice-Chairman and Chairman of that Bureau, Mr. V. M. F. Tallman of Charles H. Tenney & Co., Boston, Mass.

REPORT OF THE POWER BUREAU

BY V. M. F. TALLMAN, *Chairman*

(For Bureau Personnel, See Appendix 4)

Commercial action is called for, not only by every executive who has been upon this platform, but also called for here in this convention hall in symbolic form.

Some time ago several enterprising men of this city conceived the idea of building an auditorium. We have the privilege of being the first to use it. Those men had a commercial idea. If you don't believe that they built for commercial action, look at the symbols on every one of these curtains, and over my head—"C.A."

Now, gentlemen, if you get no other thought from this little talk of mine before this Convention, I ask you to take home with you what that means—*C.A.* It means *Commercial Action*. It means that every man in this business must get that thought into his head and see that it is carried out. It is a constant reminder of our obligations.

We have been told that two-thirds of the energy which we manufacture is sold for power and heating purposes. That is sold, as you know, at relatively low rates.

It seems to me, therefore, that it is all the more important that we not only get additional power and heating business, but also that we endeavor to maintain and keep all of the present business which we have. That, in my opinion, is a harder job than getting new business.

The competition which we have in the power and heating business today is tremendous. It is on every hand. Every time our salesmen go out they meet competition. It may be competition in power, it may be competition with some form of heat, but it is there.

Therefore, *commercial action* is necessary and mandatory.

My purpose is three-fold: first, to show you briefly what has been accomplished by the committees which are in the so-called Power Bureau. Those committees are the General Power Committee, the Commercial Cooking and Heating Committee, and the Industrial Heating Committee, all of whom have actively carried out, in my opinion, and in the opinion of the officers of our Association, an outstanding job.

Second, I want to point out some of the problems which we young men see ahead of us in developing this commercial and industrial power and heating work.

Third, I would like to make some specific recommendations which I hope will at least arouse the executive interest and the interest of the commercial men in carrying out the job ahead of us.

An account of our stewardship would not be complete if I did not tell you that it had been devoted largely to the training of men, to the training not only of central station men, but to supplying information to those men in the many factories and industries to whom we sell our service. This training has been carried on in several ways by the different committees which I have had the pleasure of sponsoring. The committees have also prepared and published many reports which we could not, in the brief time given to us, tell you about. I wish to call them to the attention of the commercial men, the power men, and the heating men, if they have not already seen them. Get them, study them, read them, present them to your executives with your recommendations as to how they should be put into effect in your companies.

Commercial Cooking Committee

The Commercial Cooking Committee is preparing a paper on Marketing Electricity for Commercial Baking, which is one of a series of reports on Marketing Electricity being prepared under the supervision of headquarters.

General Power Committee

The General Power Committee has prepared several papers dealing with the competitive situation of power, and the Industrial Heating Committee has prepared some excellent articles on the application of electric heat to industry.

During the year two schools have been held to train the central station men. One of these schools was held last fall in Chicago; it was held by the Commercial Cooking Committee. Sixty men were trained in the art of applying electricity to cooking and baking problems on a major scale.

Perhaps someone will say, "Well, what is the opportunity in this commercial cooking business anyhow; what does it give us, the central stations? It is a fine thing, but what do we get out of it?" I have two examples here of the value of the baking load, which I would like to present to you for what they are worth. In a city of 100,000 population, there is a cooking and baking load of 8000 kw. That returns a revenue equal to the revenue returned by the lighting load of a neighboring city with 25,000 population. Gentlemen, I ask you if any load which will return, in a city of 100,000, a revenue equal to the total lighting revenue of another nearby city of 25,000, isn't worth going after? Two-thirds of that load is off peak, which makes it all the more attractive. I am told that much of it was taken on without any substantial increase in the investment. That ought to appeal to the officers of the company and to the stockholders.

In another city of 100,000 population, there is one hotel at which I have been many times, where the cooking and baking load is equal to 500,000 kw-hr. a year. The lighting and power kilowatt hours are also equal to 500,000 kw-hr. a year. In other words, this cooking and baking load is equal to the sum of the lighting and the power load.

Now we believe this, that whichever fuel is best adapted to do this heating and cooking work, that it is the fuel which our men should recommend. If they don't recommend the best fuel from the customer's standpoint, but put in an application which isn't proper, that application will not be permanent and we will be the ultimate losers.

Industrial Heating Committee

The Industrial Heating Committee has also carried on schools. During the past eight years, under the direct auspices of the Industrial Heating Committee itself, we have carried on schools at the works of the General Electric and Westinghouse Companies to whom we owe our sincere thanks. These manufacturers have spent thousands of dollars to educate our men. This year we thought the scope of the school might be broadened if it were held at some centrally-located technical school. By this means we could select the speakers from the best men in the manufacturers of electrical equipment and the central stations, to talk to our men as to what electrical heating would do. We had an attendance of eighty men at that school from all over the United States, Canada, Mexico and even South America. This advanced school was held, as you may know, at the Case School of Applied Science, last May.

We recommend that that method be carried out in the future.

During the year we have also tried to carry the message to the users of electric heat. We had many conferences. Three conferences have been held at universities, Penn State College, the University of Michigan and Massachusetts Institute of Technology in Boston. These conferences gave the prospective users of industrial heating the opportunity of listening to worthwhile papers presented by the heating men in our industry.

As an example of what has been done, at the conference in Boston the latter part of February and the first part of March, we had an attendance, gentlemen, of 1200 men coming from the industries of New England. These men were the ones who actually used the service. We believe that is a good way to get our message to the ultimate user.

Valuable Promotional Effort

We have carried on another feature in our work. We have a film called "Electric Heat in Industry," which was written, filmed, and presented by this Committee. At the National Metal Exposition in Philadelphia last October, your Committee presented this film to over 3000 people. Those people were the executives, the plant engineers, the metallurgists, and the purchasing agents coming from industrial plants all over the United States. They were looking for new developments in equipment for use in the industrial arts. Your men showed them the applications of electricity for those purposes. We believe that the educational and sales promotional value of our exhibit and contact with these men cannot be fully estimated.

Plans are now under way for another exposition at Cleveland next fall, where several new features will be presented.

In January, 1929, in California, at the Western States Metal Exposition, some work was carried on in industrial electric heating through the Pacific Coast Electrical Association under the auspices of the National Industrial Heating Committee. At that exposition the film was shown. There was a total attendance at the exposition of over 52,000 people. So we think that is a good way of telling our story.

We have held geographic schools. We have carried on publicity in the trade papers and a further program of publicity is now being prepared. This has already been given indorsement by the Executive Committee of the Commercial National Section, and we hope that the publicity program will be carried out in the future.

Some Sales Problems

Second, I would like to make some general observations as to what we are up against in the sale of power and heat. As you well know, the development of the internal combustion engine has presented a problem to our power sales engineers which makes it mandatory for us to do several things. In my opinion, every central station must give heed to its power rates. Some of those rates have not been redesigned for many years. They are obsolete in form; they don't recognize load factor. There are many things about them which must be changed. Some of them are almost flat straight line rates. They may be too low for the small business; they may be too high for the big business. There may be a point in the middle of those rates where they are too high to get certain medium-sized business.

Gentlemen, I recommend sincerely that you look over your power rates and take into consideration competition where there are other forms of power-producing apparatus; take into consideration the load factor of business which is obtainable. Don't forget to take into consideration the proper cost analysis to make sure that your power rates bring to you a reasonable return on the investment devoted to that class of business. If you do this, it seems to us you will put into your power salesman's hands one working tool which is absolutely necessary.

We also believe in this competition we must have more contact with our power and heating customers. We believe, with the competition ahead of us, closer contacts, more direct contacts must be made. Our commercial men must know the problems of our customers just as well as those customers know their problems themselves. Our power men have to be highly trained technically; they have to be good economists in our business; they must in our opinion be good economists in the business of their customers if they are to succeed in putting over our sales programs.

We believe our men must be trained. We have called upon the manufacturers to train those men in the past. We have called upon the manufacturers to supply us with all sorts of technical information. Gentlemen, how long we can continue to call upon the manufacturers we do not know. They have been more than kind, they have been liberal and generous in what they have done.

Selecting and Training Personnel

Third, I would like to recommend to the executives, commercial action of this kind: First, that the executives see to it that you have an adequate commercial personnel as regards power, cooking and heating. Go to the colleges this year. Talk to the graduates of the colleges. Tell them your story. Other industries are out ofter those graduates. They are taking the pick. I wonder if we are going after our future executives now as we should.

Take those men you pick now and give them every opportunity to train themselves. Teach them. Give them rates to go out and sell the service. Tell them, more important, what your policy is in every respect so that they know what they can do for the customer. Encourage them to come back to the office with the customer's viewpoint and ask to have things done for the customer. My prediction is if you will do that you will build up a staff of men that will carry on our business as it should be carried on. The competition for the investor's dollar today is such that unless you do it your company will fall by the wayside.

Study, Study, Study!

To the commercial men I would like to make these recommendations: Train yourself. Study, study, study! There is no end to it, gentlemen. You must know your customer's business; you must know the routing in his factory; you must know his production costs; you must know all about his business as well as all about your own. May I recommend that you commercial men, power sales engineers, heating and cooking engineers, and industrial and electrical heating engineers, invest in your company. I sincerely believe that a company worth working for is worth investing your money in. Go out and borrow the money if you haven't got it, but invest in it, and you will get a new slant on your job. Then when you go out to sell the customer, assuming you have invested your own money in your company, you will make that dollar you have invested work overtime night and day. Make the load factor of that invested dollar return double what it is doing. Gentlemen, it can be done.

I would like to also ask the commercial men to no longer be "yes" men. Too many perhaps have been known to say and do only those things which were easy to do. I do not believe your executives want a commercial man who is a "yes" man. I believe they are paying us to bring to them ideas to develop our business. I believe they want us to come to them with well-thought-out programs, so they can say "Go ahead." I think they would much rather do that than turn you down.

Commercial men, please have a well rounded-out program when you go to your executive. Otherwise, you'll have nothing to say about the executive not backing you up unless you can present to him full rounded-out plans, programs and recommendations.

Finally, commercial men, know your job! Know it from the central station viewpoint; know it from the viewpoint of your stockholders; know it from the competitor's viewpoint. Know how to meet that competition and, finally, but most important, know it from your customer's standpoint.

Gentlemen, the architects of this building designed it for us better than they knew, for not only did they give us these symbols "C.A." around here as a constant reminder of our obligations to carry on a *Commercial Activity,* but they also gave us another symbol which I believe we would do well to contemplate. That symbol is up in the center front: "Libra"—the scales or balance.

When we give an account of our stewardship of the commercial business of our companies, let us not be weighed and found wanting.

I thank you!

(Applause).

CHAIRMAN SAMPSELL: Mr. F. D. Pembleton, Chairman of the Merchandising Bureau, will now make his report. Mr. Pembleton of the Public Service Company, of Newark, N. J.

REPORT OF MERCHANDISING BUREAU

By F. D. PEMBLETON, *Chairman*

(For Bureau Personnel, See Appendix 4)

Your Merchandising Bureau undertook its work with the strong purpose of accomplishing definite results which could be adopted by and reflected in the field work of the various companies. The degree to which the purpose has been fulfilled is shown by the respective reports of the Committees comprising the Bureau.

Mr. C. L. Dunn and his Committee on Refrigeration have prepared a most comprehensive plan of educational publicity which it is believed will develop a very large volume of refrigeration business. This plan has already been put into operation.

Mr. Norman T. Wilcox and his Committee on Electric Water Heating have compiled a great deal of valuable data on various problems which will be very helpful to companies planning the development of electric water heating business.

This information will soon be given to the industry in the form of serial reports.

Mr. Wilcox and his Committee have not been able to complete the compilation of all of the data necessary to a comprehensive report on water heating and it is hoped that the incoming administration will decide to continue Mr. Wilcox's Committee in order that its valuable work may be completed without interruption.

The Domestic Electric Range Committee, under the very able direction of Mr. Frank A. Coupal, set itself the task of clarifying much of the discussion that has taken place in regard to electric ranges and to compile definite data which could be given practicable application in the development of range business.

This data, as outlined in the report of the Range Committee, given herewith, has been compiled in a very thorough, painstaking manner. It is now available to the industry in the report entitled "Marketing Electricity for Domestic Electric Cookery." This report presents, under one cover, much, if not all, of the information that a salesman will need in the development of electric range business.

The report is a very accurate reflection of the enthusiasm and energy that has actuated your Range Committee.

Your Merchandise Sales Committee, under the Direction of Mr. C. L. Harold, approached its work with a very clear and comprehensive understanding that it was confronted with a number of problems that offered both opportunities and responsibilities.

The Committee undertook to handle these problems in a manner that would develop the greatest results and at the same time promote harmony throughout the industry.

Through the work of the Farm Equipment Subcommittee, an effort has been made to develop a plan of organization and work that would promote a very much broader use of electric service and appliances on the farm.

The details of this work, with which the Merchandise Committee was affiliated, are presented very thoroughly in the report of the Electric Farm Equipment Subcommittee.

In an equally comprehensive manner, your Merchandise Committee has endeavored to develop a basis for better trade relations, for maintaining quality standards and to develop a larger sale of current for residence uses, all of which are outlined in the accompanying report of the Merchandise Sales Committee.

The maximum sale of current for residence purposes will be made only when, in addition to a generous use of light, there is also, in most homes, a very general use of a larger variety of electric appliances.

Must Create Public Appreciation

What the electrical industry needs, insofar as residence business is concerned, is the creating of a great public appreciation of and greater indulgence in the comforts which complete electric service provides.

The magic of electricity must be made spectacular in order that it may catch and hold public interest, as radio and aviation have held the interest of all people.

The electrical home must be made a fad among housekeepers and home builders.

Electrical methods must be set up as a style of housekeeping and a craze for it created just as the demand for color in kitchen and bathroom was created; and as demand for electric refrigeration is now being created.

The speed with which the style of electrical housekeeping will be established will depend upon the degree of sales promotion given to the appliances that perform the house work that is hard to do. Other appliances will follow the trend of the style.

The appliance with the largest over-the-counter demand, the electric iron, eliminated hard, hot, tiresome effort; the second largest selling appliance, the vacuum cleaner, and the third largest selling appliance, the washing machine, eliminated the hardest, most disagreeable and unhealthiest of all household duties. That is why they are the largest sellers.

A recent survey developed the information that 55 per cent of the owners of electric refrigeration purchased them to eliminate the inconvenience and labor of using ice. Less than 10 per cent purchased for reasons of health.

To catch and hold the public interest, to overcome the fixed ideas and habits of housekeepers, and to set up a style or craze for electrical methods of housekeeping, requires the use of every known promotional method used with such intensity and skill as to sway a whole nation and accomplish in months a degree of progress that would otherwise take years. Such are the methods that are building the electric refrigeration business. They should be applied to the sale of all electrical appliances, regardless of type or current consumption.

The present national volume of electrical retail sales, including appliances and accessories, has been estimated to be a little over $750,000,000.

It is neither exaggerated nor unfair to say that volume of sales has been accomplished with efforts that were, in many localities, very inadequate.

So it seems rational to state that, with a great combined industry, effort that is national in scope, thoroughly balanced in organization, sincerely cooperative in spirit, operated with intensity and skill, the present electrical retail sales can be doubled in less than five years.

It also seems obvious and logical that the whole central station industry, including the executives, should immediately take a more earnest attitude toward the electrical appliance business and aggressively promote it in a comprehensive manner that eliminates indifference and mediocrity.

Service Also Interpreted Through Appliances

With a more whole-hearted interest in electrical merchandising on the part of the executives of central station companies, their respective merchandising departments can be made to win admiration for their company's efficient methods and to develop a very great degree of good will and predisposition favorable to the company, because it is through the medium of appliances, almost as much as through the medium of lighting equipment, that the company's service is interpreted to its customers.

A well organized and properly managed merchandising department is a logical and legitimate part of the central station's organization, because the department completes the central station's whole service to its customers.

Because it is a part of the company's service and because it has such a direct and powerful influence in presenting the company to the public, the merchandising department of a central station should be just as carefully and completely equipped as its generating station. Both form a part of the basis of the company's complete service to its customers. As such, both are equally important.

A central station company's merchandising methods should be based upon the economical and psychological principles that have been developed through years of study and research, and which have a basis just as scientific and irrevocable as the principles underlying the central station's engineering practices. Results in merchandising can now be predetermined with a remarkable degree of accuracy.

Retail Stores Set the Standard

There are hundreds of stores in Philadelphia all using practically the same merchandising methods, yet none have perfected those methods equal to Wanamaker. In San Francisco there are many stores selling oriental goods; but nowhere in that city nor anywhere in this country is there an oriental store equal to Gumps. In almost every large city there is some one firm which has developed its merchandise practices to a degree far superior to that of most of the stores in the city. These leaders illustrate the art and science to which merchandising has been developed. They set the standards by which central station merchandising will be measured by the public.

If there should be too great a difference between the practices of the leading merchandisers and the central station merchandise departments, the comparison is likely to reflect unfavorably upon the entire central station organization.

There is no real reason why there should be any great difference.

The merchandising methods that should be used are obvious to anyone who really wishes to know.

There is sufficient money and executive ability in the central station industry for it to bring its merchandise departments to the highest standards that have so far been established.

All central station executives should, with enthusiasm and pride, spend the money necessary to equip their salesrooms with the most modern store fixtures in a manner that compares very favorably with the stores of the leading merchants. Many central stations have done that.

If the central station sells appliances at all, then the public will expect to be able to secure from the central station any type of appliance that has been widely advertised and established to a reasonable degree.

The public will expect the central station to know about all appliances and to display a wider assortment of appliances than perhaps any other dealer; and the central station serves its own interest by doing so.

The slogan, "He profits most who serves best," applies to the central station that provides its customers with the opportunity to buy any type of appliance for which there is a reasonable demand, regardless of its current consumption.

Sell All Types of Appliances

The complete electrical equipment of homes will be attained quicker, and there will be a larger demand for each type of appliance, if an aggressive effort is made to sell all types of appliances, because then the electrical method will be earnestly promoted at every opportunity.

If a central station merchandises on any other basis, it defeats the real purpose for which its merchandise department was established; it brings about an unbalanced marketing condition; and thousands of dollars spent by manufacturers for advertising will not be given the full local support that it would otherwise receive.

So the central station should carry the most complete line of electrical appliances in the city and aggressively sell each type.

Through its merchandise sales force, a central station makes a very large part of its customer contacts.

Central station salespeople should be so thoroughly educated regarding electric appliances, and so well trained in the art of selling them, that the central station sales people will be far more expert in the sale of electric appliances and render a much more satisfactory sales service than the sales people of other merchandisers. The public expects such ability and sales service from central station's sales people.

A central station's advertising on appliances should be the product of professional experts and never that of one untrained in advertising.

When central station executives will take cognizance of all these factors and put their respective merchandising departments on a high grade basis comparable with the best merchandising firms, and render their customers a more complete service, there will be no real reason for criticism of central station merchandising practices. Then the time will be advanced when every home will enjoy a more nearly complete electric service, and insofar as the merchandise department is concerned, the central station will enjoy the respect and good will of the entire community.

Reports of Chairmen of Committees of the Merchandising Bureau follow:

REPORT OF REFRIGERATION COMMITTEE

By C. L. DUNN, *Chairman*

(For Committee Personnel, See Appendix 4)

Your Refrigeration Committee during the fiscal year which closes with the Convention at Atlantic City, in June, took for its work a closer coordination of efforts in the refrigeration industry. We found that each manufacturer of refrigeration equipment was carrying on his sales and promotion work without any regard as to the work being accomplished by his competitor.

We believed that it was possible to bring the industry closer together and work out a cooperative national educational program that would tend to sell the American public on the possibilities of electric refrigeration from the standpoint of health and food preservation.

National Food Preservation Plan

After several meetings of the Committee, a plan was formulated for the purpose of carrying on this national food preservation movement, which incorporated every manufacturer, jobber and dealer interested in refrigeration. This plan also called for the indorsement of every national and local group interested in health and food preservation, such as National Dairy Association, Federation of Women's Clubs, Medical Association and others.

This plan was approved by the Executive Committee of the Commercial Section and by the N. E. L. A., with the understanding that the N. E. L. A. Headquarters would not only approve it, but actively sponsor and direct it from headquarters through the office of Mr. C. E. Greenwood, the Commercial Director.

The plan stated that all finances connected with the national committee which would direct the activity be raised through subscription by the manufacturers of electric refrigeration and ice boxes, and that all local promotional expense be borne by the local utility and all interested groups. At this writing approximately $200,000 has been subscribed to carry on this educational program, and the Millis Advertising Agency of Indianapolis has been employed to assist in directing the movement.

Two Main Achievements

We feel the Committee accomplished two outstanding achievements:

1. By getting a cooperative spirit existing among the refrigeration manufacturers.
2. By securing their help in promoting this national educational program which will not only make our customers conscious of the fact that there is a food temperature for proper maintenance of food, but there is a heat temperature for comfort.

It is an outstanding opportunity for the N. E. L. A., as it should do more toward promoting better trade relations than any movement recently undertaken.

This entirely finished plan of operation has been turned over to the N. E. L. A. for execution as representing the Committee's work for the year.

REPORT OF ELECTRIC WATER HEATING COMMITTEE

NORMAN T. WILCOX, *Chairman*

(For Committee Personnel, See Appendix 4)

This Committee was organized with an active personnel, consisting entirely of central station men from various parts of the country, as evidenced by the list of members.

The representatives of some of the leading manufacturers have sat in with us at most of the meetings, and have been of great assistance in discussions and in obtaining necessary information for a report.

The first two full sessions were held in New York City in October. Another meeting was held in Detroit Feb. 5, which was well attended by representatives from all parts of the country, there being two from the Pacific Coast.

Useful Information Obtained

The statements by members from various sections of the country resulted in bringing out much useful information concerning conditions of operation and local limitations peculiar to the particular parts of the country in which the service is rendered.

This meeting was particularly satisfactory in that it gave the various members of the Committee a comprehensive idea of the breadth of the problem and the variant conditions under which water heating service must be rendered.

This discussion also emphasized the fact that customers of apparently the same capacity were using very different amounts of energy for hot water service. It is apparent that a satisfying hot water service must precede a full development of domestic water heating.

A third meeting, held in Chicago in March with the group meetings of the Commercial Section, was not quite so representative as the Detroit meeting, although the representative from the Pacific Coast who attended this meeting had not been able to be at the previous meeting. This meeting was also successful in bringing out some additional information for the report.

Studied Water Heating Tests

In addition to some work in the field, water heating tests from various sources have been studied. A short but comprehensive questionnaire has been circulated to various companies, who are known to be supplying a considerable amount of water heating service. Tests have been standardized so as to make them truly comparable.

Arrangements have been made for tests to ascertain diversity for various kinds of water heating equipment. The first of these tests is being made in Seattle. This part of the work will not be completed for some time, owing to the limited number of instruments available.

The material for the body of the report is well in hand, so that we expect to have the main part of the report, exclusive of the diversity tests, ready for publication at a comparatively early date. If the report is made at an early date, of course, the diversity tests and some incidental information will need to be carried over into next year's report, which should be supplemental to the main report now being prepared.

REPORT OF DOMESTIC ELECTRIC RANGE COMMITTEE

By F. A. COUPAL, *Chairman.*

(For Committee Personnel, See Appendix 4)

At the first meeting of the Domestic Electric Range Committee in New York on Oct. 15, 1928, it was very definitely the unanimous opinion of the Committee that the excellent work of the 1928 Electric Range Committee meetings be continued, especially with reference to promoting a greater interest in the "Plan for Electric Cookery."

A complete resumé of what has been accomplished convinced the Committee that a compilation of pertinent information, relating to the advantages of the electric range, would be acceptable, provided it was put in a brief and readable form. The Committee addressed itself to this problem, and at its meetings on Feb. 5, 1929, in Detroit, and on March 21, at Chicago, was developed and completely outlined this year's report, which will be issued at the Atlantic City Convention in June, under the title of "Marketing Electricity for Domestic Electric Cookery."

The work of this ambitious publication was divided among a number of subcommittees, and it is with considerable pride and pleasure to inform you that these Committees have worked very carefully and faithfully to the end that a creditable report will be produced, and in the opinion of many of the Committee will be accepted as a report concerning electric ranges, which every commercial manager and sales manager, as well as executives of the various electrical and combination utilities, will desire to have available in their offices for reference.

This report is not the work of one man, but the work of some twelve individuals, all of whom have had considerable experience in their special lines.

It was hoped, however, that it might be possible for some spectacular presentation of the report to be made at the convention in order to direct the attention of those interested in commercial activities toward this important report, but unfortunately the procedure for the presentation of the commercial program prevented any such presentation.

However, the Committee through the Commercial Director, Mr. C. E. Greenwood, has been permitted to make an attractive and interesting display in the commercial booth, which will be on the stage of the new auditorium at Atlantic City, and although it will not be as dramatic a presentation as had been planned, it perhaps will fulfill the purpose of directing, as much as possible, the attention of those attending the convention to the Committee report on electric ranges.

Furthermore, plans are now in the making, so that all the range manufacturers who will exhibit at the new auditorium in Atlantic City shall cooperate to direct attention to the report, for the manufacturers themselves are firmly convinced that the report should answer any reasonable question which might arise with any utility considering the advantages of the use of the electric range.

In conclusion, I desire to particularly call attention to the splendid cooperation given the Range Committee by the S. E. D. through Kenneth McIntyre, who placed at the disposal of the Committee George Jaquet, who has made possible the collection and briefing of an immense amount of data, as well as formulating the outline for the presentation of the report, as it will be in its final stage.

REPORT OF MERCHANDISE SALES COMMITTEE

By C. L. HAROLD, *Chairman*

(For Committee Personnel, See Appendix 4)

The Merchandise Sales Committee has advanced the work of the preceding year with the following objectives which have been pursued by the respective subcommittees:

Merchandising Advertising
Oil Burner Sales
Quality Standards
Radio Merchandising
Trade Relations.

In addition to the continuation of the foregoing activities, a new subcommittee of great importance, namely the Subcommittee on Electric Farm Equipment, was created and has already prepared a report, to be printed in serial form for general distribution during 1929. The activities of this subcommittee have produced for the guidance of all member companies interested, much valuable data which the published report will contain.

Farm Equipment Sales

The electric farm equipment market is being explored by many member companies, and the Committee is endeavoring to discover and present to the industry the most effective methods of building this type of load. Its scope, for convenience, includes not alone appliances for use in farm residences, but all practical equipment for farm operation generally. It is recognized that the development of this farm business calls for specialized attention and specialized men for promoting the sales. At every point in its work, the Farm Equipment Subcommittee is closely cooperating with the Rural Service Committee of the N. E. L. A., from which latter group two members have been drawn and assigned to the Electrical Farm Equipment Subcommittee. While the farm market development is not an engineering job, the subcommittee has concluded that the salesmen employed by the power companies must be equipped with extensive experience or training so as to talk the language of the farmer and adapt themselves to the practical needs of the farmer. This is one of the reasons why the selling activities should be so closely related to the rural electrification work of the utility.

Data in Committee's Reports

The forthcoming report of the subcommittee will contain charts showing how the power company should organize for farm salesmanship. It will point the way for various companies differently situated in the country at large. The subcommittee will list all the applicable publications which should be read by salesmen to better fit them for handling the market. All data as to performance value of various farm issues now on the market, and which may be placed on the market from time to time, will be assembled and a description thereof included in reports to be made available to member companies.

It is believed that this phase of the work can be best handled by the Geographic Division Subcommittees, most of which have already been formed and are functioning in close cooperation with the National Subcommittee.

The National Subcommittee will act as a clearing house for information concerning, and criticisms of, equipment having objectionable features which should bar them from the approval list until the manufacturers, having been informed of such criticism, may remodel their products or correct them. The subcommittee deems it exceedingly important to push the sale of only the apparatus which gives reliable and satisfactory service. It is recognized that the farmer, unless safeguarded against disappointing electrical machinery, becomes a hard prospect after experiencing or learning of inferior machines being tried out.

Typical analyses of farm appliance markets are to be made and presented to member companies by the National Subcommittee, indicating the basis on which sales should be made and credit extended as determined by the kind of crop or product of the farm territory comprising the market. Formulæ are to be developed for determining the purchasing power of farms in various sections of the country and of the territory covered by the particular member company.

Advertising

Besides the customary concurrent advertising program, the Subcommittee on Advertising is undertaking to relate more intimately the advertising men and appliance managers. It is deemed advisable to develop a better understanding of their mutual problems. Conferences through possible joint committees are to be encouraged with the hope that appliance advertising methods may be adapted to the exact though changing sensibilities of the user of domestic appliances. Also, a unique kitchen calendar, tying in with the concurrent advertising schedule, has been prepared by this subcommittee and will be made available for 1930.

Radios

The Radio Subcommittee has expressed the belief, after careful consideration of the experience of many member companies, that with the stabilization of radio sets, merchandising by central stations of this class of electrical goods may be undertaken with advantage in building load. This subcommittee expects to assemble data showing the trend of experience by central stations which have already engaged in this class of merchandising.

Oil Burners

The Subcommittee on Oil Burners is preparing, and will make available during the current year, a commercial supplement to the oil burner report prepared by the previous committee. The basic report has been of great value in reviewing the technique of oil burners, performance, load value, etc., but did not provide what the pending supplementary report will undertake to do, namely, canvass the marketing methods showing the salability of electrified oil burners. Considerable effort has been expended by this subcommittee in assembling this information from all parts of the country.

Quality Standards

Much study has been devoted by the Subcommittee on Quality Standards of Merchandise to determine whether it would be wise to attempt to develop and promulgate minimum standards of quality for electrical goods. Several of the leading manufacturers of electrical appliances responded to questionnaires on this point. While many of them responded to the idea of possibly setting minimum standards as to the .performance of various popular appliances, the subcommittee is not yet prepared to go further with any recommendation other than to adhere to standards which will reasonably insure the safety of apparatus in respect of fire and life hazards. Such insurance, in large measure, is automatically vouchsafed by the approval of the Fire Underwriters Board and compliance with the National Code.

Trade Relations

The Merchandise Sales Committee has encouraged, in its several meetings of the Merchandising Bureau and in conference of the Merchandising Bureau and Commercial Section, the adoption, so far as practicable, by member companies, of the declaration of merchandising principles, jointly subscribed to by the N. E. L. A. and various national dealer organizations, as to fair competition and ethical salesmanship. It will continue to further such trade relations without attempting to police the industry, but constantly reminding member companies of a certain moral obligation to maintain wholesale trade relations on the basis of cooperation.

CHAIRMAN SAMPSELL: I think you will all agree with me, after hearing the three reports by Messrs. Tallman, Pembleton and Kennedy, that this Commercial Section has been in good hands this year. I wish to thank each one of them here because I have not had sufficient opportunity in introducing them to do so.

It would be a very great honor to us if Mr. Swope, Mr. Martin J. Insull, Mr. Freeman and Mr. Groesbeck would take the seats that are being vacated by the Vice-Chairmen. I should like you with us. I am not going to say one word of praise about any one of these gentlemen because if I tried to do it, if I were able to properly do it, I would spend the time that they have been good enough to come here to devote to this great, inspiring meeting.

[The above-named gentlemen came to the platform. Applause.]

CHAIRMAN SAMPSELL: The next gentleman, Mr. Zimmerman, who talked this morning at the General Session—and we consented he should again talk because we believe it is of most importance that he give his message to everyone—has agreed with me that he would not get overly enthusiastic and take more time than the schedule formally gives him.

I have great pleasure in presenting Mr. Zimmerman to you.

NATIONAL FOOD PRESERVATION PROGRAM

BY P. B. ZIMMERMAN,
Secretary, National Food Preservation Council

In a recent radio address, Dr. Royal S. Copeland, formerly the Health Commissioner of New York, now a United States Senator, and a man who is closely followed because of his writings on food, and particularly health, made the statement that millionaires had offered great fortunes—Woolworth buildings or practically anything within their reach—if they could be given an extension of ten years of life, that by listening to a very simple recipe he would guarantee an extension of many years to the average individual. His recipe was this: Make certain that the food you are to eat is kept in a good container maintained at a temperature of 50 deg. or below.

He further stated that small, hidden enemies have caused most of the grief of the world, the germ life of which we know little, and it is the germs that have not been perceptible to the human eye that have been the cause of much of our ill-health.

Progress Made in Refrigeration

We have made a great deal of progress in refrigeration. Some 40 per cent of the American homes have refrigeration of some type; some 6 per cent have electric refrigeration. The family food bill is some $629, and we have a tremendous wastage sufficient to pay for all refrigeration costs if we could make this saving in food stuffs.

It was with these facts before them that the Refrigeration Committee of the Commercial Section suggested the program we have been discussing today. The National Food Preservation Council as it is now organized and incorporated, consists of Matthew S. Sloan, President; J. E. Davidson and C. E. Greenwood, Vice-Presidents, and Mr. Marshall E. Sampsell as Chairman of the Executive Committee. Associated with them are representatives of a new group to this industry, the food industries. They have invited to sit on this board representatives from the American Medical Association, American Federation of Women's Clubs, the Ice Industries, the Ice Cabinet Manufacturers, the National Dairy Council, and many other groups that are interested in this common development work.

The activities as shown in the folder that will be given to you are suggested both for national and local work. A fund has been created by the national manufacturers interested in the movement to defray the expenses of the national offices in the preparation of material that will be helpful to local activities. The campaign is essentially a local one. The time has been set for the month of September, at which time it has been suggested that local Food Preservation Councils be formed, composed of the utilities, the ice people, the milk people, the refrigerator dealers, and any other local interests that may want to participate. Those groups will endeavor to make their residents conscious of a food temperature.

The specific aims of the program, as given in the prospectus, are as follows: First, to establish the cause of food decay and bacteria growth; second, the relationship between food spoilage and health; third, the vital necessity for proper, all-the-year-around refrigeration; fourth, to establish in the public mind a perishable food temperature of 50 deg. or less.

If we could boil this down to an insignia, and could so present it to every electric customer in the United States, one that would be emblematic of this design before you, so that the customer would feel that a food temperature of 50 deg. for health is just as important to them as a heat temperature of 70 deg. for their comfort, then we would have accomplished much. So about all that has been suggested in the Refrigeration Committee is that we pool our resources, all our activities, and we support the National Electric Light Association in this one-month campaign in September, in presenting to the public this story of the relationship between better health and food conservation and preservation, and, to make it specific, we definitely establish for all time a food temperature.

Yesterday the Regional Directors were organized. The country is divided into twenty sections. We will have their sponsorship and activity in each district. We believe we will have the active cooperation of the Electric League in the larger cities. At the National Headquarters office will be ten specialists who will become field assistants to the Regional Directors and will endeavor to help them organize local groups.

An avalanche of publicity material is being prepared. National advertisements and all types of local material on the food temperature will be distributed by the millions, all tying up into an interest-getting contest in which $25,000 has been appropriated for a model home, a Cadillac car and many other worthwhile prizes. We should have at least 1,000,000 essays submitted in this contest.

We have an opportunity of working with the food industries. They are a fine group and they are carrying on a fine work of their own. If we work with them I believe we can form a permanent association. They can help us very much in our other work, and they will assist us in this. We ask everyone to make it their business to inquire locally as to who will head the Food Preservation Council in the city in which he resides. We solicit your most active cooperation. (Applause.)

CHAIRMAN SAMPSELL: It is my very great pleasure to merely mention the name of the next speaker, Mr. Gerard Swope, President of the General Electric Company. (Applause.)

FROM THEORY TO ACTION

BY GERARD SWOPE
President, General Electric Company

When Mr. Sampsell asked me to speak before you, it seemed to me that I had a good deal of boldness and temerity to come before you and talk to you about your job. I began to think what I should say and tried to put myself in your place to see how I would try to develop a business if it was my responsibility to do so. Then I listened yesterday, and especially this morning, to the very illuminating and magnificent addresses of Mr. Sampsell and Mr. Sloan, and I came to the conclusion that you do not need any thoughts of mine; you know the theory, all you have to do is to play the game. It boots us but little if we know what is required of us if we don't do it, and that seems to me the situation.

The figure Mr. Sloan gave, showing the average consumption of kilowatt-hours per family in the United States being 456 per year, was even smaller than I had thought. Really, in a way, if you will allow me to speak frankly, it is an indictment of the industry that we have done very little to establish ourselves in the home.

Then Mr. Sloan went on to say that one company, or several groups of companies, had sold 735 kw-hr. per year per family; in other words, a range of 65 per cent. If the first figure is an average and the second figure of 65 per cent bigger, I do not need to tell you, even if you are not expert mathematicians, that there must be many central stations that are selling even less kilowatt-hours per year than 456.

Of course, it would be out of place for me to mention anything about rates, inducement rates or anything else. It seems to me again that one need not do anything further than to read the papers that have been presented. If you gentlemen didn't hear Mr. Sampsell and Mr. Sloan, I urge each one of you to read their papers. I hope they will have a very wide and careful consideration because therein is expressed the fundamental theory of central station development of kilowatt-hour consumption in the home.

Education, Price and Cooperation

Therefore, assuming that you know the theory, then there is only one thing to do, and that is to do it. I am only going to mention three points, and in this order: Education, price, cooperation.

By education, I mean the education of the public to the use and advantages of electrical appliances in the home. I believe it is of greater service and value to the public service company to give a specific illustration of how electricity can help the family, than it is to have institutional advertising to tell the virtues of the central station and the fine service that it is giving. In other words, if you will be concrete, definite and specific, and the rate structure has been fixed so that every family can have a range or a washing machine, or a refrigerator, or a vacuum cleaner, or other household conveniences, then it seems to me you will be carrying the message right home very definitely to the family itself. If you do that you will be showing initiative and energy, and it will be convincing to the families themselves that you are really seeking to give better service and to a larger part of the community.

Furthermore—of course education has another effect—it stimulates the industry. It singles you out as a leader, because then people recognize that you are trying to do something constructive, that you are trying to make two blades of grass grow where maybe none grew before; that you are trying to induce people or lead people to see the advantages of electrical service in the home, not to advocate necessarily any particular appliance, though the advocacy of any one is better than none, but to advocate the use of electrical appliances in the home.

The Question of Price

Second is the price. There has been a good deal of discussion, and maybe there is some difference of opinion, and if I speak quite definitely, for I believe in what I say, please bear with me because I am speaking from my standpoint and from my experience, and I may be wrong from the viewpoint of a central station. I think in setting a price for electrical appliances, if the central station is going to sell them it should take into consideration all the elements of cost, including the education I have spoken of, which is advertising, and then furthermore allow a margin which is a reasonable return on the time, on the effort and the investment in this part of the business. The public do not ask that we give them anything for nothing. They are perfectly willing to pay for service rendered. Neither do they ask for inducements for them to buy electric appliances. You haven't any better demonstration of that than the way in which big automobile companies and others have built up their business on a perfectly definite price basis which has left them a reasonable margin for a return upon their investment and their effort, because without that of course they couldn't go forward and make improvements in the art, and be of greater service.

Nor is price the sole and only consideration from the standpoint of the public. Remember what a man from Missouri once said, that "The remembrance of quality remains long after price is forgotten." It is the character of the appliance and the service that is given that is immeasurably of more importance than the first price. There are so many people in this country with the high standard of living we have now who can afford to buy appliances on a reasonable price basis, that one need not worry about the first cost standing in the way of use.

Very much more important is the rate structure than the initial price of the appliance, because the appliance you sell but once—if it is good. The rate is a continuing source of revenue for the public service company. I think if these two elements are rightly considered—and other elements such as terms of payment for appliances spread over a period of time, but not so long as to be unsound; indeed, the central stations might offer financing service on time payments for appliances used on their lines irrespective of whether the purchases are made from the central stations or from dealers in their community —if these are well done, then you do not need to worry about cooperation in the industry; you will have it.

Mr. Sampsell spoke very eloquently of the cooperation of the four arms of the big electrical industry this morning. He has been sincere in the time and effort he has given to bring it about. But cooperation will never result unless you have a reasonable satisfaction on the part of each branch of the industry represented in the group, and the best basis of reasonable satisfaction is to have the central station take the leadership in the education of the people by advertising the advantages of the use of electric appliances; secondly, that its price should be so made, including the reasonable margin and the return upon the investment I have spoken of, that other branches of this large industry may also sell their particular appliances in the same market.

Remember this: That although the central station, rightfully it seems to me, enjoys a public franchise which gives it 100 per cent of the business of serving the public, there is no organization on earth, no matter how efficient, no matter how good, that will ever sell all the merchandise in a community. There will be differences in taste on the part of the public that you serve, even if there may not be differences in quality of the apparatus that is sold. Different manufacturers are going to bring out their wares and are going to seek their market. They are doing a national campaign of advertising. It is for the central stations in their particular fields to back up that advertising and bring it home to the particular householder in his territory.

As I said, no central station, no matter how efficient, will sell it all.

Recognizing these various elements I have spoken of, if you can take the leadership in the educational campaign, then really the work of the electrical leagues is done. You won't have to preach cooperation then because they will recognize that you are practising it, that you are giving each man a chance, each company, each branch an opportunity to serve as best it can. Then, it seems to me, will the central stations take their rightful position of constructive leadership, of an educator of the public, putting the sales on a basis where all other parts of the industry can cooperate with them to the full, so that the ideal may be reached of not only a greater kilowatt-hour consumption per capita, but also through the cooperation of the group, as Mr. Sampsell has said, we can look forward to a greater use of electric appliances in the home and in the workshop, which means, of course, greater comforts and conveniences, and greater efficiency.

You know the theory. Will you do it? I thank you. (Applause.)

CHAIRMAN SAMPSELL: Now, another name, and that will be enough. My good friend Mr. Martin J. Insull, President of the Middle West Utilities Company. (Applause.)

SELLING DIVERSIFIED KILOWATTS

By MARTIN J. INSULL

President, Middle West Utilities Company, Chicago, Ill.

My feeling this afternoon is one of congratulation to you because, first of all, if anyone asks me what was the keynote of this convention I think I should have to reply, "Commercial Development." Therefore, I think you are to be very much congratulated that your branch of the business should take such a prominent position in one of the most successful conventions that this association has ever held.

I was particularly impressed this morning with Mr. Sampsell's report for the Commercial Section, and if I caught his thought correctly, what he had in mind the Commercial Section should do was not only to sell kilowatts but to sell diversified kilowatts. It seems to me there is a very considerable difference between the selling of kilowatts and the selling of diversified kilowatts. Fundamentally, as our business grows, if it is properly handled the price of our service should go down. On the other hand, if our business grows and it is not properly handled, the price of our service has to remain about the same. The only way we can properly handle our business is to be sure that we are taking on diversified load.

Mr. Sampsell also referred to cooperation, particularly to cooperation outside of our own particular industry, and yet it brought to my mind that what is needed as much as anything else at the present time is cooperation inside of our industry, cooperation between the commercial departments and all the other departments of the various operating companies, so that they may be all working toward the end that the tendency of our business is such that we may continue to bring our rates down.

I was particularly impressed with that point of view from the figures that Mr. Clapp used yesterday, and Mr. Sloan again used this morning, and that was that in 1922 this industry had $4.72 invested for every dollar of income, and yet in 1928 that figure had increased from $4.72 to $5.58 per dollar of income. I have thought a great deal about those figures since yesterday morning, and I am wondering if some of the trouble that is represented by those figures is possibly due to the fact that we have not paid enough attention to the selling of diversified kilowatt-hours, and have been satisfied just to sell kilowatt-hours.

It seems to me you may be congratulated from another point of view in that you commercial people are just about on the edge of where you have got to pay more attention to the fundamental economics of this business than you have to purely getting orders. Therefore, your position is going to be a very much more prominent one in the future of this industry than possibly it has been in the past. I do not want you to misunderstand me in any sense. The work you have done in the past has been a great work for this industry, but it seems to me, sitting here today and yesterday listening to Mr. Clapp and to Mr. Sampsell, that your work in the future must be of a higher grade, more scientific, more economic work than you have been engaged in, and that the cooperation to which Mr. Sampsell referred will be a cooperation between you, the financial departments and the operating departments of your companies, and in those conferences your position in the future will be found more important than it has been in the past.

Therefore, I feel that I can congratulate you. It flashed across my mind this morning that possibly I had been thinking that way a great deal before I came to this Convention, but having the privilege of hearing these things talked over, it crystallized my own thoughts in my own mind. I remember only a few weeks ago I picked up what is known in our organization as the *Intercompany Bulletin,* which is published every week, and always contains a record of the various commercial departments of our different operating companies. It sort of staggered me when for two weeks running I noted that the aggregate commercial business of our operating companies was running something over $300,000 a week. It rather scared me, and I wondered what it would lead to. Was it the right kind of business?

After I had seen that I went to our commercial manager and I said to him, "Mr. Eaton, the men who work on all our various operating companies understand kilowatt-hours. They understand we want the right kind of kilowatt-hours so that our load factor is not torn down."

"Yes, Mr. Insull," he said, "we are giving great attention to that."

That rather satisfied me.

You gentlemen have got a great opportunity before you. Bear in mind that one of the greatest charges against this industry is interest, and when the investment per dollar of income goes up, interest goes up. You gentlemen in the commercial departments, if you carry on your business based on good economic principles you can keep that interest down.

Again I congratulate you on the important part that your Section has taken in this Convention. I see in it that same ability for organization and negotiation of your Chairman which has been of such help to me in the last seventeen years. (Applause.)

CHAIRMAN SAMPSELL: That last sentence was thoroughly unexpected by me, but nevertheless has affected me very deeply.

It is our pleasure now to hear from another gentleman whose name is enough, Mr. C. E. Groesbeck, President of the Electric Bond & Share Company. (Applause.)

COMMERCIAL DEVELOPMENT

BY C. E. GROESBECK

President, Electric Bond & Share Company, New York

Vice-President Owens said when he entered this box yesterday that he was nervous, very nervous. I have never had an opportunity of standing in a pulpit or in the prisoner's box before. I will probably never stand in the pulpit. (Laughter.) If any of you think Mr. Owens was telling you an untruth, just come up here and take my place.

This convention has been, so far, the most interesting one I have ever attended. It has been such in my opinion because a large amount of the work has been devoted to the business development end of our business, that is, the commercial end, and, after all, it is the commercial work that makes all the rest go. If we do not have good commercial policies, if we do not get new business, and if that new business isn't profitable, the rest of us, the engineers, the management, the financiers of the company are helpless in our efforts to make our companies grow.

Getting back to this radio thing for a moment, this is my first experience, and I hope if this is going over well I will get a few post cards telling me so. (Laughter.)

Many interesting statistics have been presented to us. They are sometimes tiresome, but, after all, they form the background of our history and give us the basis for our work in the future. I do not know that the following facts have been brought out, so I am going to take the liberty of citing a few figures to you.

For the year 1917 the gross operating revenues from all of the central stations in the United States amounted to $521,000,000, while for the calendar year 1928 this figure was $1,980,000,000, an increase of $1,459,000,000, or 280 per cent from 1917 to 1928.

The light and power customers increased during this period from 7,178,000 (I will leave off the odd hundreds) in 1917 to 23,400,000 in 1928, an increase of 16,000,000, or 69 per cent.

The interesting thing to me—and I think it will be to you—is that while our consumers increased 69 per cent our revenues increased 280 per cent. Now we all know there have been very material reductions in rates during that same period, so I think this shows impressively the result of the work the members of this Commercial Section have been doing. The business per consumer has increased, rates have gone down. We have had a very satisfactory increase in number of consumers and a more satisfactory increase in dollars revenue.

Mr. Sloan gave us some very interesting capital expenditure figures this morning, but it must not be assumed by anyone that this increase of $1,459,000,000 or anything like that amount represents an increase in distributable net earnings. It is the increase in gross earnings, and a tremendous amount of new capital had to be expended to get that increase.

The census shows that in the year 1919 the total horse power required to operate all the industries in this country was 28,297,000, of which only 31 per cent, or 9,200,000 h.p. were driven from central station service. For 1928 the comparable figures are total horsepower for the nation 39,040,000, of which 19,144,000, or approximately 50 per cent of this power, was derived from central station service. In other words, over the period from 1919 to 1928 the use of central station power for industrial purposes increased from 31 per cent to 50 per cent—another very satisfactory showing for the members of this section.

All of this indicates that the commercial departments, the new business departments, of this industry have been doing a wonderful work. These figures also indicate, particularly the last figure I have given you, whereby we find that only 50 per cent of the industrial power used in the country today is from central stations, that we still have a tremendous job ahead of us. Most of our companies, I think, are well organized in their efforts to get after the industrial power, the motor load. It is big enough to be spectacular, and warrants special attention.

I am very interested in seeing that one of the principal themes of this convention is the building up of load factor on residential consumers. That is where we are going to get our most stable business. The residential consumer forms the backbone of our business. If times are bad, the industries may drop off and curtail manufacturing, curtail output, and consequently curtail the use of power, but the household use must go on, and does go on. The household business can be increased with much less new capital investment per dollar of gross earnings than usually can the power consumer, and that is very important to the company and to the financial end of the company.

The Inducement Rate

We have heard at this Convention much about the inducement rate. It is the thing that is going to encourage the more general use of electric appliances and electric energy in the household. It is a subject we should all give great thought and study to. Rates are closely involved with the question of politics and policies. The man who wants to attack the electric company and get some newspaper publicity starts in on the top rate. The nature of our business is such that it is very difficult to explain to the public and have them fully understand that we are rendering a service, and that we are not selling a commodity. The average man will understand what you mean when you say you want your dollar to earn interest all the year round, and not for two or three hours a day, and not on Sundays, but he overlooks the fact that we have got these dollars in plant and property, and that we must pay our charges on them, our interest and our dividends for twenty-four hours a day, 365 days in the year, whether he uses any service or not. He would like to pay on a kilowatt-hour basis, but in order to serve him on a kilowatt-hour basis we would, as you all know, have to charge small householders such a high rate that it would discourage or prohibit the use of appliances and even lighting, and would also subject us to very severe attack on the part of those who through lack of understanding or from ulterior reasons are prone to deal with top rates only.

The Political Factor

The political factor, the public relations factor of the inducement rate is to my mind just as important as the inducement of new business. If your top rate is 15 or 16 cents, and the people read in the paper that some large city is getting a 7-cent, or an 8-cent rate, the fellow that wants to attack you starts in on your top rate regardless of what the real facts and equities are. Considering the value from every point of view of our service our rates have always been attractive. We are still getting them down. We are rendering the cheapest service the householder gets, and we are now beginning to state our rate schedules in forms the householder can understand. Of course, we must protect our investment, and that means on these inducement rates a higher demand charge, or some sort of a fixed or minimum charge to protect us against the customer with a large connected load and a low load factor.

I am sure all the members of your Section, Mr. Sampsell, have all this in mind, and that they are all working accordingly. We can get more dollars of revenue with less capital investment from the increased use of these appliances; we can get a more stable business than from any other department of our industry. I hope your Section will foster this inducement rate, and work in conjunction and cooperation with the rate departments of the companies and of this Association to accomplish that end.

Thank you very much. (Applause.)

CHAIRMAN SAMPSELL: It struck me that perhaps some of you may not have arrived here early enough to see our President, and with the help of Mr. Insull who went out and recovered him (I saw him escaping), we brought him back to the platform. It is a great honor to introduce Mr. Arkwright, our President, to you.

PRESIDENT ARKWRIGHT: It has almost come to be an obsession with me this matter of having these meetings meet on time, move rapidly and adjourn shortly. I would not spoil that record by attempting to make any kind of a talk.

I merely want to call your attention to the fact that Mr. Sampsell was Chairman of the Commercial

Section before he was a Vice-President. The Nominating Committee of this Association selects ordinarily the Vice-Presidents, who, generally, if they behave themselves and are not found out, succeed to the presidency after a while, but this particular year one of the Vice-Presidents resigned and I nominated Mr. Sampsell myself. So I know he is a good one. (Applause.)

Also, by the time he gets to be President, when he has served the Commercial Section for a year and gone through all the others, he is going to be the best qualified President the Association has ever had.

I also am glad to be here to see the verification of what our idea was, that if we did not run these sectional meetings in parallel we would give opportunity to people to come where they wanted to come, and they would be here. Your presence proves the wisdom of that plan. I do not believe there has ever been so large an attendance at the Commercial Section. We are having a wonderful Convention. Everything seems to conspire for good.

A gentleman met me on the Boardwalk and said. "Arkwright, you certainly are in luck to have this wonderful new Auditorium open for your convention."

I said, "What do you mean luck? That wasn't luck, that was planned and designed. You don't think they could build this house in a night! We started it three or four years ago and finished it just in time for this convention, not too late for it and not too early that someone else could meet in it first.

"Well, it was designed. If you think it was an accident, then how do you account for the fact that it is located on Georgia Avenue?" (Laughter.)

Then he said, "The sun is shining brightly this week, and you know that must be an accident."

"Oh, no, not at all," I said. "Look at the electric lights we have, the wonderful lighting in the room, the great display of lighting on the Boardwalk. Why, the sun didn't want to be put to shame, and all day long he has been shining his brightest. No luck about that."

I only come to indicate the interest of the Association in the Commercial Division, and only for that purpose, and not to make a talk. I do not care what the industry is, or what the enterprise within it is, or how large it is, or what its past reputation is, or anything about that, if it loses, or if it doesn't possess an active, energetic spirit, it is on its last legs. I am firmly convinced of that, and I know, therefore, or, rather, I believe, therefore, that there is no more important activity in the electric light and power industries and its companies and this Association, than a continued, intelligent, energetic, enthusiastic commercial spirit throughout the organization. That is what you are engendering and pushing forward, and I come only to make acknowledgment of your contributions to the industry and this Association, and to thank you so far as I am permitted to thank you for it. (Applause.)

CHAIRMAN SAMPSELL: Now, another name, Mr. W. W. Freeman. Although he has many titles, it is my pleasure to introduce him as President of the concern where he does not get any money for bread and butter, The Society for Electrical Development. (Applause.)

THE ELECTRICAL INDUSTRY SALES CONFERENCE

BY W. W. FREEMAN,

President, The Society for Electrical Development, Inc.

Please understand at the outset that I am not in competition with the speakers who have preceded me. When these gentlemen can be brought together to discuss any subject, it is needless to have anybody follow them and undertake to say anything they have left out, or to add to what they have said. My task is slightly of a different character. They have undertaken to completely answer the why of this commercial problem, and I am certain that after you have heard them and the speakers at the previous sessions, no one can possibly raise the question of why we should be concerned in furthering our commercial activities.

The job that has been assigned to me for a few minutes, as I understand it, is to talk about the how of the problem rather than the why of it. Mr. Sampsell had the precaution to send me very specific instructions, stating what he was asking me to say at this afternoon's session, and taking no risk that I would not be advised as to these instructions, I have his letter stating at this afternoon's session of the Commercial Section, Mr. Freeman, President of The Society for Electrical Development, will discuss the present status of this plan, referring to the industry's sales conference plan; "its value as an agency for intensive development of our market; its advantages as a messenger of good will, and its far-reaching benefits to all elements in the electrical industry." With that as a text and my instructions, and with ten minutes allowed me, of course the task is easy.

I am also instructed to make a report concerning this industry's sales conference plan, and I have been handed since arriving here this morning a half dozen or so documents that might properly constitute that report. I have only been able to glance through them and pick three or four that I think should be mentioned as evidence of the rapidity with which this work has been carried on, taking into consideration its great scope and its importance.

More than a year ago the plan was conceived of forming an industry sales conference in which we could focus the experience and the judgment of the various branches of the industry in formulating an effective and sound plan for saturating the homes of our country as rapidly as may be possible with electric service. Each branch of the industry was invited by The Society for Electrical Development, that being the organization which seemed perhaps closest to these various branches of the industry by means of its structure, to designate official delegates to such an industry conference. Those delegates were appointed.

They found shortly after they began their studies that in their opinion they needed information which it would take time and money to acquire, but which in their judgment was essential to the formulation of a sound plan. That work was financed, and an agency was engaged to make a survey according to the ideas of the members of this conference. It took months to complete that survey. A report was submitted to the members of the industry sales conference, and by them to the directors of the Society under date of Jan. 16 last. I want to read just two extracts from the report of that survey:

Purposes of the Survey

"Among the specific purposes for which it was planned are the following:

"1. To learn the adequacy with which typical American homes are wired: ,

"2. To find the number and nature of electrical appliances in the typical household.

"3. To study consumer interest and appreciation of the value of electricity.

"4. To determine ways and means to develop a large market for electricity in the homes of America."

Here are five conclusions following the months occupied in making that survey in enough cities in the United States to represent really a cross section of the country:

"1. The American home offers a large, undeveloped market for wiring, electrical appliances, and an increased use of electrical current.

"2. There was no evidence that the housewives interviewed had ever been approached with any plan to introduce into the household the use of electricity in a comprehensive way.

"3. The appliances most aggressively advertised and merchandised had by far the widest distribution, pointing very definitely the way by which the market can be cultivated for much larger purposes.

"4. Inadequate instructions to educate the housewife in the effective use of the appliances she possesses is generally reflected in many abandoned appliances found in the homes.

"5. The absence of a rate graduated to volume is not only discouraging toward the acquisition of more appliances, but productive in many cases of bad feeling toward many of the central stations."

With a survey along those lines the industry sales conference undertook to prepare a specific plan for promoting sales in the household. They submitted that plan on Jan. 1. It developed in a discussion of the plan between the members of the industry sales conference, some 25 men, the best commercial men that could be picked, representing the several branches of the industry, and the directors of the Society, which also represented the various branches of the industry and had the benefit of the presidents and the managing director of each of the national associations on the board, that there was some difference in viewpoint, as one would naturally expect, with regard to certain features of the plan.

Subcommittees were appointed to discuss the matter further, a committee from the directors and a committee from the industry sales conference, Mr. Sampsell acting as chairman of those combined subcommittees.

Those committees made a report again to the directors under date of May 10, and further reported at another meeting which was held yesterday, and following those reports this resolution was adopted by the directors of the Society:

"On motion seconded and unanimously carried, the modified program as submitted was approved in principle, and the committee continued with Mr. J. E. Davidson added, with instructions to complete the advertising copy, supporting literature, the details of local tie-in plan; submit the complete plans to the several associations; make recommendations as to financing and proceed with the securing of the underwriting of the national fund required."

I must try to condense the rest of this in just as few minutes as I possibly can.

What I would like you to understand is that we are very near to the culmination of a very sincere and a very definite effort to focus, as I said before, the experience and the judgment of our industry in all of its branches, into the best, most effective, most definite plan which can be generally followed in our various communities in promoting increased sales of energy in the households of our country.

Approved Plan Will Be Definite

If this plan is not workable, it will be because the industry itself hasn't the capacity to develop such a plan. Any such suggestion as that is, of course, unthinkable because we know we have. This plan when submitted, as it will be in a very short space of time, for complete operation throughout the year 1930, will be definite and will have the specific approval, before presentation, of the official boards of each of the branches representing the various divisions of our industry.

It will be a plan which each of those divisions of the industry has passed judgment upon favorably. It will be specific and definite, and the how of solving this problem will be suggested so that it can be carried out in your discretion in each local territory.

We have had suggestions in past years of possible conflicting interests in the industry, that what the central station people think should be may conflict with the best interests of the manufacturers, or vice versa, or of the jobber, or of the contractor-dealer. If this plan which is submitted is not accepted in good faith by individuals in certain communities as not being in line with their best interests, it merely will mean that their judgment is in conflict with the judgment of the men whom they have placed in charge of the protection of their interests in their respective national organizations.

This program will represent an absolute agreement between these divisions as to plans that are sound, fair and reasonable, and plans which, if executed in good faith and with enthusiasm, will solve this problem that we are discussing.

I take very great pleasure, indeed, and very great pride in being able as the representative of these various interests to report the progress that has been made to date in the cooperative movement. The plan will be definitely presented, as has been stated, as soon as it is completed. Where we may fail in any of our local communities to realize the results that speakers have told us should be realized, the fault must rest upon the people in the various localities for their failure to take advantage of the judgment of the industry and of the tools which this Association, in cooperation with other associations, are prepared to furnish to them. (Applause).

CHAIRMAN SAMPSELL: With no desire to do other than exact justice to the gentleman who has just left the platform, I want to say that, when this plan is finally worked out and approved, it will be due more to him than to anyone else.

Mr. Earl E. Whitehorne of the Residence Kilowatt-Hour Contest Committee, will now announce the prizes.

AWARD OF PRIZES OF KILOWATT-HOUR CONTEST

By EARL E. WHITEHORNE

Residence Kilowatt-Hour Contest Committee

It is to be my very great pleasure and privilege to present $9,000 in prize money to the winners of the Commercial Section's Kilowatt-Hour Contest. To make the transfer of the money complete, and to demonstrate the fact that the Committee is letting go, no matter how much it hurts, I am going to ask those gentlemen who have been notified of their good fortune in this contest to come forward on the platform, please.

Two years ago at the Convention in Atlantic City the Commercial Section announced a contest to be participated in by Class A companies of the National Electric Light Association. The objective was to see how great an increase in average kilowatt-hour consumption per residence customer might be achieved by a competitive spirit in the industry. A purse of $9,000 was raised by small contributions from a large number of manufacturers who felt that this project would have a worthy influence.

Purpose of the Contest

There were two purposes in view. First, we wanted to focus the attention of the industry on the importance of the average annual consumption per residence customer as a measure of public service. Second, we wanted to stimulate a closer scrutiny, a closer comparison, between the average in one city and the average in another. The terms of this contest were as follows:

> That the competing companies should register with the Committee the average kilowatt-hour consumption per residence consumer, metered current, in their communities for the year 1927; then keep a record and report at the end of 1928 the average total kilowatt-hour consumption per residence consumer for that year. The greatest increase would indicate the greatest achievement. Companies competing were classified under three heads:
>
> Class A companies, those who in the year 1927 had an average total consumption per residence customer of 451 kw-hr. or over.
>
> Class B, those who had a total average consumption of 351 to 450 kw. per year.
>
> Class C, those companies who had an average consumption of 350 kw-hr. or under.

One hundred and fifty-seven companies participated in this contest, and the awards are six prizes, three first prizes of $2,000 each in cash, and three second prizes of $1,000 each in cash. The winners are as follows:

Cheney Power & Light Company

The first prize in the contest among the Class A companies, that is, the companies who in 1927 had an average of 451 kw-hr. or over, has been won by the Cheney Power & Light Co. of Cheney, Wash. This company, although operating in a small community, having a small number of customers, increased its average residence consumption from 491 kw-hr. to 686 kw-hr., a total increase in the year of 195 kw-hr. (Applause). I might say that this company entered the contest with considerable misgivings, because they had only 336 residence customers, but by the enterprise and energy that they displayed, and the good work that they did during the year, this result was achieved.

San Joaquin Light & Power Company

The second prize for the Class A companies was won by San Joaquin Light & Power Co. of Fresno, Cal., with an increase of from 625 kw-hr. in 1927 to 724 kw-hr. in 1928, a total increase of 99. (Applause).

In this class honorable mention is extended to the Portland Electric & Power Co. of Portland, Ore., for an increase from 760 kw-hr. in 1927 to 853 kw-hr. in 1928, a total increase of 93. (Applause).

Alabama Power Company

In the Class B group, being those companies whose average in 1927 was between 351 to 450 kw-hr., the first prize has been won by the Alabama Power Co. of Birmingham, Ala., for an increase of from 433 to 496, a total increase of 63.

Western Public Service Company

The second prize in Class B goes to the Western Public Service Co. of Scottsbluff, Neb., for an increase of from 387.3 in 1927 to 449.1 in 1928, or a total increase of 61.8. You will see that they are very close to the record of the Alabama Power Co.

In this Class B honorable mention is extended to the Durham Public Service Co. of Durham, N. C., for an increase from 437 in 1927 to 495 in 1928, or a total increase of 58. Honorable mention is also extended to the Southern Colorado Power Co. of Pueblo, Colo., with an increase from 387 to 441, or a total of 54.

Central Power & Light Company

In this competition between the Class C companies, that is those companies having in 1927 an average of 350 kw-hr. a year or under per residence consumer, the first prize is awarded to the Central Power & Light Company, of San Antonio, Tex., for an increase of from 256 to 415, or a total increase of 159.

Western Public Service Company (Texas)

The second prize goes to the Western Public Service Company, of Beaumont, Tex., with an increase from 264 to 367, or a total of 103.

Honorable mention in this class is extended to the Annapolis and Chesapeake Bay Company, with an increase from 331 to 431, or a total of 100, and to the Montana Dakota Power Company, of Minneapolis, Minn., with an increase from 314 to 398, or a total of 84. Honorable mention goes also to the Michigan Electric Power Co. of Lapier, Mich., for an increase of from 331 to 412, a total of 81. (Applause).

There will be published very shortly a complete report of this contest, in which will be listed the names of those manufacturers too numerous to read here, who have so generously provided the fund for this contest.

Analysis of Contest

There are one or two points I would like to make in closing. First, an analysis of this contest has shown that those companies that have recorded the best achievements have been those that were particularly fortunate in having the heartiest kind of executive support. Also, in every case, employee interest in the campaign was actively solicited. Every company who did an outstanding job was hitting on all six. By "all six," I mean these six selling points which seemed to be particularly stressed as effective in this campaign:

1. The stressing of heavy load builders.
2. Increasing the wattage of sockets.
3. Consistent, continued, cumulative campaign effort.
4. Coordination of home service department in these contacts with the home-maker.
5. An effective and consistent program of advertising.
6. A hearty and healthy degree of dealer cooperation.

I have here the checks. Is the representative of the Cheney Power & Light Company present? (Not present.) Then there's $2,000 left over for the committee.

Is there a representative of the San Joaquin Light & Power Company present? (Not present) Ah! another thousand for the committee!.

Alabama Power Company? (Not present) Now that's too bad. Where's our old friend Ash. Collins?

Western Public Service Company, Nebraska? (Present.) Well, that's better. I take great pleasure in presenting this prize to you, and I congratulate you, sir. (Applause).

Central Power & Light Company? (Present.) I take great pleasure in presenting this prize to you, and I congratulate you, sir. (Applause).

Western Public Service Company, Tex? (Present.) Splendid. I take great pleasure in presenting this prize to you, and I congratulate you, sir. (Applause).

CHAIRMAN SAMPSELL: I have asked Mr. J. E. Davidson to announce the winner of the Federal Electric Company's prize of $1,000 given for the best promotion of electrical advertising. After all, the success of this Section is largely due to the two hard years Mr. Davidson put in as Chairman, and to those put in by Mr. Lloyd and the respective predecessors. Mr. Davidson!

AWARD OF FEDERAL ELECTRIC COMPANY PRIZE

By J. E. DAVIDSON

President, Nebraska Power Company, Omaha, Neb.

The field of electrical advertising offers one of our major opportunities to build commercial load. The liberal offer of the Federal Electric Company to stimulate further interest in this phase of our lighting and sales work was, therefore, willingly accepted.

The Federal Prize is a Gold Medal to the Company, and $1,000 to the responsible individual of that company who made the greatest contribution to the promotion of electrical advertising in any one year.

As happens in most contests, my associate judges, Mr. Paul Holister, of Batten, Barton, Durstine & Osborn, advertising advisers, Mr. Earl Whitehorne, of the *Electrical World*, and I had difficulty in determining the winner. However, we were unanimous in our decision in declaring as winner a company that we often find in the prize-winning column of other achievements, the Edison Electric Illuminating Company of Boston. (Applause).

A close competitor for this honor was the Electrical Advertising Division of the Penn-Ohio Edison Company, which received honorable mention, and we cite the commendable activity of the New York Edison Company.

As chairman of the Judges, it becomes my pleasurable duty to award a gold medal to the Electrical Illuminating Company of Boston, represented here by its President, Mr. Charles L. Edgar, and to present a check of $1,000 to Mr. R. B. Brown, head of the Electrical Advertising Division of that Company. (Applause).

I wish that I might have the descriptive powers of Graham MacNamee so that I could describe to you the beauty of this gold medal. I might say in passing that it is so heavy that should I carry it into Wall Street I am sure it would have a stimulating effect on the stock quotations. (Laughter).

It is a very great pleasure to hand this medal to a gentleman of our industry who has done so much over a period of years, not only for the National Electric Light Association, and the Association of Edison Electric Illuminating Company, but also for his own company that has had an outstanding record for many achievements and operations in selling its service and merchandise.

It is with great pleasure, Mr. Edgar, that I present to you this beautiful medal.

Before I leave this "pulpit" I shall present to Mr. R. B. Brown the check for $1,000. I congratulate you both.

MR. CHARLES L. EDGAR: It is needless to say that we are greatly pleased that the Federal Award should be given to my company. In the promotion of the use of electrical advertising in our territory we have not alone directly promoted the use of the electric sign, but have taken every opportunity to improve the status of the sign manufacturers and our cooperation with them. Our local Associated Sign Craft have aided in every way in all our promotional activities, and we feel that the success is in a great measure due to our friendly relations with this group.

We thoroughly believe that at no time in the history of our industry has there been such an opportunity for commercial development as at present, and we will consider our achievement this year not a finished program, but part of a continuous business-building effort.

I accept this medal with a great deal of satisfaction. I am going to take it home with me and put it alongside the Coffin Medal which we were fortunate enough to win two years ago. I do not know what Mr. Brown is going to do with his $1,000, but as far as I am concerned he is instructed to divide it between himself and his eight or ten associates who actually have done the work.

I thank you. (Applause).

Nominations

CHAIRMAN SAMPSELL: Mr. M. C. Huse, will you kindly report for the Nominating Committee?

MR. M. C. HUSE: Mr. Chairman, your Nominating Committee has been given the task of submitting fifteen names from which will be elected the officers of the Commercial National Section. The names are as follows:

Marshall E. Sampsell, Central Illinois Public Service.

J. E. Davidson, Nebraska Power Company.

S. L. Nicholsen, Westinghouse Electric Mfg. Co.

T. O. Kennedy, Ohio Public Service.

C. L. Harold, Brooklyn Edison Co.

A. C. McMicken, Portland Electric Power Co.

M. E. Skinner, New York Power & Light Co.

M. C. Huse, Philadelphia Electric Co.

A. K. Baylor, General Electric Co.

A. P. Good, Commonwealth Edison Company.

H. C. Thuerk, Associated Gas & Electric Co.

J. Daniels, Edison Electric Illuminating Co., of Boston.

J. L. Pollard, Pacific General & Electric Co.

F. D. Pembleton, Public Service Electric & Gas Co., of Newark.

V. M. F. Tallman, Charles H. Tenney & Company.

CHAIRMAN SAMPSELL: You have heard the report of the Nominating Committee. Do I hear a motion for its adoption?

[A motion was made and seconded.]

CHAIRMAN SAMPSELL: Are there any other names to be submitted from the floor as provided by the Constitution? If not, all in favor of the motion, properly seconded, will please say "aye." It is adopted.

I should like also to have a motion thanking Messrs. Swope, Insull, Groesbeck and Freeman, with their appropriate initials and titles, and also our President, for the words of advice and encouragement they have given us this afternoon, in order that we may have the lasting record of their interest in this Section's activities.

[A motion was made, seconded, and carried to thank the above-named gentlemen for their contributions to the Commercial Section.]

CHAIRMAN SAMPSELL: Unless there is objection, the meeting stands adjourned.

The meeting adjourned at 5:30 p.m.

ENGINEERING NATIONAL SECTION SESSION

ENGINEERING NATIONAL SECTION SESSION

TUESDAY, JUNE 4, 1929

[The meeting convened at 3 p. m. in the ballroom of the Atlantic City Auditorium and Convention Hall, Atlantic City, N. J., Mr. E. C. Stone, Chairman of the Section, presiding.]

CHAIRMAN STONE: I will ask the meeting to please come to order.

The first thing I have for you this afternoon is that we are honored by the presence of our President, Mr. Arkwright, and I am going to ask Mr. Arkwright if he will be good enough to say a few words to us. Mr. Arkwright! (Applause.)

PRESIDENT ARKWRIGHT: Having known Mr. Stone and watched his work, I will swear to whatever he says, because I know it will be true.

This is the first meeting of the Engineering Section that I have attended. I don't want you to think that is because of a lack of interest. Perhaps it is a shrinking due to the feeling that I don't know the business. When I first went into the electric light and power business it came as a very great surprise to me, and I said, "Why, no, I can't take the job; I don't know anything about the business." And the gentleman who owned the company said, "All right, you don't need to know anything about it; we will get a lot of engineers who do know about it, and they will run it for you." So it is that whatever we may say about the other branches of the business we all know that this business primarily rests upon the engineers. There is no question at all about it.

While I say I feel a lack of knowledge of the business because I haven't the engineering talent or engineering education or comprehension of what is necessary in so technical a business, I think the engineer maybe sometimes labors under the handicap of knowing too much about the business. I don't think that everybody should be a speaker. I really think sometimes that it gets to be a disease, this speaking stuff. I don't know that I care very much for the engineer orator, if that is all he is. Nevertheless it is also true that if you know a matter very thoroughly, are extremely familiar with it, you think everybody else ought to be familiar with it. Consequently, it isn't worth telling.

At times when I have wanted to talk about my own business down home I would naturally go to the engineer to find out something about it, and I would almost have to take a corkscrew to him to get it out, and when I did get it out I found something of intense general public interest, of the romance of the business that was useful to tell the public.

So I say that it is pretty bad not to know enough about the business, but sometimes maybe we suffer a little handicap from knowing too much about the business. Which brings me back to the statement that perhaps only applies to talking about it. Sometimes people who talk about things seem to get the impression that talking about them is doing them—no such thing. We can't get along in business except by the doing of the business, and for that we look primarily to the engineers. The advance in this business did not come from any other department, fundamentally, except the engineering. The type and the character of the business is such that always and forever the greatest advance in this business is going to come from the knowledge, the experience and the devotion of engineers who understand and work and plan.

Thank you so much for letting me talk to you. I wish to express my appreciation to you for your contributions, not only to the industry but your devotion to this Association and all its members through the work you have done in all the years, and especially in this one. Thank you very much. (Applause.)

CHAIRMAN STONE: In accordance with the Constitution, the Executive Committee of the Section has appointed a Nominating Committee, who will report at the close of this meeting and submit the nominations covering fifteen members of the Association, from which names the officers for next year will be selected. The Nominating Committee appointed consists of C. M. Allen, Chairman; Howard Cole, R. F. Danner, R. D. DeWolfe, and B. E. White.

Before proceeding with the rest of our program I will call upon one of our Past Chairmen of the Engineering Section, Mr. Moultrop, for a resolution which he has. Mr. Moultrop!

MR. I. E. MOULTROP: Mr. Chairman and Members of the Engineering Section, I want to speak of the sad loss that one of our old and valued members suffered a few days ago. I refer to the death of Mrs. A. D. Bailey, which occurred in Chicago through an automobile accident on Decoration Day.

Now this suggestion may be a little bit out of place, but in view of the fact that Mr. Bailey is one of our old members, almost one of the original members, a Past Chairman of the Prime Movers Committee, and the Vice-President of this Section, it seems to me it would be very appropriate at this time for this body to pass a resolution of sympathy to be sent to Mr. Bailey on the matter of his sad misfortune.

Mr. Chairman, I move you that that resolution be forwarded to Mr. Bailey, the exact wording to be prepared by some one who is gifted in saying the right thing in the right way.

[The motion was seconded, was put to a vote and carried.]

CHAIRMAN STONE: I am told that in London there are 38 different kinds of electric power for sale in different parts of the city. I am also told that the per capita use of electric power in London is something less than half of what it is in New York. I believe the two things go together largely, although, of course, there are other factors in the situation.

The standardization in the power industry that has gone on over the past years has certainly been one of the very important factors in bringing about the enormous development that has taken place, and I am therefore very glad to have on the program today a talk on the Practical and Economic Aspects of Standardization. The speaker is, I believe, the man in our National Electric Light Association who is best fitted to discuss this subject because of the fact that he has been associated with it from some of its earliest manifestations, and has very closely followed the developments in standardization, and has been a very important force in bringing about much of the useful standardization that our industry has accomplished.

I am very glad, therefore, to present to you Mr. L. L. Elden of the Edison Electric Illuminating Company of Boston. Mr. Elden! (Applause.)

PRACTICAL AND ECONOMIC ASPECTS OF STANDARDIZATION

By L. L. ELDEN
Technical Advisor, The Edison Electric Illuminating Company of Boston

Standardization is not new in industry, although the intensive efforts of recent years are indicative of new interest in this subject.

Competition for industrial and commercial supremacy has forced a new order of things, in that production and marketing methods have been developed on a scale hitherto unapproached in business life.

In most standardization work it is difficult to distinguish between simplification and standardization, yet in the end it is a combination of both, coupled with methods for eliminating waste, that prove to be fundamental factors underlying the success of most undertakings.

Many standards are temporary and subject to change to conform with progress in any art or industry. To accept as final any given development would be fatal to national progress. Research and invention will ever continue to develop new materials and processes, which in their commercial applications will displace many existing standards in favor of newer methods.

Under the present high pressure urge to extend standardization to include every possible activity, material progress is being made toward the desired end. Through the cooperative efforts of international and national organizations, societies, corporations and individuals, standardization is being continuously extended into new fields of endeavor, with results which must in the end favor the ultimate consumer.

Early Standards Utilized

Critics who for various reasons deplore the slow progress which is being made toward complete standardization appear to lose sight of past accomplishments, or the extent to which early standards are still utilized. The adoption of standard gages for railroads and vehicles were events of national importance in the light of later experience. Standardized steel products, now indispensable in all construction work, quickly revolutionized many processes upon their introduction, following the invention and development of modern methods of producing steel.

The old time lamp wick still enjoys extensive use in oil burning devices, as does the open flame gas burner in its respective field, where it has not been replaced by the more efficient mantle burner.

Bolts, nuts, screws, nails and tacks still retain the general appearance of their early days, although new manufacturing methods have refined and cheapened these products to a remarkable degree.

Writing materials, ink, paper, postage stamps, our national currency, and tables of weights and measures, all long since standardized, are continued in daily use without a thought of their status in the field of standards.

Governmental and other agencies have largely standardized almost everything that comprises the home, including the materials used in its construction, the clothing we wear, and the food we consume. Even the humble cow must provide milk conforming to prescribed standards, or she is taboo.

Examples of both existing and obsolete standards might be multiplied indefinitely without further effect other than to present more evidence of tangible results which have already been accomplished in work of this character.

Turning to the present we find in the telephone, our sister industry, the most highly standardized undertaking in the electric utility field anywhere in the world. This status has been reached by successive steps, only, as the result of intensive research and experimentation by a highly trained organization, without which the present day perfection of communication facilities could never have been attained.

Lack of standards during the first thirty years of the electric light industry was undoubtedly responsible for serious losses in many directions. This situation was but the natural outcome of independent development of systems and apparatus in a new industry.

The combination of numerous frequencies and voltages, direct and alternating currents, series and multiple systems, and overhead and underground distribution methods, were handicaps which would have destroyed almost any other new industry. In this case, the world-wide desire for better illumination provided the necessary incentive to continue development work in the hope of ultimate reward.

Minimum Number of Types

Most of these troubles are now behind us. The adoption of sixty cycles as a national standard, supplemented by twenty-five cycles for special applications, solved the frequency question and paved the way for the development of systems and standardized equipment on a scale even now unapproached elsewhere in the world. Concentration upon a minimum number of types of systems for generation, transmission and distribution, and the elimination of the many odd and special voltages utilized in early practice, have been contributing factors to present success.

With these fundamental factors established, progressive standardization has followed in other branches of the business, all designed to secure maximum operating efficiency.

For steam plants the designs and construction of boilers, piping, fittings, and associated equipment have been reduced to definite standards through the creation of standard specifications.

The designs of generators, converting and switching apparatus, and overhead and underground construction have also been more or less standardized at intervals in recent years, although such standards have been subject to frequent changes to keep pace with a rapidly changing industry.

Insistence on special designs and failure to adhere to the use of existing standard apparatus have materially retarded efforts toward standardization in many directions. In view of such success as has been attained in recent years it may be of interest to comment upon some outstanding examples of standardization which have been of major interest to utility interests and their customers.

Incandescent Lamps

The present day incandescent lamp is perhaps one of the best known examples of accomplishment through standardization. Progress in this work from the days of the carbon lamp has been reflected, insofar as public interest is concerned, in a steady improvement in efficiency accompanied by heavy reductions in selling prices.

Efficiencies of one-half to one watt for modern lamps may be compared with five and six watts or more per candle for early carbon lamps. Selling prices have been reduced 53 per cent since 1914, and 50 per cent since 1920. Two 40-watt lamps, for example, may now be purchased for the price of one in 1920.

Important factors in this accomplishment included the adoption of the Edison screw base as a national standard for lamps, sockets and fuses. A single standard base thus replaced twenty-six types of bases.

Standardization of lamp voltages within a range of 100 to 130 volts in 1914, reduced the number in common use from 20 to 5. Similar action in 1924 further reduced this number to three.

A new standard line of internally frosted lamps, comprising five or six units, introduced in 1925, replaced 45 individually different types of lamps then in general use.

Concentration of demand on a few types and sizes, the extensive use of automatic machinery, and the introduction of mass production methods have in this instance, as in many other lines of business, effected large reductions in the cost of the manufactured product.

Recording Wattmeters

Twenty-five years of intensive effort in the development of recording wattmeters have produced the present simplified and standardized product. This work has involved the closest cooperation between manufacturers and utility interests in order that meters might be produced which would be accepted as country wide standards for general use. This policy is in direct contrast with foreign practice where it has been customary for different countries and even individual companies to require meters of special designs. Under our national program, meters have become a thoroughly standardized product embodying many features contributing to substantial savings in all directions.

Interchangeability between the product of different manufacturers has been secured through the adoption of designs embodying uniform dimension and terminal chambers.

Marked improvement in the appearance and safety of modern meter installations, and appreciable reductions in installation labor costs, have been effected through the utilization of other standard materials including standard switches, cutouts, connectors, and last but not least, identified wiring.

Refinements in design have added materially to the speed and accuracy of calibration in the shop and field.

Meter performance has been so improved that a high degree of accuracy is maintained under overloads of three to four hundred per cent. Temperature compensation is so perfect that the effects of high and low ambient temperatures at meter locations may be disregarded. Meter overload capacities for short time loads have been substantially doubled.

Potential coil losses in the most used sizes of meters have been reduced from two and one-half watts to one watt. In a large system with 1,000,000 meters, such a reduction is equivalent to a reduction of 1500 kw. in the generating capacity required to energize the meters, and over 13,000,000 kw-hr. in the non-productive annual output of the system.

In the face of enormous development costs, the average selling price of a-c meters has been reduced from $11 to $9. On an annual production of 1,500,000 meters, the saving to purchasers of this single commodity reaches $3,000,000.

Transformers

Distribution transformers have undergone many drastic changes in design before reaching their present day perfection. To effect desired standardization and meet changing operating requirements, air-cooled transformers have been largely superseded by oil-cooled types, sheet steel has replaced cast iron cases in many sizes, special steels have been developed for core structures and many electrical and mechanical features introduced to improve transformer product as a whole.

New insulating materials have replaced inferior types, some of which were unsuited for use in conjunction with modern insulating oils. Electrical and operating characteristics have been steadily improved until standardization of performance characteristics and tap connections to conform with recently approved voltage standards appears to be all that is required to complete the standardization of this product.

Voltage standardization has been an important factor in transformer development through making possible substantial reductions in the number of sizes and types of transformers regularly manufactured. Through the joint action of N. E. L. A. and N. E. M. A. interests in 1924 in agreeing upon a schedule of standard voltages, a reduction of 50 per cent in the number and sizes of ratings was affected.

For this greatly improved product, selling prices have been steadily reduced to about 42 per cent of 1896 prices and are now only about 7 per cent higher than 1914 costs in the face of higher general costs now prevailing which exceed 1914 costs by 46 per cent for raw materials, 72 per cent for living costs, and 140 per cent for cost of transformer labor.

Motors

Motor standardization has long been required for economic reasons. Recent progress in this direction has fully justified the extended efforts which were required to secure general agreement upon satisfactory performance characteristics and rating methods controlling the design of the great bulk of motor production. Settlement of the long standing controversy between advocates of 40 degree versus 50 degree bases of rating, by the adoption of a single standard of 40 degrees plus a service factor, as the future basis of motor rating paved the way for general standardization.

Selling prices of motors now reflect in part the results of this work, for example, three one horsepower general purpose motors cost slightly less than one similar motor in 1902. Another example is the well known one-quarter horsepower washing machine motor costing $25.00 in 1921, which now sells for $9.50.

In this development nothing has been taken away, but on the contrary operating characteristics have been improved through improvement in efficiency and power factor, features of the utmost importance to both utility and consumer.

Manufacturers have recently concentrated their efforts upon a simplification program directed at standardization of motor parts and dimensions. In a single step one manufacturer reduced the number of bearing sleeves required for its product onehalf and in a final adjustment now requires but fourteen sizes for thousands of motor ratings.

All such developments make for volume production with favorable effect upon the entire product even though the output of certain individual units contributes little to the output as a whole.

Rating Standards

The rating of electrical machinery is one of the most important problems before the industry. Failure to adopt methods of rating which will insure the maximum possible output for a given investment results in an economic loss to all concerned. Temperature being for the most part the limiting factor in the performance of all electrical apparatus, standards have long been established, indicating the maximum temperature at which various types of insulation may be safely operated, as determined by standardized methods of temperature measurement. These standards while primarily designed to be utilized for test and guarantee purposes, have also been regularly employed to control the loading of apparatus in service to the disregard of existing temperature conditions favorable to securing greater output.

Under pressure of utility engineers, previously existing standards have been modified to provide supplementary ratings for apparatus under "service conditions." Recognition of this principle, as already applied to general purpose motors and transformers, permits an increase in the rating of these specific classes of apparatus, ranging from 15 per cent upward under prescribed temperature conditions.

The inclusion of "service ratings" in all rating standards based upon limiting temperatures, should engage the attention of all standard making interests, pending the time when rating standards based upon maximum temperatures may be properly substituted for prevailing methods.

Voltage Standards

The establishment of voltage standards has been of paramount importance to every branch of the electrical industry. Even the earlier indecisive efforts in this connection were important in their effect on lamp production and the development of appliances and much of the vast array of apparatus now in general use.

Concentrated efforts on this general problem have finally resulted in an agreement upon a new basis for voltage standardization which recognizes for the first time in the history of the industry the various steps in voltage regulation from power house to the consumer, which are necessarily encountered in actual practice.

These standards as now constructed are primarily based upon delivered voltages and, therefore, include specifications for primary and secondary transmission and distribution voltages with the necessary tap connections required under standard operating procedure. Under this program we may anticipate rapid concentration upon the use of not more than two lamp voltages under conditions which will react favorably upon the design and operation of a multitude of miscellaneous appliances and kindred apparatus.

International standardization of voltages appears impossible at the moment, largely due to long standing differences in national practices which now preclude wholesale changes in construction and operating procedure to secure international agreement on this question.

Miscellaneous Standards

Further examples of electrical standards which have been developed to overcome obvious defects in equipment and system operation, incident to the prevailing large scale development of the industry, would include many individual undertakings of this character.

Cable insulations have undergone complete revision, insulators for high tension service have been redesigned, switch performance and design have been improved, and insulating oils for transformers and switches have been reduced to a common standard which is approved for general use in a vast amount of equipment within prescribed voltage limits.

Various organizations working in special fields have created standards which have assumed national importance. Prominent in this field is the Board of Fire Underwriters whose work in developing standards for wiring and wiring equipment is well known to all.

To those who are familiar with efforts of this character it will be evident that such a list could be expanded indefinitely to cover actual accomplishments.

Standardization to be effective naturally requires the closest cooperation between affected interests and in this respect utility interests may be well satisfied with their participation in this work.

From the very nature of their position it has been necessary to evaluate the merits of almost every new piece of apparatus by actual trial on their respective systems. While their contributions have been large through personal effort, and absorption of the cost of development and experimental work in the cost of apparatus, it has only been through actual use under service conditions that the merit of most equipment has been demonstrated.

From this "cut and try" experience numerous constructive suggestions have been advanced by utility engineers and it has been their continuing spirit of cooperation and compromise that has led to the approval of those acceptable standards which are controlling factors in the advancement of the industry.

So far, attention has been directed to certain examples of standards which affect quality, performance, and finally the cost factors of products in their particular fields.

There remains a vast array of miscellaneous standards which deal with processes, dimensions, materials, and construction, or take the form of specifications, rules, regulations, and codes. Each has its appropriate application, but whether its existence is justified or not depends largely upon the economic advantages derived from its use. We may view many standards with unmixed satisfaction, knowing their effectiveness in application, while others less productive of good results may be appraised upon a less favorable basis.

In the matter of safety codes designed to reduce life and property hazards, no one will dispute the desirability of such guidance, yet the inclusion of mandatory provisions governing construction details may require excessive investment for outweighing any possible advantage secured through their use. Failure to control the personal equation has been a fatal weakness in most safety code standards.

On the other hand, regulations requiring standard coupling and breaking systems for railroads and uniform braking and gear shift controls for automobiles have been welcomed as a national asset promoting the safety of the general public.

In the preparation of standards designated as "Codes," the present tendency to resort to details or to prescribe specific construction methods detracts materially from their merits. Standards of this character should preferably contain no mandatory provisions and be limited to general recommendations if they would be of practical value. The administration of mandatory codes by local authorities inevitably leads to conflict and losses through inability to take advantage of improved methods not recognized in a prevailing code standard.

The advantages derived from simplification and elimination of waste in any undertaking should be too well known to require enumeration at this time.

The manufacture of munitions during the late war furnished an outstanding example of the adadvantages derived from simplified manufacturing processes in developing volume production.

Business Procedure and Processes

Standardization of business procedure and processes has not infrequently restored a failing business to prosperity. The success of the Pullman Company has been built upon standardized construction and service methods. In the automobile field the name of Ford has long been synonymous with efficiency and simplification in manufacturing and marketing processes. Waste materials early claimed his attention and in this phase of his operations he came to emulate Swift and Armour in their utilization of waste products.

Certain undertakings, for example, the gas, copper and oil industries, have found the development of marketable materials from otherwise waste products a practical means of increasing revenues.

Standards, to be useful, must be practical and capable of application. No standard should be created until its need is fully justified. Economies or other favorable developments should follow their adoption. Standards once established should be adhered to in practice, as long as they are useful.

The continued requirements for special apparatus often indicate failure on the part of many engineers to recognize the advantages of standard equipment.

Important manufacturers of electrical apparatus report that orders for specials constitute 50 per cent of their operations. A full realization of the costs involved, and injury to the interests of the purchasers, should lead to an early discontinuance of this practice.

Standardization must continue at all events if for no other reason than in self defense of our national institutions and personal welfare.

Foreign countries now engaged in rehabilitating their business interests through the prosecution of intensive standardization programs, will inevitably become formidable competitors in the future when the full benefits of their present efforts are fully reflected in the cost of their products.

With all that has been done in our own industry, many important projects require further study and possible standardization. Rating standards, switching apparatus, high tension insulator design and performance, lightning protective equipment, distribution systems and their allied devices, cable insulation, insulating oils, appliance performance, service regulations, and motor rules, are all projects warranting continuous efforts toward complete standardization.

The cost of prosecuting this work is high, involving the time and efforts of hundreds of individuals supplementing annual expenditures variously estimated at from $8,000,000 to $10,000,000.

Standards may be nothing to enthuse over, yet there is a considerable measure of satisfaction in viewing past accomplishments in the standardization field. It is apparent on every hand that this work has already contributed to the welfare of the ultimate consumer and the public at large in such a liberal measure as to warrant recommendations for continued support and prosecution of standardizing activities on behalf of the electrical industry.

I thank you. (Applause.)

CHAIRMAN STONE: One of the many results of the extremely rapid growth of power systems particularly since the war, has been the discovery of the necessity for planning ahead for future system development. One of the first companies to see this situation and to take advantage of the possibilities of it was the Detroit Edison Company, and I am therefore very glad to be able to present to you this afternoon the man who has fathered the handling of this subject and the development of systematic planning in the Detroit Edison Company ever since its inception some tyears ago.

Mr. A. C. Marshall will speak on the subject, "Shall We Grow Like Topsy or According to Plan?" Mr. Marshall! (Applause.)

SHALL WE GROW LIKE TOPSY OR ACCORDING TO PLAN?

By A. C. MARSHALL

Vice-President and General Manager, The Detroit Edison Company

American business today is a science, and the successful business man is a real scientist whether he knows it or not. A manufacturer asked a college professor how science could help business, and he replied, "Where would the suspender business be were it not for the law of gravitation?" (Laughter.)

The public utility business is a science, and the successful utility man is one who studies his business from the scientific viewpoint. In any such study there are two ratios that stick up like a sore thumb. The first is the investment per dollar of earnings, and the second is the operating ratio, or the ratio of direct operating expense to gross earnings.

While these two figures are vitally tied into the prosperity of a company, still they are independent figures. Changing one does not necessarily change the other, but conditions of solvency sometimes require that if one is changed, the other must be.

Consider for a moment the first figure, the total investment per dollar earned. In water power systems this will be higher than where steam generated power is used. But in such water power companies the operating ratio is low, so a return can be earned on a larger investment per dollar of earnings. In companies of which all or a large part of the output is generated by steam, the investment is about four to five dollars for every dollar of annual gross earnings.

My first point is that there are developments in the industry tending to increase this figure, in spite of rapidly growing earnings. Contrary to the opinion of some executives, I believe an increase is a very real possibility. There is an increasing amount of necessary expenditures especially in our larger cities that do not bring in a cent of additional earnings. Some of these are as follows:

A. Replacing poles and overhead wires with underground lines in greater and greater areas, not only in the congested downtown districts, but in more and more cases of rather important streets throughout the city.

B. Cost of better and more ornamental substation buildings to conform to high grade residential or commercial environments.

C. The increasing necessity for reliability of service requires expenditures continually for better equipment, more stand-by or reserve in lines and stations, and better relay protection. This greater reliability is necessitated by the development of new uses for power, such as the use of oil burners, refrigerators, and ranges in residence service; and increased use of power for heat treating and basic processes where an interruption will result in large loss, in addition to the mere loss of time and output. We can no longer look with toleration on even comparatively short interruptions in residential or industrial service.

D. The trend in all industry toward replacing man power with mechanical power is being felt in our own operations. In other industries this change results in great benefit to our business, as every such move requires a greater use of mechanical power which it is our business to furnish. In our own operations, while it may result in decreased operating expenses, it also increases the investment per dollar of earnings. This change is going on not only in outside plants, such as the development of automatic substations and water power plants, and automatic equipment like post hole diggers for maintenance work, but in other departments as well. Mechanical accounting devices are an illustration. Our accounting departments are beginning to look like fine machine shops, and the end is not yet.

E. The large capacity of our interconnected systems has increased the duty on circuit breakers and other equipment. This has required increasing expenditures for larger and better circuit breakers, the cost of which has risen following an alarmingly steep curve.

F. The lure of greater economy of generation is leading power plant designers to constantly strive after higher steam pressure and temperature and to incorporate more and more new and costly features. The result is that in spite of 150,000 kw. turbines, the total cost of power plants per kw. does not seem to be decreasing.

Two Classes of Expenditures

It will be noted that these expenditures fall into two classes. None of them contributes to earnings, but those in one group do result in lower operating expenses, while the others do not, or at least do so in a very indirect manner. These latter are contributions to civic improvements or to the requirements of a higher grade of service.

It is admitted that there are a few developments tending the other way. That is, toward getting increased earnings from the same investment. Residence service is promising. We certainly expect to increase materially the annual sale of kilowatt hours per residence customer. Here again, however, the electric range, one of the most promising sources of increased revenue, requires a considerable increase in investment to service it satisfactorily. The refrigerator and oil burner are almost pure gain, as they require very little, if any, additional equipment. But earnings, in dollars per residence customer will not increase as fast as the kw-hr. consumption. The kw-hr. sales will increase because of lower rates. As an extreme example, in one water power city the average annual use of all residence customers in 1928 was 3384 kw-hr. but the average rate was so low that the earnings per customer were less than $30 per year. This adjustment of rate or of rate form to increase residence consumption is good business, and we can well afford to do it, but it may not go very far toward reducing our investment per dollar of earnings.

So I still think that on the whole the developments tending to increase the investment per dollar of earnings are going to over-balance the contrary tendencies, and there is almost surely going to be a net increase in this figure during the next ten to twenty years. Those utilities now attempting to make forecasts for ten or more years confirm this opinion.

How to Offset the Increase

Assuming then for the sake of the discussion that the total investment per dollar of earnings is going to increase for some years to come, a serious question arises as to how this is to be offset. If we want to retain approximately our present return on total investment, there is just one remedy. That is, a reduction in the operating ratio. This is the ratio of direct operating expense to gross earnings; as usually used the operating figure includes taxes, but no appropriations to depreciation or retirement reserve. Expressed as one figure, it is the amount of every dollar of earnings that must go for this direct operating expense. It is usually lower for water power systems than for companies generating their power by steam. For the latter type of companies, the ratio will probably fall between 50 and 60 per cent.

There seems to be no way of getting around this fact that, if the investment per dollar of earnings increases, to earn the same return on the investment the operating ratio must fall. Like all ratios, this value can be altered by changing either term of the ratio. We can reduce the operation ratio either by reducing operating expense or by raising rates. You will remember the story of the sick darkey, as told by our old friends, the two Black Crows. He was advised by his doctor to eat chicken broth every day, and stay in nights, "and everybody knows you can't do that." That applies with equal truth to the matter of raising rates. "Everybody knows you can't do that." The only alternative is to reduce operating expense.

It is easy to figure the reduction necessary for a given increase in the investment per dollar of earnings. Consider an increase from four dollars to five dollars (which has occurred in the property of some companies in a comparatively few years). If, as an illustration, 13 per cent is required to cover return, fixed charges, except taxes, but including depreciation reserve, then an increase of one dollar in the investment per dollar earned means that out of every dollar of gross earnings there will be required 13 cents to cover the cost of this extra dollar, in addition to the 52 cents required to carry the original four dollars. This makes a total of 65 cents for fixed charges, leaving 35 cents for operating and taxes. "And everybody knows you can't do that." In other words, for every increase of one dollar in the investment per dollar of earnings, the operating ratio must drop 13 per cent to maintain the same rate of return unless rates are raised.

Decreasing Operating Rates

At the risk of tiresome repetition let me summarize. If there is going to be for some years to come a tendency to require more capital per dollar of earnings, and if we want to maintain or improve our present rate of return, a quite decided reduction in the operating ratio will be necessary. If an increase in rates is impossible, then the operating ratio can only be decreased by a decrease in operating expense; and to lower operating expense by an amount corresponding to or required by an increase of, say, one dollar in the investment per dollar of earnings, is almost impossible.

Now that is rather a long introduction to a rather short conclusion. That is nothing new; you all know that. It is only putting in unit figures for the sake of emphasis what we all know, and setting it forth here is to emphasize one effort that may be made which will improve the situation at both ends. That is, will tend to decrease our investment per dollar of earnings, and at the same time reduce operating expense. This is to get more and better system capacity per dollar of investment. One way to approach this is by better and more comprehensive system planning.

Most of our systems have "just growed" like Topsy. The result is they have been rebuilt time and again to meet the duties imposed by increased system capacity. The responsibility for this condition is not entirely on the engineers; in fact I am not attempting to place the responsibility. If the executives did not foresee the great growth of the industry it is no wonder the engineers did not do so. Also, equipment has not been available except as developed by the experience of living with these high voltage and large capacity systems. Some of our companies have rebuilt substations several times, each time putting in the very best available equipment, and each time seeing the whole thing scrapped in a short time because it failed to meet new duties.

Executives, engineers and manufacturers have all had a part in this lack of comprehensive system planning, but our present purpose is not to place responsibility, but to discuss remedies.

It is unnecessary to go into detail to show how costly this method of growth has been. Millions of dollars have been spent for transmission lines, circuit breakers, and substation equipment, that have proved inadequate and have been retired long before the end of a reasonable life. In spite of many drastic write-offs, plant account is certainly much greater than it would have been if it had been possible to develop a system plan years ago that would have provided indefinite expansion without going back and scrapping the beginnings.

As to the other term of the ratio, operating expense, this inadequacy of equipment has decidedly increased operating and maintenance expense, as these early and frequently recurring failures have caused abnormally high maintenance expense.

Orderly Development Desirable

Are we going to keep on growing like Topsy? If Eva typifies orderly and thoughtful development, as contrasted to the haphazard growth of Topsy, should we not emulate little Eva for a while? The time is surely ripe for definite system planning on a permanent basis, and this is up to the engineers as to the details of the plan and to the executives to visualize the problem. The past methods have worked fairly well in the sense that reasonably good service has been given, but they have proved expensive because of retirements from service long before the end of reasonable useful life.

Any system that does not provide for indefinite expansion without going back and tearing out the foundations, is all wrong. A master plan is necessary. This master plan should be flexible; it should be capable of adaptation to meet shifting conditions, and it should provide for almost indefinite expansion. Master plans which do not avoid inherent limitations to the growth of a system, such as the presence of excessive short-circuit currents, the lack of adequate quantities of condensing water, or streets choked with conduit runs, and so forth, are not suitable. There must be a prearranged solution to such foreseen difficulties, which are bound to arise as the system grows, and investment made in accordance with the plan should remain useful for a normal period of life. It should not be rendered obsolete in a few years because an unexpected growth has made necessary a complete rearrangement.

As a concrete illustration, assume that to serve a certain district a company has built a substation of 40,000 kw. capacity. The load grows rapidly until it is evident that very soon an additional twenty, thirty or forty thousand kw. will be needed, and it is not thought advisable to increase the capacity of that one substation. Is it too much to ask or unreasonable to assume that the system has been designed so that all that will be required is the construction of another substation of similar design to serve the increased load, and that it will not be necessary to rebuild the first substation as well as building the second; and that it will not be necessary to go back to a power plant and install new circuit breakers that cost many times the price of the discarded ones?

Once again I am saying that our business could have developed otherwise, but I am pleading for a start now toward a comprehensive system planning that will make for a different situation five years from now.

Distribution Development Slow

As to that part of the general system most susceptible to improvement, it would seem that distribution, in theory, practice and equipment, is far behind generating plant, transmission lines, lamps or meters. There has not only been slow development of distribution equipment that will operate satisfactorily on our present high voltage and large capacity systems, but there is an absolute lack of agreement among the engineers of large companies as to the best method of distribution for a large city, served by several power plants and many substations, through both overhead and underground lines.

It is no doubt inevitable that in the rapid development of a complicated industry, some parts of it will be perfected and standardized more quickly than others.

Budget control of both construction expenditures and operating expense is a great help to the executive and to the engineer in working out a comprehensive plan of system development. The budget provides a convenient and automatic method of a review by the executive of the engineers' plans and estimates. The engineer, if he avails himself of it, finds the budget a convenient means of coordinating his plans with past developments, and of judging the reasonableness of his proposed expenditures.

A good budget is the climax of the whole series of studies that begins with the consideration of the progress of the art of central station service and of changes in the habits and methods of living of the people who may be customers of the electric utility ten or twenty years from now, and that terminates in the project sheets for new items to be added to the construction program.

So we come back to the title of this discussion. It is largely up to the engineers as to the choice of our heroine. Is it to be Topsy or Eva? Thank you. (Applause).

CHAIRMAN STONE: The rapid growth of our systems has brought about other situations besides the necessity for planning, particularly a more difficult and a more complex problem in general for our engineers. It makes it necessary for greater demands to be made on the engineers. The engineer must come up to a higher, more rigid specification. The man who is going to discuss this subject has come up through the operating and engineering line. He has had experience broad and varied in operating problems and in engineering problems, so that what he will say is based not on theory but on continuous and extensive contact with the problems at hand and with the men who are doing them.

Mr. F. R. Phillips, Vice-President and General Manager of the Philadelphia Company, is in that capacity in charge of all of the electric, gas and street railway utilities in Pittsburgh. He has very recently been made President of the Duquesne Light Company, which is of course the Company in the group that is particularly interesting to us here. And I want to say also that Mr. Phillips is my boss, and he is a mighty fine boss. I take pleasure in presenting Mr. Frank Phillips, who will speak on Engineers and Engineers. Mr. Phillips! (Applause.)

ENGINEERS AND ENGINEERS

By FRANK PHILLIPS

Vice-President and General Manager, The Philadelphia Company, Pittsburgh, Pa.

It is with some embarrassment that I approach you at this particular time, for a number of reasons. One is the very generous and perhaps inspired introduction of the Chairman, and the other is that what little courage I had left when I came up on the platform a while ago has entirely disappeared since I walked into this box stall and I instinctively looked for the hay and the oats in the front. (Laughter). And then again, when I have to gaze through this barbed wire entanglement before me, it reminds me somewhat of an old gag of Artemus Ward in the days when one of our trunk line railroads was occupying the position that the Scotch now occupy.

You remember something to the effect of a discussion that he had with the conductor of a train, calling attention to the fact that there was no barrier of apparently seeming strength on the rear car of the train, and the conductor was surprised to think that any such thing was necessary.

Mr. Ward replied, "Why, what is to prevent a cow on the side of the road from coming right up into this car and biting somebody if you don't put the proper barriers before her?"

Perhaps these things before me are put here for the purpose of preventing somebody in the audience from coming up and biting the speaker.

The progress in the development of speech transmission has been all but miraculous, and I want to pay my little tribute to the engineers who have worked so assiduously, and to whom have come such great successes in the almost unbelievable progress in speech transmission, but I have this little suggestion to make. Perhaps it may have been thought of, and quite likely it has been. It would be much more comfortable for the speaker if the same improvement is made in the receiving apparatus, such as the microphone, as has been made in the transmission apparatus over our head. It would relieve the speaker and perhaps the audience, from some embarrassment. Certainly I believe that it will remove a detraction to the speaker on the part of the audience.

Somebody asked me to talk about engineers, and therefore the subject, "Engineers and Engineers." And before we talk about any subject, it is assumed that we find out something about it. The term "engineer" is rather an expansive one, and before I forget it I want to remind you that while I have a very carefully prepared speech on the inside of this envelope, what I am going to say is written on the outside, but for fear that somebody might break down the barbed wire entanglement and come up and bite me, I am going to use the paper for reference purposes.

I have no doubt that perhaps 90 per cent of the men, and perhaps some of the women—I am not so sure—before they arrive at the discretionary age of about ten years of age, have decided to be at least a locomotive engineer. And as time went on they became other kinds of engineers. In the construction of this building we have had all sorts of engineers, hoisting engineers, shovel engineers, stationary engineers, architectural engineers and others. I don't know whether they call the inside decorators engineers or not. And when I came down to Atlantic City I had the pleasure of following a locomotive engineer for about 450 miles. And then I think of all the other types of engineers.

So the question comes to me naturally, just what is an engineer? And I have come to the conclusion that we are all engineers. The latest type of engineers that you hear spoken of around the corners occasionally is the human engineer, the engineer of perhaps human psychology, which to my mind is more entrancing than any other type of engineer. Engineers are builders, and I believe anyone who is a builder, whether it be of concrete and steel and stone, or thought and ideas, is an engineer.

President Arkwright made some reference to his difficulties with engineers. I think it was a fair criticism of engineers. Engineers are full of ideas, and they owe it to the general public to tell about those ideas and tell them in an instructive, entertaining and effective way.

I was so entertained by Mr. Elden's paper about standardization and its tremendous effect upon the economic development of this country of ours, and then the story of Mr. Marshall about scientific planning—and on the side, let me say that we have quite an effective system development department under the very efficient leadership of your Chairman, Mr. Stone—those two subjects so engrossed me that I forgot what I was going to say myself about engineers.

Engineers Are Builders

But engineers are builders, and I fear sometimes that our engineering friends do not get the big broad picture of what it is all about. Why are we engineers? Why did we build this building? Why do we plan for the future of our electric systems? I was tremendously interested and charmed and encouraged by a remark that our President made during the political campaign of last fall. You will recall that in his various speeches he dwelt considerably upon the perfection of an economic system for this Government and this people, but he never failed to say that the very purpose of the development of an effective, economic system was the improvement of the home life of our country. In other words, we should bend our efforts toward the development of a great economic system for the purpose of banishing poverty from among us.

And that is where I fear that some of our engineering friends are losing sight of the goal. We build tremendously interesting, magnificent and far-reaching power systems or power stations for example. What is the function of a furnace and a boiler? Merely to generate steam? What is the function of a turbine? Merely to revolve a generator? And so on through the whole picture until we come to the consumer's place of business, or home. Is that the ultimate of our endeavor? I think not. I think, as Americans, as a progressive people, a people who seem to have been chosen especially to develop a plan of life or philosophy of life which will lead the world, that there is something more to our business than merely delivering kilowatt hours.

And that is the thought that I would like to leave with you, ladies and gentlemen; it is a far-reaching one and worth your careful and thoughtful consideration.

Engineering Defined

I will call your attention to a definition given by Mr. Henry G. Scott—all of you engineers know him—at his inaugural address, when he was made President of the American Institute of Electrical Engineers. This is his definition of engineering—Engineering is the art of organizing and directing men and of controlling the forces and materials of nature for the benefit of the human race.

I think he had the idea that I am trying to transmit to you. I think it is the ultimate goal that we should all look forward to, not only, as was so admirably displayed before you by Mr. Marshall, plan for the development of our power systems and our manufacturing systems, but for our social systems and for our political systems, to the end, as has been said so admirably by President Hoover, that poverty, suffering and sorrow, in so far as is humanly possible, will be banished from among us. Thank you. (Applause.)

CHAIRMAN STONE: If the usual parliamentary practice were to be observed, I presume that I should now call upon someone to take the chair while I read the Chairman's report on the work of the Section. Our meeting, after all, is informal, and for that reason I am simply going to read the report without going through the formality of having a temporary chairman.

REPORT ON ENGINEERING NATIONAL SECTION

By E. C. STONE, *Chairman*

"More System Capacity per Dollar of Investment" continues to be the principal objective of the Engineering National Section. The secondary objectives chosen as means of attaining the major objective include definite planning of system development, comprehensive engineering research, constructive cooperation in the standardization movement, and recruiting and training of adequate engineering personnel.

System Planning and Research

Further progress has been made along the lines of system planning and research through the creation last fall of the Power Systems Engineering Committee and the Special Engineering Research Committee. Both of these committees have already given good accounts of themselves, as will be noted from the record of their activities given below.

"More System Capacity per Dollar of Investment" is emphasized because of the increasingly important part that fixed charges are playing in the total cost of electric power service. With fuel efficiency at its present high level, the cost of generation has become almost a minor item, so that system investment now offers the greatest field of opportunity for further major economies. In the past, attention has been centered on reducing fuel and other operating costs. In the future it will be devoted particularly to economical system design and control of construction costs.

Major Purposes of the Section

For the information of those not closely associated with the Section's work, its major purposes are set forth as follows:

(a) To accelerate the development of the art through studies of important engineering problems and interchange of ideas between engineers.

(b) To keep the engineers of member companies thoroughly informed as to the latest and best developments and operating practices in power system engineering by providing opportunity for free discussion of their problems and by the compiling of serial reports on important engineering developments and practices for distribution to the engineers of the industry.

(c) To set up authoritative engineering policies for the industry in matters dealing with codes and standards, joint construction with other utilities and all other subjects in which engineering contact is had with other interests.

Serial Reports Cover Rapid Developments

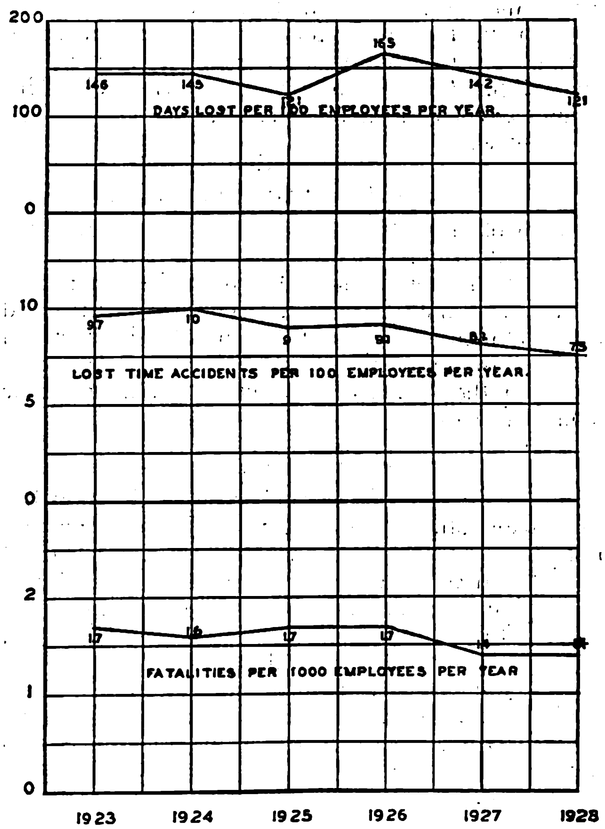
As usual, the work of the engineering committees during the past year has covered in a very comprehensive way the entire field of power system engineering. It is impossible in this brief report to record all of the interesting and valuable information developed from their studies and discussions. Rather, the purpose of this report is to present the present trend of power system engineering, to point out the subjects that are being given attention by the industry's leading engineers, and to suggest the lines along which engineers of member companies may direct their attention to best advantage. The complete story is told in detail in the serial reports that have been published during the year. Power system engineers can hardly be expected to keep abreast of the rapid developments in the art unless they are thoroughly conversant with the contents of these serial reports. All of them should be in the hands of and carefully studied by the engineers of every member company. The best way to be sure of getting these reports promptly as issued is to put in a standing order at N.E.L.A. Headquarters.

Engineering Administration Committee

The Engineering Administration Committee has continued during the past year to render an extremely important service in the administration of the work of the Engineering National Section. In addition to furnishing executive guidance in the many important subjects which have been placed before it during the year, the Committee has worked out with the N.E.M.A. a proposed standard patent clause to be incorporated in purchase contracts for electrical apparatus. This clause will be published in an early issue of the N. E. L. A. *Bulletin.*

Accident Prevention Committee

The Accident Prevention Committee has placed emphasis on two general lines of action. The first is the necessity of management's support for accident prevention work. Without continued interest and pressure from the very top, there will not be continued employee or supervisory interest. Both the credit for a good accident record and the blame for a poor one must be accepted by the chief executive. The second line of action is attention to engineering design. However well trained and managed the employee forces may be, human error and weakness will be experienced. There are many devices, guards, and other methods of proved efficacy in offsetting human error. This has probably been the least thoroughly cultivated means of prevention, and hence more careful attention to the safety features of engineering design are vigorously recommended. Emphasis on these matters is not intended to indicate any lessening of attention to the selection of employees or to their education in the proper attitude toward their work and the fostering of safety consciousness which always has been and always will be a necessary and effective means of prevention.



ELECTRIC LIGHT AND POWER INDUSTRY EMPLOYEES' LOST TIME ACCIDENT TREND

Compiled by Statistics Subcommittee, Accident Prevention Committee, N.E.L.A.

The accompanying statistics from the Accident Prevention Committee show a very satisfactory decrease in the rate of accidents in the industry.

Considerable public attention has recently been directed toward electrical hazards in the home. This is probably because, while such accidents are very few, they are necessarily spectacular in nature when they do occur. Recent statistics of the National Safety Council indicate that the chance of a fatal accident in the home from a fall is sixteen times that from electricity. Nevertheless, the Accident Prevention Committee has sensed the need for some sane recognition of this situation and prepared, with the cooperation and approval of the Commercial National Section and other interested parts of the Association, a safety in the home pamphlet under the title of "Common Sense." This pamphlet will be available shortly.

Resuscitation

The booklet on "Resuscitation," prepared last year jointly with other interested organizations, has had a circulation unprecedented for N. E. L. A. publications. Including reprints issued by insurance and manufacturing concerns, this circulation has reached into the millions. The work of the industry in educating the public in methods of resuscitation is having a very beneficial effect in building public good will.

Rubber Gloves

Intensive study of the rubber glove situation has been made during the past year. At the present time it is recommended that rubber gloves should not be used on lines where the voltage is in excess of 3000 to ground. For greater voltages high line tool work should be adopted. Improvements may, however, be expected in rubber glove manufacture, and it is hoped that a glove much stronger electrically and much more uniform in quality than gloves now available will be developed within a reasonable time.

Power Systems Engineering Committee

The scope of the Power Systems Engineering Committee includes consideration of all engineering and associated subjects involved in the development and design of the power system as a whole, including all steps from the forecasting of system loads to the financial statement justifying the necessary investment. The creation of this Committee provided for study and investigation of the now very important subjects of system planning and design, and intense interest has been shown in the work by engineers generally and by the Committee's own members in particular. Expression of this general interest is found in the fact that the Chairman of the Committee has by invitation presented talks on the work of his committee at engineering meetings of many of the geographic divisions.

Two fundamental objectives have been stressed this year. One is the development of a perspective whereby the utility system will be viewed as a complete assembly, requiring economic as well as engineering knowledge to develop. The other is promotion of the idea that system growth should be planned and that a planning department is a necessary function in the electric utility business.

Planning for system development starts with load studies and ends with a financial balance sheet. Engineering design of the system is thus only one element, although a very important one, in the complete problem. The master plan must reflect expected financial and economic as well as engineering and operating conditions. The Committee has found a very definite, well crystallized and uniform opinion among those executives who have developed planning organizations in their own companies that comprehensive future planning will bring about important savings in overall investment and operating cost.

System Stability and Lightning Protection

Two major problems of power system engineering, system stability and lightning protection, have received much attention during the past year. Increasing interest in these subjects is logical, in view of the constantly increasing importance and volume of the power companies' business.

Careful analysis of stability troubles by operating companies has thrown considerable light on the problem, but there is necessity for much further study. Instability may develop under conditions of normal system operation when the impedance of the transmission circuits is high in relation to the load involved, as in transmissions over very great distances or where relatively small line capacity is used to connect power plants for parallel operation. For improving stability in these situations, high speed excitation and power factor control are the most effective means. Instability may also occur under short circuit conditions in all systems. Under these conditions the means available for improving stability are the use of generators with high short circuit ratio, the maintaining in operation of proper relation between voltage, power factor and load on generators, and the introduction of reactance at strategic points in the system. In many cases generators must be operated at or below 90 per cent lagging power factor in order to obtain a safe margin of stability. High reactance is often placed at strategic points in the transmission system to limit to a portion of the system the disturbance and accompanying instability effect of a short circuit. Examples of this practice are found in the interposing of the high reactance of the distribution system between generator units (synchronizing at the load) and by the use of the so-called synchronizing bus in the power plants. If the governors of the prime movers do not shut down the units they control on short circuit and do not have normal periods of oscillation close to the period of the electrical system, they will not be a factor in system stability.

The only other means in sight at the present time for accomplishing major further improvement in system stability is quicker interruption of short circuits. It is therefore to be hoped that high speed circuit breakers and appropriate methods of selective relaying will be developed in the early future.

In lightning protection, the laboratory and field tests made by the manufacturers during the year have brought forth much enlightenment as to the true character of lightning discharges over transmission lines. Laboratory tests have developed more facts with respect to the breakdown voltage of insulation under lightning discharges. Manufacturers are in close agreement as to the ideal for lightning arrester performance and arresters are now built within reasonable approach to the ideal. The adoption of standard wave forms for comparative tests of lightning arresters and the development of standard test procedures will make it possible to buy this class of apparatus under logical specifications such as are available in connection with the purchase of other kinds of electrical apparatus.

Standby Capacity Problem

The problem of standby capacity needs careful study. The relation of installed capacity to load in all parts of the system should be based on accurate knowledge of operating conditions, and much more data are needed on the service availability of equipment and probabilities of simultaneous breakdown on different parts of the system.

Other basic system engineering problems requiring further study include control of plant frequency and of load distribution on the transmission system, voltage regulation, selective relaying and methods of grounding the system neutral.

Prime Movers Committee

The Prime Movers Committee reports that there has been no material change during the past year in steam pressures and temperatures. While several new plants or extensions are under way to be operated at 1400 lb., most of the new installations are for pressures of 400 to 500 lb. The pressure used in any case is mainly dependent on local conditions, including cost of fuel and operating load factor. The rise in steam temperature seems to have halted at about 750 deg. fahr., pending the development of new alloys for higher temperature service.

The size of individual boiler units has kept pace with the increase in size of turbo generators. Several boilers having a maximum capacity of 800,000 to 1,000,000 lb. of steam per hr. will be in service before the end of the year. Each of these boilers will be capable of serving upward of 80,000 kw. of turbine capacity. The almost universal use of water cooled furnaces, particularly in connection with pulverized fuel firing, has very largely decreased boiler outages. One large station so equipped has operated for the past eight months with a service demand availability of 100 per cent, thus indicating that power plants may yet be built with only one boiler per turbine.

The present limit of individual stoker capacity seems to be about 500,000 lb. of steam per hr. There is no indication, however, that the limit of capacity for pulverized fuel furnaces is in sight.

An extensive survey of the operating records of both single and two-pass condensers has been made. No decided advantage is shown for either type. On the average, heat transfers of about 80 per cent of the makers' guarantees are realized on both types under operating conditions.

Turbine Operating History

The operating history of large turbines has been brought up to date. A slightly improved record is shown, but the improvement is not sufficient to be significant. This operating history, which has now been kept for a number of years, is of particular importance because of the light it throws on the availability for service of installed generating capacity. Obviously accurate knowledge as to the expectancy of outage to generating machinery will permit of more accurate determination of the installed capacity necessary to serve given loads.

Hydraulic Power Committee

The Hydraulic Power Committee has given considerable attention to the problem of taking care of fish that pass up and down streams in which dams are located. This problem has assumed importance on the Pacific Coast streams particularly, and involves providing means both for assisting the large fish upstream over the dams and getting the small fry safely down on their way to the sea. Substantial progress has been made in cooperation with the United States Bureau of Fisheries. The electrical fish screen for directing the movements of fish and preventing their entry into regions where they are not wanted has proved quite successful. The next problem is the selection and improvement of a satisfactory form of lift or passageway for safely lifting the fish over dams and other high obstructions.

Recent disastrous failures of certain dams have caused the Committee to take up the study of such failures with a view of making recommendations that will result in safer practice in dam design and construction.

Further progress has been made in developing methods of forecasting water supply. While progress is slow, new ideas of a practical sort are constantly developing and are being broadcast by the Committee to interested operating companies. The problems of speed or frequency regulation and proper division of load between units in interconnected systems have brought about a need for better regulating equipment on hydroelectric generating units. Substantial progress has been made in crystallizing the requirements, from which it will be possible to develop necessary apparatus to adequately meet the situation.

Electrical Apparatus Committee

The Electrical Apparatus Committee has given much study to the apparatus problems associated with satisfactory operation of interconnected power systems. Further developments of interconnected operation have imposed the need for further study of the engineering problems associated therewith. In this connection, the necessity was brought out of basing interconnected operation of the systems of different companies on a form of business agreement sufficiently flexible so as not to arbitrarily force an operating scheme along uneconomic lines. One group of financially independent operating companies has interconnected its systems and pooled its power resources without a single word of written agreement. Satisfactory operation with substantial economies is reported.

The control of system frequency has become a major problem. Automatic systems of control are available, based both on indicated and integrated frequency. Further study and experience will be necessary, however, to determine the most desirable method, although it is reasonable to suppose that in the end automatic frequency control will be generally adopted. Phase control at strategic points in the transmission system is being found desirable in certain instances either for the purpose of distributing loads in accordance with line capacities, or in order to make possible the observance of contractual limitations in complicated interconnected networks.

This Committee definitely expressed itself in favor of operation of electrical apparatus on a temperature basis by approving the proposed operation standards of the A. I. E. E. for transformers as a suitable basis for securing experience on the effect of operation of transformers at ambient temperatures other than 40 deg. cent. for air and 25 deg. cent. for water. It is to be expected that standards for operation on a temperature basis will be developed for other types of electrical apparatus as rapidly as the necessary basic data can be obtained and agreed upon. This should result in a substantial increase in efficiency of use of electrical apparatus.

Insulating oil is a complex chemical compound which has been little understood. Recent studies, however, and observation of oil in service, have removed much of the mystery. New developments include preparation of a purchase specification by the Oil Subcommittee, adoption of the practice of reconditioning for future use of oils that have been used in transformers and circuit breakers, and further progress in interchangeability permitted by the manufacturers. Reconditioning plants generally employ the filter press for removal of sludge and sediment and a combination of centrifuge and filter press for elimination of carbon from circuit breaker oil. The cost of treatment varies from $15 to $50 per thousand gallons of oil. With certain limitations, insulating oil furnished by either the Westinghouse or General Electric Company may now be used interchangeably in circuit breakers and transformers manufactured by both companies.

Utilization Subcommittee Findings

In recognition of the probable engineering requirements in connection with the intensive load building effort that will be put forth in the next few years, the Utilization Subcommittee was created this year in the Electrical Apparatus Committee to deal with the problems involved in the utilization of electrical energy, including the engineering of present applications and the development of new uses. Following are some of the findings of this subcommittee:

Time delay under-voltage release devices, now available for the protection of motors, will prevent in most cases the shutting down of motors on drops in system voltage such as result from line short circuits. For this reason their use should be encouraged, and it is to be hoped that in due time they will generally replace the older and less effective instantaneous type of low voltage release.

Fractional horsepower motors having characteristics satisfactory for operation on lighting circuits, as specified in the agreement reached last year between the manufacturers and our representatives, should be available in the very early future to the manufacturers of electrical appliances without additional cost. It is of fundamental importance to the satisfactory performance of power systems that motors with these improved performances be generally used, and all member companies are accordingly urged to exert their influence toward the general adoption of such motors by appliance manufacturers. The adoption of appropriate motor rules by member companies will promote this desirable end.

Motor Starting Currents

Further attention was given to the matter of motor starting currents. It is recognized that starting current rules must be based on the combined cost of the motors themselves and the power system required to serve them, in order to give to the user the minimum overall cost of power. Furthermore, the size of a motor in proportion to the total load fed by one service has a major bearing on the problem. The starting current of a small motor in a large installation is of no importance to the power company, but if a motor is practically the total load on a service connection the starting current may necessitate an increase in the power company's facilities.

Other subjects dealt with include service voltage standards, wiring problems in connection with the National Code revision, effect of voltage variation on radio, operating characteristics of Neon signs, and installation rules.

Generator and Synchronous Motor Design

In generator and synchronous motor design there is a trend toward higher voltages and machines for 16,500 volts and 22,000 volts have been built. Two 22,000 volt generators have been in service in the humid climate of India since 1918. Double winding generators are being employed where large currents are to be carried, the advantages being reduction in short circuit kv-a. to one-half, additional synchronizing power, and reduction in cost. The use of hydrogen for cooling has been developed for synchronous condensers, and has the advantage of increasing the capacity of a given machine about 35 per cent. Investigation shows that the proportions of hydrogen and air which will cause an explosive mixture are such as to make explosion quite unlikely.

Marked progress is shown in the development of high duty circuit interrupting devices for operation without oil. The "Deion" circuit breaker offered by one of the manufacturers and successfully tested by a large operating company gives promise of great possibility. Development work has also gone forward on devices for interrupting the arc by gas blast, by the use of inert gas under high pressure, and by the use of the vacuum principle. The latter principle is reported to offer much promise. The Special Committee on System Testing of Oil Circuit Breakers continues in existence and stands ready to assist member companies in carrying out circuit breaker tests on their own systems.

The so-called metal clad switch gear in which switching equipment and auxiliary apparatus are all assembled in a single metal inclosed grounded unit is being found useful under certain circumstances by a number of companies. An installation of this sort may be made with the same compactness as an indoor installation and yet does not require a building.

Work of the Meter Committee

The Meter Committee has completed the correspondence course for electrical metermen and the greater part of it has been published by the Educational Committee. This course reflects the best practice in meter work, and is earnestly recommended for use by all electric utilities in connection with the adequate training of their metermen. Already a thousand copies have been sold.

By close coöperation with the manufacturers through which operating requirements have been made known, further advance has been made in the accuracy of watthour meters, particularly at overloads, in the development of polyphase watthour meters with bottom connected terminal chambers, in the accuracy and insulation of instrument transformers, and in the development of a 2½ ampere meter for use with instrument transformers which will result in measurements of greater accuracy.

The Committee keeps continually in touch with the service rules for meter operation in the various States. A report has been completed and published showing the similarities and dissimilarities in rules so far adopted. This work is with the definite objective in view of attaining uniform meter rules throughout the country. Various member companies have been supplied with information enabling them to prepare requests to regulatory bodies for the extension of periodic test intervals.

Outdoor Metering

Outdoor metering has received considerable attention. It is the opinion of the Committee that with the modern temperature compensated meters, outdoor metering is entirely practicable wherever local conditions may warrant. This method should prove useful in connection with rural line extension, summer resorts, and transiently occupied homes, places difficult of access, and in general in locations where climate and operating conditions make it feasible and economical.

The trend of modern meter installation practice provides metal inclosures for all service boxes and metering equipment between company mains and the load side of the meters. The advantages of metal inclosures have become generally recognized because they minimize accidental damage, make tampering more difficult, provide additional safety, and aid in standardizing meter installations.

Overhead Systems Committee

In the Overhead Systems Committee, the research work on the strength of overhead lines, together with the collection of information on loading which may be expected in various localities, continues to be probably the most important activity. The experimental line which was erected near Ann Arbor to study the effect of wind on aerial line structures has been subjected to a considerable number of wind storms throughout the past winter and a large amount of data have been secured which are now being analyzed. It seems quite likely that another winter season will give a sufficient number of winds of high velocity to collect all of the data necessary to determine the effects of wind upon wood pole structures.

A start was also made on a study of wind gusts. Special anemometers are being developed for the recording of wind velocities, and it is the intention to obtain simultaneous readings of velocities along vertical and horizontal fronts so as to obtain a more accurate idea of the way the wind acts. In connection with the wind gust study it is proposed to erect a 260-ft. steel tower on the same site as the experimental line for the purpose of obtaining the vertical variation in wind velocities.

The work of collecting information on storms involving both wind and ice loads has been carried on this year with much more satisfactory results than previously. The assistance of the Geographic Divisions in carrying on the collection of this information has been productive of very good results, and the cooperation of the Weather Bureau stations has been very helpful. A considerable mass of this storm data is now in the hands of Headquarters Staff, and if this can be carried on for several more years it should be possible to draw up some general conclusions which will be very valuable.

Subcommittee on Insulator Research

The Subcommittee on Insulator Research appointed this year to study deterioration of high voltage porcelain insulators has visited many of the insulator factories and has talked with those most closely connected with the research work that has already has been done on insulators. As a result of its investigations, it is recommending the initiation of a research project to study the behavior of high voltage suspension type insulators under conditions which would accelerate the deterioration of porcelain. Its purpose is to develop a better understanding of ageing in high voltage porcelain and a means of testing high voltage insulators to measure deterioration in its insulating value. At the present time it is only possible to determine if the insulator is totally unfit for service.

Subcommittee on Safety Codes

The Subcommittee on Safety Codes expects to start immediately on a Code of Principles which should govern the safe construction of overhead lines in all situations and which may be used as a basis for the next revision of the National Electrical Safety Code.

Other subjects studied include wire crossings over railroads, preservative treatment of wood poles, rural lines, highway lighting, methods of service restoration after interruption, and radio interference.

Inductive Coordination Committee

The Inductive Coordination Committee is made up of a group of representative engineers who form a very effective staff which is available for consultation by member companies in connection with coordination cases which may be troubling them. In this capacity the Committee dealt with nine cases during the year.

Recognizing the desirability of the engineers of member companies being better informed with reference to the fundamentals of inductive coordination, this Committee recommends the compilation and publication of an educational course covering the principles of inductive coordination. Because of the specialized character of the work, it will be necessary to have such a course compiled by an engineer especially assigned to the job, and the Committee accordingly recommends that provision be made in next year's budget of the Engineering National Section for the supplying at Headquarters of the necessary personnel to undertake the job.

Carrier current communication systems are being put into service in the transmission lines of power companies in a great many places. Little interest, however, is being shown in space radio so that the Federal Radio Commission has not felt justified in setting aside any frequency channels for the specific and undivided use of power companies.

Underground Systems Committee

The Underground Systems Committee reports improvement in the quality of cable as manufactured. The percentage of deficiency is lower, dielectric strength by short time puncture tests is somewhat higher, insulation resistance, power factor and ionization factor are distinctly improved. It is not yet possible to predict with certainty from the tests made during manufacture whether cable will give satisfactory service, but research investigations are under way to determine the nature of cable deterioration and to develop methods for indicating beforehand whether cable is going to be satisfactory in service.

It is obviously desirable to determine accurately the maximum loads that cables can be depended upon to safely carry. In this line, progress has been made toward the development of accepted methods of determining cable operating temperatures so that future tests and investigations by various operating companies can be compared upon a common basis and data presented to the industry that will make possible the maximum utilization of cable investment with resultant lower cost per kilowatt in the underground system. Much attention has been given to the measurement of earth temperatures in various parts of the country. Various methods have been developed and studies have been made of the relations between air and earth temperatures, the time lag which occurs between the two, and of the results which may be expected from the various elements influencing earth temperatures.

Reports for the year indicate a decided improvement in the operating performance of cables, joints and potheads, particularly in cables operating at 20 kv. and above. Over two-thirds of the cable failures are due to external causes and probably half of them could be overcome by greater care on the part of the operating companies. No failures occurred in oil filled cables. Single-conductor cable showed the lowest rate of failure from internal causes, followed by three-conductor shielded and three-conductor belted. Operating experience with alternating current low-voltage networks continued satisfactory. Most of the companies are using single-conductor cables on their secondary systems and depending on clearing secondary faults by burning off the cables. Experience so far indicates little difficulty in clearing faults in this manner where the mains are tied in solidly.

Arc proofing of cables in manholes has become accepted practice, and although there is no uniformity relative to material used, generally satisfactory results are reported.

Cable Insulation Research

Extensive research in cable insulation is being carried on both by manufacturers and operating companies, but there is still a great deal to be learned regarding the effects of entrained moisture, occluded air, nature of impregnating compounds and processes, use of special gases as inhibitives to ionization, nature of paper on cable in service.

One large company, after making a long series of tests on samples of paper insulated lead cables removed from service, has secured a portable equipment for making tests to determine the dielectric losses of cables in service for the purpose of getting information on effect of age on losses and rate of cable depreciation, and for developing a method of determining the safe loading capacities of cable runs.

Headquarters Engineering Staff

The Headquarters Engineering Staff, under the able direction of Major Bennion, is now very effectively organized, and although undoubtedly undermanned, has given an excellent account of itself during the past year. The engineers of the staff are at the same time the sentinels and ambassadors of the industry in engineering matters. On the one hand they keep in close contact with the activities of many other organizations whose work may affect our interests and promptly bring to the attention of the proper parties all matters on which action may be required. On the other hand they constitute an official point of contact with outside organizations and provide a channel for effective cooperation in engineering matters. Thus they not only protect the engineering interests of the power industry, but also make possible the cooperation of our industry with others in such a way as to bring about coordinated physical development and general good will.

During the past year an outstanding activity of the Headquarters Staff has been in connection with the working out of a satisfactory revision of the National Electrical Code. As is now well known, a vigorous attempt was made about a year ago to introduce into the wiring code certain requirements in connection with grounding which the power industry felt were undesirable at the present time, were too experimental to be standardized, and would in the end increase the complexity of interior wiring to the extent of seriously curtailing its normal development. The Headquarters Staff took this situation in hand, and through the machinery put in motion has now secured a satisfactory modification of the original proposals for grounding, which has been accepted by all interested parties. In this work the staff secured the creation of, and collaborated with, a Special Grounding Committee composed of commercial and engineering representatives appointed by the Association to participate in the Grounding Conference held last November by the National Fire Protection Association and a joint committee formed with the National Electrical Manufacturers Association to deal with wiring problems, and more particularly with the National Electrical Code.

Company Code Representatives Plan

In accordance with the recommendation of President Arkwright, company code representatives have been designated by many member companies to serve as channels for information to and from Headquarters direct to member companies. The arrangement throws a heavy task on Headquarters Staff to maintain this contact, but the records which are being built up as a result of this plan, and the solidarity which results from the closer contact is going a long way toward solving the code problem which has been confronting the industry in recent years.

In this connection the overhead line research of the Overhead Systems Committee already referred to, the collection of ice storm data from points all over the country, and the surveys now being made by an assistant engineer from N. E. L. A. Headquarters of old woodpole lines to determine their present conditions and record of performance, is a most valuable contribution, not only toward the establishment of sound code provisions, but toward fixing good practice.

Joint Development and Research Program

The joint development and research program with the Bell Telephone System has made further progress. The field investigation of the past two years at Terre Haute, Ind., which has covered extensive measurements on the toll lines from that city to Chicago covering circuit characteristics affecting noise-producing currents, will be concluded within a month. It is planned to follow this up with a brief test in North Carolina on an open-wire toll line employing decreased wire spacing and other features which will minimize susceptiveness of such telephone lines to the inductive influences of power supply lines. Among matters included in the Terre Haute investigation, upon which progress has been made, is a new method of test to determine the inductive effect of a power line on a telephone circuit which gives a much more accurate index than was had by the method previously used, and will serve to simplify the solution of future inductive coordination problems.

It should be noted that, while the Development and Research Project Committees are not in position to send out specific detailed reports, nevertheless the officials of member companies may obtain information with regard to the work by making specific request to the Headquarters Engineering Staff for such information.

In order to determine the magnitude of the noise-producing harmonics that accompany the fundamental 60-cycle power wave and are transmitted along the power circuits, a country-wide wave-shape survey has been conducted, covering many of the larger power systems in the country.

Telephone conversation is affected by room noise, as well as induced noise from power circuits. Apparatus has been developed for measuring and recording room noises, and a survey has been made of such noises covering a wide range of conditions under which the telephone is used.

A set of principles governing the physical relations between the power supply lines and the circuits of the Western Union Telegraph Company has been prepared and has just been printed for distribution to member companies. A subcommittee of the Overhead Systems Committee has developed with a similar committee of the American Railways Association a set of principles and practices governing crossings between power supply lines and railroads. This Committee will next proceed with the preparation of a set of specifications for such crossings.

The Headquarters Engineering Staff has also cooperated with Committees of the Commercial National Section in dealing with wiring problems, studies of oil burners and studies of the water heating problem. The Statistics Division is doing a most valuable work in assembling, analyzing, and distributing authentic vital statistics covering the operations of the industry.

Special Engineering Research Committee

The Special Engineering Research Committee, after making a comprehensive survey of the status of engineering research in the power industry, finds that there exists considerable duplication of effort, which is wasteful of time and money, although entirely unavoidable under the circumstances. The Committee, therefore, concludes that proper coordination of research work in the industry cannot be obtained unless a paid secretary is installed at Headquarters and provided with ample funds to defray traveling expenses. The duties of such a secretary, who would naturally be placed in the Headquarters Engineering Staff, should be to maintain a complete file on research projects of interest to member companies and to keep informed regarding their progress, to arrange for adequate publishing of information regarding results as rapidly as they can be made available, to arrange for the initiation, placing and financing of new and desirable research projects, and in general to do all that a staff member can do to coordinate and guide research work so that it will be of maximum use to member companies. The general situation in respect to engineering research in the industry is such as to make the adoption of this recommendation of primary importance. The Executive Committee of the Engineering National Section has approved it, and it is earnestly hoped that appropriate provision for carrying it out will be made in next year's budget of the Association. It is also recommended that the Special Engineering Research Committee be continued next year.

Standardization

An important step in standardization was made possible when the Executive Committee of the Engineering National Section approved the report of the Joint Committee of the N. E. M. A. and N. E. L. A. on preferred voltage ratings for alternating-current systems and equipment. This report has already been referred to by Mr. Elden. The adoption of the recommendations of this report generally by member companies will simplify the manufacturers' lines of apparatus, will bring about better adaptation of equipment to its service under prevailing conditions and will generally improve conditions for the interconnection of adjacent power systems. While the recommendations cannot be uniformly adopted at once, it is to be hoped that member companies will direct their system development toward the complete acceptance of the preferred voltage recommendations as soon as practicable.

Progress of Geographic Division Committees

The Engineering Committees of the various Geographic Divisions have made further progress during the past year in finding themselves, and their activities have been more extensive and more effective than heretofore. With the more definite understanding of their purpose and scope, the geographic organizations are being molded to specifically meet the local conditions. While the national organization is being used as a guide, each division is setting up only those committees in which it has a direct interest, while in some instances special committees have been organized to meet special conditions. This is as it should be. Such encouragement and advice as appeared useful has been given by the officers of the National Section to the Geographic Organization. The chief recommendation has been maximum simplicity of organization to meet clearly defined local requirements. In the working out of geographic engineering activities, a definite trend has been noted toward the conference form of meeting. That is, the various Engineering Committees of the respective divisions have met together once or twice a year for general conference and exchange of ideas. Definite programs have been prepared in advance, with carefully selected and well qualified speakers to cover the subjects set up for discussion. These programs have been advertised in advance. The result has been most gratifying, and indications are that this method of carrying on divisional work will be generally adopted. Very favorable comment must also be made of the valuable serial reports on timely engineering subjects which have been prepared by a number of the divisions. These reports form an important part of the work, but after all must be considered secondary to the major purpose of bringing together the engineers of the various companies for interchange of ideas and discussion of mutual problems.

Coordination of Associations' Activities

A very complete development of associations, particularly in the technical fields associated with the power industry, brings about an urgent need for coordination of activities. A cooperative arrangement developed recently between the Electrical Apparatus Committee of the N. E. L. A. and the Power Generation Committee of the A. I. E. E. sets a precedent which should be generally adopted.

Association organization is along two distinct lines. There are the trade organizations, of which the N. E. L. A. is a typical example, and the technical organizations, such as the A. I. E. E. In the latter class also belong such bodies as the National Safety Council. The trade association is interested in all lines of endeavor which are engaged in by the industry it represents. Its primary duty, however, is to handle for its industry as a whole such matters as cannot be effectively dealt with by individual companies, but many of these associations have added to this primary duty more or less extensive activities along the lines of training and educating the employees of the industry they represent.

The technical associations, such as the engineering societies, are also concerned with the education and technical development of their members, so that many overlaps develop from time to time between their work and similar work in the trade associations. Such overlaps often represent unnecessary duplication of effort and, therefore, waste of time and money. Coordination of the activities of associations, particularly those which affect the power industry, is of major importance at the present time.

One of the objectives of the Engineering National Section is constructive cooperation in the national movement for standardization. This subject has recently been of major interest to some of the Engineering Committees. Obviously standardization may be overdone; nevertheless, it is undoubtedly one of the major reasons for America's prosperity today.

It seems evident that standardization affecting the power industry up to the present time has been generally advantageous and has resulted both in economy of power production and in extension of power uses. There may, however, be a possibility in our present enthusiasm for standardization of allowing the pendulum to over-swing. The kind of standardization which established frequencies, utilization voltages, ratings of equipment, factors of safety of equipment has been a major factor in developing the use of electricity in this country. In the field of simplification, however, which results in a reduction in the capacities of equipment or qualities of material available, the immediate result is a less close adaptation of the available products to the service for which they are to be used. This fact alone means some economic loss. On the other hand, the results of simplification bring about economies, such as reduced costs of manufacture and reduction in stocks to be carried. It is thus necessary to balance the advantages and disadvantages of a given standardization project of this kind in order to determine its true economic value. The major purposes of standardization, to effect economies and extend use of product, must always be kept in mind in setting up this standardization program.

It is suggested that the Engineering National Section during the coming year give some attention to the subject of standardization, with a view to determining the lines along which standardization may be promoted to best advantage and wherein over-standardization with economic loss is a possibility.

"More System Capacity Per Dollar of Investment"

The vast amounts of money which are being expended every year in the generating and distributing systems of the power companies impose an ever-growing responsibility on its engineers. Broadly speaking, power systems engineers determine and specify how their company's money shall be spent. The exacting demands for the highest possible grade of service and the economic pressure to get the greatest possible value out of every dollar spent puts up to the engineer an even bigger job than he has had heretofore. The objective of the Engineering National Section of "More System Capacity per Dollar of Investment" tersely expresses the problem.

The years immediately to come will bring to the electric utilities a closer approach to saturation in available business and greater competition from other power sources than have heretofore been experienced. For this reason the power industry at the moment is particularly interested in commercial development. The engineer will play an important part in the new business program by indicating the character of load building that will most effectively use the system investment, and by furnishing costs of the various classes of service to be used as a guide in making rate structures.

Probably in no field of engineering are the requirements broader and more exacting than in power system engineering. Dr. Hirshfeld has said that the successful engineer in the power industry is a scientific business man. The job of the power system engineer starts with getting the solution to his physical problems, but by no means ends there. In addition to a thorough knowledge of the engineering principles involved and broad gage operating experience, successful power system engineers must also understand the business principles of the power industry and the major economic factors involved, must have analytical ability, good judgment, ability to sell their recommendations, and enough understanding of human nature to work successfully with those with whom they come in contact.

In many cases it will be necessary to broaden existing organizations if their engineering is to be done in such a way as to accomplish the most efficient use of the dollars spent for power system development. It will be necessary to set up places for those engineers who are to carry on the necessary development work. Mature judgment based on experience is necessary, as well as inherent ability to work out the problems involved. Hence provision must be made not only for the selection of engineers of the necessary ability, but also for their continuing service over a period of years, through recognition, by adequate step-by-step promotion, of their ability as it develops. Then there must be sufficiently attractive opportunity at the top to make it worth their while to stay in the game.

The Power System Engineer's Outlook

In the past the requirements of the rapidly expanding power industry for executives have diverted many, if not most, of the industry's best engineers into executive channels just at the time when, if they had remained engineers, they would have brought the biggest dividends to their companies. It is to be hoped that in the future it will be possible to retain in the engineering work more of the engineers who have shown unusual ability, in order that their judgment and experience may be applied to this problem of ever-growing importance, the most efficient possible use of the dollar spent in the power system.

For the power system engineer with the necessary qualifications and experience a most promising future is ahead, both in the strictly engineering field and in the broader field of management.

In closing, I wish to voice the appreciation of this Association for the continued interest in the generous contributions to the work of the Engineering National Section by all of its members during the past year. Without this, nothing could have been accomplished. I also wish to express my personal thanks as well as those of the Association to the chairmen of all of the Engineering Committees for their able leadership and untiring support of the Section's work, and to the Engineering Staff at Headquarters for the splendid cooperation given the Section at all times. Engineering Committees of the National Electric Light Association are doing a work and filling a place of such importance in the industry as to make certain their continued growth and prosperity. (Applause).

We have one more number, the report of the Nominating Committee, and in the absence of the Chairman I will ask Mr. Byron White, a member of the Committee, to please step forward and present the report. Mr. White!

Nominations

MR. BYRON E. WHITE (Utica Gas & Electric Co., Utica, N. Y.): In accordance with the provisions of the Constitution of the N. E. L. A., the Nominating Committee appointed by the Executive Committee of the Engineering National Section has selected the following fifteen names of members of the Association, from which President-elect of the Association may select the Chairman, Vice-Chairmen and Members-at-Large of the Engineering National Section for the administrative year beginning July 1, next:

A. D. Bailey, Commonwealth Edison Co., Chicago, Ill.
Thomas Sproule, Public Service Electric & Gas Co., Newark, N. J.
A. H. Kehoe, The United Electric Light & Power Co., New York, N. Y.
K. R. MacKinnon, Nebraska Power Co., Omaha, Neb.
W. E. Mitchell, Alabama Power Co., Birmingham, Ala.
F. E. Andrews, Public Service Co. of Northern Illinois, Chicago, Ill.
E. B. Ricketts, The New York Edison Co., New York, N. Y.
J. W. Sylvester, The Philadelphia Electric Co., Philadelphia, Pa.
R. L. Thomas, Pennsylvania Water & Power Co., Baltimore, Md.
Harold Cole, The Detroit Edison Co., Detroit, Mich.
L. L. Elden, Edison Electric Illuminating Co. of Boston, Boston, Mass.
E. E. Hill, The New York Edison Co., New York, N. Y.
N. E. Funk, The Philadelphia Electric Co., Philadelphia, Pa.
D. W. Roper, Commonwealth Edison Co., Chicago, Ill.
E. H. Collins, Washington Water Power Co., Spokane, Wash.

CHAIRMAN STONE: I will read a short paragraph from the Constitution:

> "The submission of names by the Nominating Committee shall not, however, debar any accredited representative of a Central Station Company Member (Class A) or a Manufacturer Company Member (Class D) from making nominations for any or all of the several offices to be filled. Such nominations, if seconded, shall be submitted for election at the same time and in the same manner as those of the Nominating Committee."

Does anyone wish to make any nominations from the floor? If not, then our session is finished, and I declare this meeting adjourned.

[The meeting adjourned at 5 p.m.]

PUBLIC RELATIONS NATIONAL SECTION SESSION

PUBLIC RELATIONS NATIONAL SECTION SESSION

THURSDAY, JUNE 6, 1929

[The meeting convened at 3 p.m. in the Grand Ballroom, Auditorium and Convention Hall, Atlantic City, N. J., Mr. J. F. Owens, Chairman, presiding.]

CHAIRMAN OWENS: I would very much appreciate if those who are sitting in the rear of the room and on the sides would occupy these front seats.

There is on the program this afternoon a space for remarks by the Chairman. In many respects I would if I said much, merely duplicate what I said the other day. Your interest, however, in our relationship with the public as evidenced by your presence here, perhaps warrants my making a few remarks as to the objectives of the Public Relations National Section, and the reason for such a section.

It was Alexander Pope who said, "The proper study of mankind is man"—a world of philosophy, a wealth of meaning in that short sentence.

It is another way of saying that everything in creation must be, if it is to be worth while, subservient to the interest of human beings. That is what creation is for. The Public Relations Section deals with our business in its human aspects and in its human relationships. It has for its objectives, securing of the cooperation of those whom we would serve on the theory that through that cooperation our service to them and they themselves, may be benefited.

It has for its ambition the creation not only of a material service, but a service that will be in a real and true sense, if I may use the term, a spiritual service—a service that has within itself a real contribution to the social order.

In the early days of our business we men were hard put to secure the capital necessary in launching a new and untried venture. Naturally, most of the best minds of the industry were given to the material side of the industry, or rather, may we say, to the application of the results of investigation, research and study in a practical way, to the furtherance of the industry.

Importance of Human Relations

Men began to realize, however, that the job when they furnished the material service is only half done, and as a means of introducing practical methods of developing that job to its full possibilities, they began to see that they were overlooking perhaps their best asset, that is, the men and women who had joined with them in this service. They began to see that if their service was to reach its full fruition, the men and women identified with them must be their real interpreters. They began to see that with the handicap of being a natural monopoly, they encountered a natural and latent, perhaps, resistance, or an aversion on the part of the public to forego their right of choosing where to bestow their favor. So out of that feeling grew an organization founded on the theory that human relations are certainly as important as the material aspects of our business.

It is very gratifying I am sure to you who have opportunity to come in contact with the men and women in this industry throughout the United States, to realize that that movement is bearing fruit. It makes little difference whether it is evidenced in the so-called public relations department, but rather it makes more difference that the evidence is found in the acts, the feelings, the consciousness of the men and women who constitute the industry, and in the reaction in the minds of the public.

It has been my experience in the contacts I have had—and I assure you they have been most pleasant during the past two years—to realize that by and large the operating companies in the United States have the confidence of the public whom they serve, and they have that confidence because they deserve it. They have that confidence again because they have surrounded themselves with unusual men and women, men and women capable of interpreting their industry to the public.

Industry Furnishes Leaders

It is rather an interesting thing to note that in almost every community, at least among the outstanding leaders of that community, are men and women of the electric light and power business. If a man is needed to head a Chamber of Commerce drive the chances are ten to one an electric light and power man will be chosen for that important job. If it is a president of a community fund that is needed in a city, an electric light and power man is chosen for that position. If it is a position of trust, a position that requires ability, an electric light and power man will always be among those considered for it. That in itself is evidence of the fact that the men and women of the industry have the confidence of their public. I think that is a real tribute to us and I believe that it will be a source of gratification to you.

Appointment of Nominating Committee

It is part of the routine of this meeting to appoint at this time a Nominating Committee which shall submit to the incoming President the names of fifteen men from whom shall be selected by him the Chairman of this Section, the Vice-Chairman, and the members-at-large for the coming year.

I would like to announce that Nominating Committee at this time:

Jackson Dick, Georgia Power Co., Atlanta, Ga.
Chas. Penrose, Day & Zimmermann, Inc., Philadelphia, Pa.
Guy Talbot, Pacific Power & Light Co., Portland, Ore.
A. W. Robertson, Westinghouse Elec. & Mfg. Co., New York, N. Y.
D. A. Elias, Harrisburg Light & Power Co., Harrisburg, Pa.

I am sure you would like to know the men and women who have done the work of this section during the past year. I have therefore asked to come to the platform the Vice-Chairman of this Section and the Chairmen of the various Committees. You know we have eight committees through which the work of the Public Relations National Section is done.

I would like you to know Mr. D. C. Green, Vice-Chairman. Will you stand up, Mr. Green? (Applause).

Mr. E. A. Barrows, Vice-Chairman! (Applause).

Mr. Leavitt L. Edgar, Vice-Chairman! (Applause).

Mr. McManus, Chairman of the Manufacturers' Advertising Committee! (Applause).

Mr. Vivian, Chairman of the Public Speaking Committee! (Applause).

Mr. Niesz, Chairman of the Industrial Relations Committee! (Applause).

Mr. Charles Jackson, Chairman of the Committee on Cooperation and Educational Institution! (Applause).

Mr. Clarence Law, New York, a member of the Executive Committee.

Some of the chairmen are a bit modest. They are not on the platform; therefore they cannot be introduced. If they come on the platform later I will introduce them.

I want to take the privilege of reserving to the last, but not the least, the Chairman of the Committee responsible for some very constructive work. I am going to play a little favoritism here by asking this Chairman to come on the platform, Miss Malicki. Now a woman's prerogative known from creation, is to talk. I am not going to let a single Chairman of any of these committees talk, but I know you want to hear from one of the greatest women in America. Miss Malicki. (Applause).

WHAT IS YOUR WOMEN'S COMMITTEE DOING?

By MISS SOPHIA MALICKI, *Chairman,*
Women's Committee

(For Committee Personnel, See Appendix 4)

The Women's Committee of your company should be able to do these things:

Correct any untruths or misunderstandings they meet either in their work or in social contacts outside of working hours.

Explain why a utility company differs in corporate structure and regulation from other companies women are dealing with.

Explain the rates domestic customers are paying—not the top rate to which most customers and our enemies are accustomed to refer, frequently not allowing for the discount—but the average rate that home owners pay over a month or a year. Many of our own people do not realize how low the average domestic rate is. Our women should tell to all they meet the constant reduction of electrical rates.

They should understand that cost of electricity is not the deterring influence to electrification of households; that they pay a negligible fraction of their household expenditures for all the uses of electricity in the home, not only lighting.

They should be able to tell all women they meet of your company's aim for the very best service at lowest cost.

They should have earned the recognition and respect of homemakers and their organizations in your community and they should be called on to cooperate in activities toward home and community betterment.

Representatives of homemakers should be coming into the meetings of your Women's Committee where they will come to know you better, your organization and your principles.

Your Women's Committee should be the recognized authority on household electrical equipment in your territories.

They should be telling homemakers through the home service department and the entire women's group, about electrical housekeeping and they should help to establish it in every home.

They should discover the little, and to us frequently insignificant, misunderstandings of homemakers with your service, which so often are the root of real mischief to best service.

They should be teaching resuscitation and first aid to women's groups and they should take their place in community safety activities.

In a word, they should, through their education and abilities, be intelligent representatives of your company on all occasions and in all places.

Not Theories But Facts

These are not theories; they are items of work actually being done in all sections of the country.

If your group is not doing these things, go over your committee program with your chairman. Give it a little of your and your executive's interest and counsel that the work may follow more closely your policies and your belief of what it should be.

There can be no industry with a more loyal woman personnel, one so eager to translate to the public its pride in the achievements of its industry and its responsibility in the social advance of this country.

If it is possible for one group to develop to a degree where its chief executive considers the Women's Committee one of the most important influences in building understanding between the company and the women of the community, it is possible for all committees whose executives have the same interest and have given the support which this executive did.

Homemakers are adopting the statement, "ask the light and power women." We cannot disappoint that expectation.

CHAIRMAN OWENS: So outstanding has been Miss Malicki's work that she has been invited to attend the conference in England, where I am certain she will contribute much to movements that are under way in that country in an attempt to put into effect the practical application of our industry to home-making. I am sure you will be glad to know that.

We are honored today by having with us one of the outstanding economists of the nation, a man who has always been sympathetic with our hopes to properly interpret our industry to the public, a man who has been very sympathetic with us in our attempts to keep the public thoroughly informed of our business. He has done more than assume a pacific attitude. His encouragement has taken a very definite and tangible form, and he has for a number of years offered a prize in a Public Relations Contest. I refer to Mr. B. C. Forbes of the Hearst Publications and Forbes Magazine, who will now announce the awards of the Forbes Magazine Public Relations Contest. Mr. Forbes! (Applause).

AWARD OF FORBES PUBLIC RELATIONS CUP

By B. C. FORBES,
Hearst Publications and Forbes Magazine

As I stand in this magnificent hall and on this very imposing platform, a rank outsider, I am reminded of a fellow countryman of mine who was going home late one evening, after having had rather a jolly time. As he was walking along toward his suburban home he happened to look into a ditch full of water at the roadside. He stopped, very much startled. He looked again, drew back, and looked around. He saw a policeman a little distance off.

"Officer, officer, come here!"

The policeman came up in a hurry.

"Officer, do you see anything down there?"

The officer looked and said, "No, there is nothing there but the moon."

He said, "*Is* that the moon? That is just what I suspected."

"Yes," said the officer, "that's the moon."

"Well," he said, "if that is the moon down there, what in thunder am I doing away up here?" (Laughter).

I am up here as a humble representative of the ordinary public, but I am up here for a very, very unusual purpose for a Scotsman, namely, to give away something. The only thing they say that a Scotsman ever gives away freely is advice.

We, the ordinary public, looking from the outside at the utilities industry in the last year or two, have been somewhat bewildered. Various people and interests have put in very energetic efforts to arouse our suspicions against you gentlemen of the utility industry. For a year or more now, almost daily, the Federal Trade Commission has been holding up to us a very uncomplimentary picture of you gentlemen.

Then, more recently a still more unfortunate incident occurred which has again tended to make us ask just what you men are after, just what you are doing, just what do you aspire to do toward the public.

Also, we have seen your stock prices go up very, very much faster than your rates have been coming down.

Also, we pick up the newspapers almost every day and read of this, that, and the next new gigantic consolidation. We read very recently that the greatest financial organization, the most powerful financial house in the whole world, had decided to become interested in your industry on a colossal scale, the usual American billion dollar scale.

We ask again, just what is the meaning of this, what prompts this?

Our Socialistic friends whisper in our ears, "Let them go ahead, let them go ahead and gobble up all the utilities of the country into two or three mammoth trusts, and then it will make it very easy for us to take them over."

Now, is that likely to happen? I for one think not.

I remember addressing the N. E. L. A. convention two or three years ago, and in the usual role of offering something that cost me nothing, advice, I counseled your industry, "Say it with lower rates." I was delighted to hear my friend, Matt Sloan, take up this theme at this convention and urge that course. I believe that, notwithstanding all the bad breaks—that is what I would call them—the utility industry has been having in the last year or two, everything will come out O.K. for you in the end, because I have the privilege of knowing personally many of your outstanding men in the industry, and I know their character, I know their caliber, and I know their motives.

Customer Ownership

As an offset to this breakneck concentration and integration which is going on, this corralling of the public utility companies scattered over the continent in a few hands, I believe that you are on the right track in bringing about an offset to the impression which that is creating on the public mind, namely, your efforts to develop tremendously widespread ownership of your securities.

It was your industry that was the first to inaugurate customer ownership of stocks. It is your industry that has proved far more successful in that very worthy movement than any other industry. That policy, I know, is going to continue. So that, while we are having and are going to have tremendous concentration on the one hand, we are going to have what I personally regard as the very best kind of public ownership on the other hand.

As I say, I think everything will come out all right after the present bewilderment, mystification, has had time to pass.

Earning Public Confidence

There is nothing, of course, more important for your industry than to earn the confidence and the good-will of the people. Realizing this, my own little organization has done what it could to encourage public utility companies to earn and deserve the confidence of their local communities.

It, therefore, gives me very, very great pleasure to present the Forbes Public Relations Cup, awarded to the company adjudged having conducted the most effective and most successful public relations activities during the last year, to Mr. Alton Leonard of the Puget Sound Light & Power Co., and I ask him to come up and receive this cup. The exhibit which won it, a very elaborate exhibit showing what the company did in detail during last year, can be found on display out in the exhibition hall. (Applause).

[Presentation of cup to Mr. Alton Leonard.]

MR. ALTON LEONARD (Puget Sound Light & Power Co., Puget Sound, Wash.): In accepting this splendid cup and the tribute which it carries, I wish to express to Mr. Forbes the appreciation which I know is felt by the entire industry for his splendid public-spirited and generous effort to annually remind us of our duty to the public. Over a period of many years Mr. Forbes, in his extensive writings for the press and through his splendid magazine, has devoted serious thought and careful consideration to the relationship between utilities and their public. He is recognized as one of the eminent authorities of the time on public utilities. So this annual award takes on deep significance and the winning of it becomes an honor indeed.

As I stated a year ago in accepting the Charles A. Coffin Award for the Puget Sound Power & Light Co., we have endeavored to build up within our organization men and women whose whole-hearted thought and purpose is to carry out the true intent and purpose of our industry—service to the public.

We have also tried to so conduct our business as to inspire within the public mind a confidence in both the financial and moral integrity of the company.

In the grateful acceptance of this cup I again pledge to you the continued efforts of the thousands of loyal employes of our company, who by their successful endeavors to carry out this policy have made the winning of this award possible. (Applause).

CHAIRMAN OWENS: Mr. Forbes has brought to us, as he puts it, the viewpoint of an outsider. He has brought us a picture, and I am sure it is a real picture of what the public is thinking and the questions that the public is asking. He has given us food for thought. He has outlined to us our job.

A man said to me the other day that there was no longer any need for a Public Relations National Section. He said, "I hope the time may soon come when there shall be no need. When material things assume a higher place in the scheme of life and in the general scheme of things than do the reactions of men and women and the interests of men and women change. Then we need not think very much about the question of public relations."

I said I hoped the time may soon come when we will not need a Public Relations National Section. I know the time will never come when any business that does not give first thought to the effect of that business on the lives of men and women can survive.

In the last analysis the question of consolidations, amalgamations and mergers will rest solely on the question of whether the results obtained through those consolidations are in the public interest, and we in our business, more than in any other business, must measure our acts by that test. Mr. Leonard, I congratulate you, sir, on having won this highly coveted prize, and you Mr. Forbes, have made us a real contribution.

One of the outstanding men of our industry who has always had at heart the public relations movement, and who was one of its first prime movers, is unable to be with us today, having been called to Europe. He has prepared what I am sure is a treat for you in the form of a paper. His paper will be read by Mr. Homer E. Niesz of Chicago, vice-president of the Commonwealth Edison Co. and Chairman of the Industrial Relations Committee of the Public Relations Section. Mr. Niesz! (Applause).

MR. H. E. NIESZ: I shall present Mr. Gilchrist's paper just as he has prepared it, and in a manner which I hope he would like to have you hear it.

SUPER HUMANS FOR SUPER INSTITUTIONS

By JOHN F. GILCHRIST

Vice-President, Commonwealth Edison Co., Chicago, Ill.

To the strong, intelligent, thinking young people of America; to the self-sacrificing men and women of high purpose and high attainment who constitute the faculties, and the officers and trustees responsible for the policies and properties of the great educational institutions of this country; and finally to the directors, officers and personnel of the companies, already great, producing and distributing electricity in this land, this address is respectfully directed.

Upon you rests the responsibility for the proper development of a great fundamental industry, possibly to become the greatest of all industries and the one to which more than to any other will the people of our country and the world be indebted for the greatest measure of human life and happiness—the industry whose product gives one man the producing power of scores of men of only a few generations past, that spreads the noonday light over the hours of darkness, that for a trifle provides the poor of today with relief from grinding labor and with comforts and conveniences, life lengtheners, which the money of the rich could not buy in the days of our grandparents.

What Electricity Has Become

I ask you in all modesty to stop a minute and consider what electricity and the electrical industry has already become in our lives only fifty years since the first practical discoveries were made and we first began to know this wonderful energy, more flexible than the hand of the maiden, more powerful than the arm of the giant, a superb and ideal servant which is already performing so manifold a service in the home, the mart and the factory, and which has already become the life spark of so many great industries, such as those making automobiles, airplanes and radios, which would fail and disappear without it, that we can hardly vision the chaos which would prevail if the electric industry were suddenly to be withdrawn.

The production and distribution of electricity is an industry engaging directly between three and four hundred thousands of our people, and as an initiator of the use of electricity it may be said to be responsible for the employment in all branches of the industry of over a million; an industry engaging ten billions of the savings of our people, and therefore more democratically owned and managed than any of our great industries, for its seven to ten millions of average citizen-owners far outstrip in numbers that other great group which owns the farms of the country; an industry which serves twenty millions of customers with an amount of energy equivalent to the works of thirty million horses laboring continuously twelve hours per day every day in the year.

One-half of this great development has taken place in the last ten years, forty years of previous growth doubled in ten, the result of a great and numerous people awakening to what electricity will do for them. And who will say that this rate of growth will not continue and even increase?

Naturally, this great and rapidly growing industry creates many demands on world resources, any one of which might be the subject of much discussion. I wish to discuss but one, the one which I believe is the greatest of all.

Looking to the future, the greatest need of this industry is for men and women, or might I say for superior men and women, superior in mental and physical vigor, superior in common sense, superior in general and special education, trained young people with an intimate knowledge of the present-day conditions in the business in which they expect to embark, so that on embarking there shall be the least time lost in finding themselves.

The period of physical vigor in the human being is so short that in occupations where experience added to other qualifications is a matter of so much importance, it is essential that no time should be lost in orienting the trained novitiate so that he may promptly assume the responsibilities of the position for which he has been trained.

Much thought is being given today to the question of what will be the limitation in size of our great commercial and industrial institutions, how much larger they can become, or, to put it in another way, as a recent speaker has said, "Are we building up something that will finally overwhelm us physically, mentally, sociologically and politically? Is this machinery of our life getting so complex and overpowering that the human machine is breaking down under it?"

What are the limitations of our modern institutions? And if growth is desirable from the standpoint of humanity's best interests, how can we extend these limitations? Will the human intellect, the human body, the vision, appreciations, determination, self-control of man be such that bigger men and women, better educated, better trained, will develop to take the bigger jobs? Or, to put it another way, must the jobs stop growing in size regardless of the advantages to the many because we have reached the absolute limit of human capacity?

To a certain extent we are facing this problem in our industry today. The big jobs are being filled, but no one appreciates more than the people that are in them, regardless of their capability, regardless of the fact that they are the best available, how much better fit they might be if they had had the benefit of special training for their present positions, or if they had known when they were young students, or if their instructors had known then as much as the occupants of these jobs now know of the requirements. Of course, that would be impossible and will continue to be at least until we can see much farther into the future than we can at present, but we now have a much better opportunity to judge of the requirements twenty-five years hence than the present executives had when they began, and much can be done to provide for the future if all concerned will cooperate and make the best use of the knowledge now available.

Always Room at the Top

If the student anxious to prepare himself for a useful and effective life, the educator devoting his education and culture to the turning out of a well-developed, well-educated and practical human product, and the executives in the electrical industry who are in a position to have the best vision of what is required, will work together on this problem, they certainly can accomplish much.

The old statement that there is always room at the top was never truer than it is today in commerce and industry. How often it occurs that the greatest difficulty is experienced in finding the persons to fill the vacancies left by death or retirement, and while this is conspicuous in the case of the heads of great institutions, it exists in just the same way in the case of the subheads, of whom there are a much greater number.

It is not at all uncommon in the present day for a large company to acquire a smaller one principally for the purpose of securing the services of the head of the smaller institution. And to illustrate in another way this dearth of supermen capable of filling the biggest of earth's jobs; we can recall many cases where some great property has been seen to thrive and make progress under one man only to retrograde under his successor. In such cases it is impossible to avoid the conclusion that when the able man died or retired, there was no one of equal or superior capacity coming along to take his place.

Such situations as I have referred to have not occurred frequently in the electric utility industry, but we are reaching a size, and the young men who have grown up with the industry and brought it to this point, are reaching a period of life where changes must occur, and therefore if we are to be alert and progressive and ready for the emergencies, it is important that we should give thought to meeting such situations in our business.

Here, as I have indicated, is a task and a situation in which foresight, proper education and training are most important factors, a situation which should be of the greatest interest to the young men and women of the nation looking for careers, to the educators of the nation who wish to serve by preparing young men and women for effective, useful lives, and to the owners, directors and executives of the utilities who wish to constantly improve the efficiency of their service to the public by having superior material to recruit and build up their organizations so that they will render the most complete service in the most satisfactory and economical way.

Look to Colleges for Trained Men

The very natural way to attack this problem is for the executives of the utilities to turn to the institutions of learning, universities and colleges, present their matter and ask for cooperation. There is little question in the minds of most people at this time that as a preparation for business a college education is very desirable, or, to put it another way, men and women of otherwise equal talents and ability are enough better prepared and consequently enough more effective in business positions if they have college educations than if they have not, to justify the expenditure of the time and money.

The utilities, therefore, naturally turn to the producers for their supply of college-bred men and women. In order that these young people may be particularly prepared for the work into which they are going and in order to stir up the interest on all sides, it is desirable to have a very general understanding of the character of the work into which the student is going so that he may fit in to the best possible advantage, and may avoid discouraging experiences and delays in finding himself and getting started. There is so much information which he will want and will have to have that he could so easily acquire along with his other studies and preparatory work, that I do not think anyone would question the desirability of such cooperation as I have discussed. Without much study it is difficult for the college professor or the layman to appreciate the possibility for the employment of trained men and women in the utility business due to the growing complexities requiring superior training, and also due to the rapid growth of the business and its potentialities generally.

Three Pertinent Questions

May we consider three questions which seem to be very pertinent to this discussion:

1. Why should the young college-bred men and women want to take up work in the electrical industry as their life work?
2. Why should the universities and educational institutions of the country take a great interest in the electrical industry, want to know the most possible about it, and want to educate young men and women in a way which will qualify them to do the best and most serviceable work in this industry?
3. Why should the electrical executive want to take into the employ of his company all the specially trained college-bred men and women he can possibly use, and to that end want a close intimacy with the faculties of the nation's higher schools?

Before answering these questions, let us give a little further consideration to the importance of the electric light and power industry and its probable future. Are we wrong—are we egotistical—in believing that our business is quite likely to become the greatest of all businesses?

All business is based on human needs and wants. If the human being sits still upon the earth he soon dies. If he gets up and becomes active—that is, exerts power and directs it intelligently—he provides himself with the necessities, the comforts and the luxuries of life and living, and the rapidity with which he accomplishes this and the extent to which he goes is primarily dependent upon the amount of physical power at his command.

Doctor Scott, President of Northwestern University, has shown in a most interesting way how a high standard of life for the few in past ages was dependent upon some power in excess of the physical power of the individual, generally supplied by slave power and animal power, and how in modern times the new electric power is becoming a substitute, and as a result even with present development of electric power there is an equivalent force equal in labor to the labor of many slaves already available to each citizen of our country, which is primarily responsible for present-day prosperity and the great improvement in the standard of living of our people. It would, therefore, seem that the want for power might become the greatest human want as methods for applying it are worked out and as these methods become known to the individual. Mr. Henry Ford is quoted as saying: "Power is the foundation of material prosperity," and also that, "This is the age of power." And one hears similar statements on every hand.

However, this does not necessarily mean that the power business will be the biggest business measured in dollars and cents of sales per annum, even though it may be fundamental.

Cost of Power Small Part

As indicated, the modern automobile, the airplane, the radio, are all dependent for existence as well as for operation on electricity. Without electricity we would not have them, and yet the cost of power required in the making of an automobile and the operation of it, even including the power required to produce, refine and transport the raw materials, may be only a small part of the price which you pay for the finished motor, so that while power is the dominant factor and controls all the wants, it probably is not the largest item, but even in this last thought we may not be looking sufficiently into the future.

Ten billions of capital is invested in the power business today, and the requirements of the people are making it necessary to invest a billion a year at the present time, and this rate of requirement is likely to accelerate, so that I should say it is most conservative to estimate that in twenty years, or at the time when the boys and girls coming out of the colleges today have reached their maximum value, there should be at least forty billions of capital invested in this business.

There is no question in my mind that this industry will shortly pass the railroad transportation business in capital invested and yearly earnings, even were it not almost certain that the operation of all parts of all the railroads by electricity purchased from the power industry is only a short distance ahead.

While it is speculation to attempt to look into the future, it seems reasonable to think that just as we have found ways of transmitting through the air sounds and signals which in the early part of the last century we could transmit only by wire (automobiles and aeroplanes have in an experimental way already been controlled and in that sense operated from remote points by wireless), so may the transmission of power by air follow the present distribution methods, opening up great fields for the increased use of power, which, with all the problems of control, distribution, sale and metering which would attend such a wonderful development, will afford fascinating occupation for large numbers of intelligent, trained people.

In short, there is no reason to think that for many years to come the rate of increase in the electrical requirements will not accelerate as compared with the period we have just gone through rather than decrease, and therefore, while I might go into great detail in speculating on what the development may be, I cannot but feel that we are justified in believing that this is a business which any able young person seeking a life work and an opportunity for service may place at the head of his list of possible occupations, and an industry which will have no difficulty forcing itself upon the active attention of those engaged in preparing the young men and women of our nation for the activities of life.

Returning to the questions propounded, the youth should desire to enter the electrical business because it gives him an opportunity for a vigorous, active life of service, which is the most worthwhile, in a large and important world's industry, perhaps destined to be the greatest of industries, at good remuneration, with an excellent opportunity to invest his savings advantageously, which is the most sure and honorable way of becoming independent. It brings him into an industry involving some of the biggest and most interesting problems that he will find in any modern world occupation, such as dealing with the human passions, jealousy, envy, personal ambition and greed in organization and overcoming these great obstacles to cooperative progress; and study of human nature and methods of dealing with it to bring out the best in those reactions which develop harmony, collective ambition and all the states of the human mind which result in accomplishment and high production; the art of building the organization where great men with no loss of spirit will work under other great men; intricate, absorbing questions of finance, administration, law and other fields and participation in a business where the opportunities for becoming well acquainted and becoming well known and useful citizens in the community are greater than in almost any other industry.

Interest in Power Industry

The institutions of learning should take a vigorous, personal interest in the electric power industry. First, from the general standpoint, it offers a great boon to humanity, and in order to know all these advantages and derive the greatest benefit from them, general education should involve a rather intimate acquaintance with the up-to-date electrical situation. Further, because of the industry's importance and extremely rapid growth, increasingly large numbers of people will become engaged in it each year, and there is not only a great opportunity of assisting the young people of the nation to get into most desirable occupations, an opportunity to render a great service to humanity by providing most practical education for young men and women who desire to go into this industry and are going into it in large numbers and who very shortly will be dominating its policies, but there is the greatest opportunity of having an important hand in molding the underlying principles and policies which will govern these utilities a few years hence. Thus responsibility for the public utility service of the future is now resting upon the shoulders of the educators of the country.

And lastly, the utility executive should welcome the advent of the college-bred men and women in his business, because it will raise the standard of his company's personnel and will put him in a position to render a better, more satisfactory and more economical service to his public. It will result in the application of brains, modern methods, research and high purpose to his industry, all of which follow in the wake of a well-selected and well-educated personnel. His business will develop scientifically and will grow more rapidly than it would possibly have an opportunity to do if served by mediocre and poorly trained people.

These are not new thoughts. What has already been done to develop such activities and the kind of cooperation we have been discussing? Some sixteen years ago the suggestion was made that relations should be developed between the electric public utilities and the great institutions of learning, and acting on this suggestion, a committee of this Association was formed, composed of professors from a number of the prominent universities and colleges and men prominent in the electric light and power industry. The reason for this desired relationship was that the electric industry was at that time growing at such a rate and furnishing a service of such great usefulness to the people that those engaged in it began to have some vision of what it was likely to become and to realize that not only should the institutions of learning be familiar with it and up-to-date with regard to it, from the standpoint of general useful information to the great body of their students, but that the industry was requiring more and more college-bred men to take up its work, and it was of the greatest importance that there should be closer relations between the educational institutions and the industry so that these young men would be prepared in a way to make them most useful in the industry, in the shortest possible time.

At that time the electrical manufacturing interests of the country had begun to pay considerable attention to the engineering graduates and the telephone interests also were watching the students through their courses and each was endeavoring to pick out the cream of the men.

Relations With Colleges

This activity on the part of the National Electric Light Association developed the fact that quite a number of electric light and power companies already had relations with their neighborhood colleges. The first work of this committee was directed toward accomplishing four things:

1. Assisting faculties, by consultation and suggestions, in the choice of studies for their curricula covering their electrical courses.
2. Working out plans by which more of the undergraduates could get summer work of a class which would be of some value to them from an educational standpoint and at a fair compensation.
3. Furnishing the libraries of the universities copies of worthy and valuable pamphlets and books bearing on the electrical industry.
4. Arranging for an interchange of lectures by electric light men before faculties and student bodies, and by members of the faculties before groups of utility employees.

This committee continued its work up to the outbreak of the World War. Then there was a cessation for a year or two, but after the war the committee was reorganized and has continued with growing interest up to the present time. There is a very excellent understanding on the part of the members of the committee of each other's situation. Through the medium of its various reports, a great many people in the utility industry are informed as to the work of the committee, but until about a year ago its work was not so well known among the educational institutions other than those that had representatives on the committee. Therefore it was deemed wise to have a representative of the committee who knew the work very well visit the more important educational institutions and familiarize them with what the committee was trying to accomplish.

Advantages of Close Relationship

The committee was most fortunate in being able to make an arrangement with Professor Ruggles, who at that time had just been called from the University of Ohio to Harvard University, and for that reason could arrange to give more time to this matter than would otherwise have been possible. This was a very happy arrangement, as it would not have been possible to secure the assistance of a man who had a better grasp of the subject, who was better able to present it, or who had as wide and as favorable an acquaintance among college people.

While the primary importance of this relationship between the educational centers of this country and the utilities is the securing of properly trained people for the utilities and the interchange of information which is essential to intelligent prosecution of that work, it is realized by the committee, and was by the original committee, that there are matters of general interest on each side which should be known to both parties, and to the utilities particularly it is of tremendous value to have the benefit of the unbiased views of these men of broadest attainment who make up the faculties of our schools. We have the great forum of the public, but it is not so tangible or accessible as this very logical forum of the leaders of the intelligentsia of the country, and there are many questions which come up in our industry, with regard to which we think we are pretty well informed and of which we believe we are taking a pretty broad view, in regard to which our views may be greatly broadened and our policies undoubtedly greatly improved by taking advantage of this natural contact.

Relations With Public

The range of these subjects is very wide, involving studies of relations between the utilities and the public, what should be and what is the attitude of the public toward the utilities and the utilities toward the public, what affects this attitude, studies of the relation between large numbers of the people working together cooperatively in one institution like a modern corporation, what conditions are conducive to the most effective work and results, financial questions, engineering questions, sociological questions, matters of research and investigation and almost innumerable questions and angles, all of which have a decided bearing on our business, and all of which should receive proper, organized attention in the well-managed institution.

The work of this committee should be receiving the very wide interest and support of the leaders of our industry. The farsighted ones, if not all of them, have begun to concern themselves with finding the well-balanced, healthy young people with superior intellects in their respective organizations and training them to fill the important executive positions in the future. Here is a branch of your Association's work which will be of great assistance in this task. I therefore commend it to you from the standpoint of your own interests, as well as from the standpoint of the general interest of the industry.

A Wholesome Opposition

I fully realize that this relationship between our industry and the educational institutions has been challenged as something improper by certain men in public life and a certain section of the public press, but if we are right in this matter, and I do not think any unbiased person who will take the trouble to learn the facts will think otherwise, this should not deter us. Furthermore, allowances should be made for the necessary time for information as to such activities to be digested by all branches of our body politic. Also, allowances should be made for the fact that, thanks to the sensation-loving proclivities of the average newspaper reader, some of these agencies have personal interests of a circulation character which are served by such attitudes and should not be taken too seriously. Such opposition is, on the whole, wholesome, and, despite the fact that many of the statements made by this opposition lack truth and most of the balance are grossly extravagant and misleading, they do tend to develop discussion and careful consideration, and will finally without doubt be found to contribute somewhat to the universally approved plan in the public interest which will ultimately be worked out.

Therefore, as all of the outcome of this situation and responsibilities will greatly affect the good of the nation and its people, we hope that this entire matter will receive serious, careful consideration, and that all working together we may, with interest and courage, proceed to work out a proper plan of procedure having in view the best interests of our country, our people and our prosperity. (Applause.)

CHAIRMAN OWENS: I am sure you will all agree that in this paper Mr. Gilchrist has made a very valuable contribution.

Our President has just come into the room. He is tired, I am sure. He has been a hard-working President. He has thrown himself into this job in the past year in a very vigorous way, and to be President of an Association such as this, widely scattered as are its members all over the United States is some job. However, I cannot let him get away without giving you a word of greeting. President Arkwright!

PRESIDENT ARKWRIGHT: The tiredness is not mine; the tiredness is that of the audiences to whom I have been speaking around and about. I do not need to come to a Public Relations Section to evidence my belief in it. I am stamped "Public Relations" all over. I told Mr. Owens I didn't think it was necessary for me to say anything to indicate the value that this Association and its officers, and I in particular, place upon the work of the Public Relations department.

I also say again I have almost got an obsession that these meetings should start on time, run along snappily, and adjourn shortly. I am sure I am not going to ruin yours by any speech of my own.

I would like to say, however, there was a time when they said the public utility had a "public be damned" attitude. Well, I do not think anybody ever made any such remark as that, but I do know that in our own industries, as in all public utilities, there was sort of a public indifference to the public attitude. It has completely changed. We are anxious to render such service in such spirit of co-operation—consideration of the other fellow's rights and viewpoints. I know very well that that change of attitude on our own part has been due in large measure to the activity of the Public Relations Section of this Association which has been spreading the need for that kindly treatment of the public and the customer, and stimulating a similar conduct on the part of our various members throughout the country. So if there is nothing else gained from it, or any other reason for the existence of it, the Public Relations Department justifies itself in the greater consideration, the better treatment, the more careful effort on our part to see that our acts are justified and done with consideration for the rights of others. If there were no other arguments in favor of it, that itself more than thoroughly justifies it.

Physical service alone does not, in our business particularly, answer the question. It is absolutely essential that we continue to conduct our publicity and our public relations activities.

Thank you. (Applause).

CHAIRMAN OWENS: Before announcing the next number, I want to call attention to a very special feature of this program this afternoon. In a very short time you will be privileged to hear one of the outstanding leaders in a movement that has for its purpose the assistance of home life, and its additional purpose, as I understand it, of encouraging men and women of every line of endeavor to give greater attention to the home and to the improvement of the conditions in the home. We have an authority on that in this program. You will admit, I am sure, that it is one of the finest things of this convention. We in this business are tremendously and vitally interested in learning from those who are authorities along this line. So after the next interlude, Miss Bane will talk, and I urge that no one leave.

There will be no Ripley lecture. I should announce we have substituted something else. The Western Electric Company who has always co-operated so splendidly with this convention, has given us something very interesting. I hope you will like it.

[Showing of talking-moving picture.]

CHAIRMAN OWENS: Before introducing Miss Bane, I should like to present to you Miss Eloise

Davison, Home Economics Director of the National Electric Light Association. (Applause).

I will now present to you Miss Lita Bane, Past President of the American Home Economics Association, and of the Home Economics Department of the University of Wisconsin, Madison, Wisconsin, who will discuss "The Part Electricity can Play in Better Home Management." Miss Bane!

THE PART ELECTRICITY CAN PLAY IN BETTER HOME MANAGEMENT

By Miss Lita Bane,

Past President, American Home Economics Association

It is something of an adventure, and perhaps rather a hazardous one at that, for a college teacher to address a group of so-called "hard-headed businessmen." Coming of pioneer stock where adventure was a part of everyday living, I have dared to take the risk.

Standardization, large scale production, and efficiency, have become words of such power that they have come to dominate most of our work and some of our play. However, even an efficiency engineer has been known to revolt when someone suggested that he apply efficiency principles in his own home.

Only last year one of our popular magazines carried an article which stated "For the man, Home is or ought to be the place to which he can escape from the more or less artificial postures of public life. It is where organization and efficiency should show their ugly faces as little as possible, where tidiness and system and the doctrine of a place for everything and everything in its place are abominations. Are we not sated with neatness and orderliness and schedules and filing systems in the office?" This will indicate to you how difficult is the problem of the home manager. Do we want standardized homes? Do we want efficient, standardized equipment? Do we want precisely standardized procedure? Do we want our every act controlled by standards of efficiency? If not, where should efficiency stop and inefficiency, so to speak, begin?

Proper Function of a Home

Some of the confusion regarding acceptable standards for home management arises out of the fact that we have no clearly defined, universally accepted definition of the proper function of a home in our present social order. Someone has well said that the chief function of the home is "to build men and women having noble minds and souls." While that is a perfectly legitimate purpose, what are the factors to be considered in so administering the home that it shall best discharge this function?

In some ways our attitude toward our homes resembles our attitude toward recreation. It is the process rather than any measurable accomplishment that we enjoy. Take the game of golf. There are many more efficiency ways of getting a ball around over a pasture, dropping it in holes and extracting again and going on, than by knocking it about with a queerly shaped stick. You might carry it around in a basket, or in your pocket, dropping it carefully into the holes as you come to them. It is this point of view regarding home-making that is sometimes missed by the person of little imagination, the person who insists that every woman should hail with delight any piece of equipment that offers a shortcut.

I have purposely begun at this point not because I believe that homes should be inefficient, but because I am so thoroughly of the belief that they should be efficient in accomplishing their objectives, which are in the main quite different from the objectives of a factory or perhaps industry in general.

We all know, however, that no matter how much "play" may enter into the doing of some of the housework, there is much of it that most women are glad to delegate to machinery. While a woman may delight in mixing and baking the special kind of cookies her family likes best, she would without doubt welcome any machine that would relieve her of dishwashing. In fact, it seems safe to make the general statement that women are glad to routinize, standardize, and mechanize any frequently recurring tasks whose processes no longer hold any interest for her.

Electricity is one of the home manager's valued allies. It is our aim to help her make it more adequately serve her needs, not forgetting that she will always look upon it as a means to an end, that end being in most instances a fairly intangible one, falling more in the realm of the spiritual than of the physical. Nevertheless, physical needs are ever present and insistent, and the home-maker can often use machinery to shorten her time of work and lessen the manual labor involved.

Technical Processes Improved

The home of today finds itself in a rapidly changing world, a world in which technical processes have been enormously improved both in the house and in the world outside. We are indebted to Dr. Ogburn of the University of Chicago, for collecting figures which indicate the way in which housekeeping practices are changing. The number of servants is decreasing. The number of waiters in restaurants, the number of delicatessen shops, and of bakeries, is increasing rapidly. The use of canned foods is increasing. Families are increasing the number of their washings sent to public laundries. The number of sewing machines in use in homes is decreasing relatively. The relative number of apartment type dwellings is increasing. These figures indicate that women are delegating to outside workshops an increasingly large amount of work formerly done in the home. Electricity can thus indirectly benefit the home manager by further perfecting factory processes. Notwithstanding these rather startling figures, it seems likely that for many years to come there will be much manual labor for a woman or for a machine to perform in most households.

The home manager's responsibility is to so manage the time, energy, money, and abilities at her disposal as to make the home yield to all members of the family the greatest possible amount of satisfaction. Electricity can aid her in several ways. (Power) By furnishing power to drive some of the machinery. On this point a few comments are perhaps in order. Some family budgets are entirely inadequate to finance the buying and operating of power driven machinery. When the mother of the family is well and strong, it may be the best kind of thrift for her to save money by using her own strength to do the manual work of the household. Many women prefer to do this in order to have money for some other items in the budget which they believe will make a larger contribution to the welfare of the family. It is a mistake for her to be persuaded to buy power driven machinery. On the other hand, for the frail woman, or for the ample budget, it is highly desirable and usually proves to be less expensive than servants.

I had an interesting personal experience only two weeks ago. A student reported the following: "My father happened to bring home a Kitchen Aid. He had learned a little about how to operate it, and he tried to teach my mother. She used it a few times. We have a maid of all work. She does some cooking, serving, and general things about the house. Mother tried to teach her the little she knew about it, and the maid said it was more work than it was worth."

A Practical Helper

I pointed out to her a woman whom I knew very well, who lived in a suburb, did considerable entertaining, is not strong physically, and finds it difficult to get any part-time help, who has made very good use of her Kitchen Aid. On inquiring what was one of the things that enabled her to do the large amount of entertaining that she does do, she replied it was very largely due to the fact that she had this particular piece of equipment.

So you see the equipment has to be selected to meet the needs of the particular household. However, one of the most important things it seems to me is to have someone teach the women how to use each piece of equipment efficiently. In the first place, father had bought the machine, learned a little about it, but he didn't know much about cooking in the first place. He in turn tried to teach what he had learned to his wife. She in turn tried to teach it to the maid. There was too little information, and the tool seemed to be useless in that household, while if the person who was to use the tool had been taught just how to use it, it might have been a labor-saving device even in this household.

One way to make the costly equipment available to families of low income is to own it cooperatively. You occasionally find an apartment house where tenants own a washing machine, vacuum cleaner, and other equipment cooperatively. There is still a large field for encouraging people who have limited incomes to pool their resources and purchase one or more expensive pieces of equipment and pass them around for use.

One of the things that we always have to meet in trying to persuade women to use machinery is the fact that they do not know much about machinery, and feel much as they do about mathematics when they say that they cannot "fiddle with figures." They often do not have any confidence in their ability to run a machine.

Many women doubt their ability to master the techniques involved in operating even the simplest machinery, though I believe the automobile has been effective in reducing the number of doubting ones, since so many women are now driving cars. Women have reported that men are not so effective as are women in persuading them that they can use motor-driven equipment. Neither do men seem to be so successful in teaching them how to operate and care for their machines once they have bought them. As we all know, cooking with electricity involves a technique differing in many respects from that used in cooking with gas, coal, or wood. Someone who can teach women this technique with patience and thoroughness is a real asset to any electrical company. Many women who have reported dissatisfaction with other electrical devices find them invaluable after having been taught how to use them.

So Many "Contraptions"

In reply to the question, "What shall I say to the National Electric Light Association?" put to a woman who is an ardent advocate of electrical devices, I received the reply, "Tell them not to try to get people to use so many 'contraptions.' " To my inquiry as to what she meant by "contraptions," she mentioned several complicated pieces of equipment devised to perform tasks which in such a small unit as the home could be done more efficiently by hand or by a simple hand-operated machine. There again it seems to me that women who actually do household work, know what should be done in the household, and should be useful in advising regarding equipment.

While there may be a limited demand for specialties of some kinds, women seem to agree that they would like to see the major efforts directed to devising power machinery to take care of the time-consuming, heavy, frequently recurring, likely-to-be-monotonous tasks. For example, an electrical device for making beds would not be likely to meet with much enthusiasm in most homes, whereas witness the enthusiastic reception given to electrically operated cleaning devices, and to some electrically operated cooking devices. Bed-making is not a particularly heavy task. It has to be done only once a day and requires comparatively little time. Consequently this process and kindred processes can well be performed without the aid of power-driven machinery, for the present at least.

Freedom from Manual Tasks

It seems worth while to note in passing that with the advent of more freedom from manual tasks in the home, women will have a better opportunity to devote themselves to the care and training of their children, to making the home the place of rest and satisfaction that we all want it to be, and to participation in worth while community activities. It seems likely also that the home may regain some of its former prestige as a center of recreation for the family and small groups of friends. Electricity is making a direct contribution to this situation through the radio and electrically operated musical instruments, and indirectly by making the house more comfortable and convenient for the entertainment of guests. It will undoubtedly make even larger contributions in the future.

Had I the mind of an inventor, I could doubtless suggest many needed devices that some of you would go home and straightway produce and have on the market tomorrow. My secret ambition at present regarding tools seems to be to invent some kind of electrically driven can opener that would be cheap and effective. Someone has suggested that cans should be equipped with zippers, and I am sure I approve the suggestion. If you follow out the various tasks the woman has to perform, you will find there is no more awkward task than this one being performed by a tool which is as yet far from perfection.

(Heat) There is considerable division of opinion regarding the electric stove. Unquestionably where gas is not available, an electric stove is a real boon. Some of us have not yet been persuaded that an electric stove is just as much a convenient, all-around stove as a gas stove. I see no reason why it should not be made so, and I think in a great many instances the difficulty lies in the fact that we have not yet learned how to expertly use an electric stove.

Because it is clean and is fairly easily controlled, it will probably serve as a satisfactory source of heat if the price of equipment and current are sufficiently reduced to make it practical for the lean purse.

Electricity as Source of Light

We are so familiar with electricity as a source of light that I scarcely need mention it more than to congratulate the makers of light bulbs and fixtures upon the progress they have made both from a practical and aesthetic point of view. My friend referred to previously, suggested that I urge you to devise some inexpensive method for using indirect lighting in private houses, particularly in living rooms. Having spent my childhood days where lamp chimneys had to be washed, and that being assigned to me as my particular chore, I bow my thanks to the electrical world for changing our method of lighting. My only comment here would be let the good work go on.

It was my assumption that you wanted someone representing a group of people who are making a careful study of the home-makers' needs, to pass on to you any suggestions that we may have. Therefore, acknowledging our indebtedness to you and assuring you of our eagerness to cooperate in making housekeeping less arduous and more interesting, may I suggest that efforts be made as follows:

1. To produce and sell electrical current as cheaply as possible. In my contacts with women in their own homes, I often mention electricity and ask them why they do not use electrical equipment. The answer invariably is "it is too expensive." Perhaps there is nothing that can be done about it, but we hope there is. I grant you that some of this is prejudice. We have so long thought of electricity as being expensive that there are a good many women who automatically say it is too costly, without having the facts. Those facts we want to get from you, and we in the home economics profession are glad to pass on any information that will help to correct prejudices that may have been carried over from previous years when electricity was more expensive.

As you know, reports indicate that only slightly more than half of our population live in electrically lighted houses. There are other figures that indicate that a relatively small proportion of our houses have vacuum cleaners, refrigerators, and electric washing machines. More of them have electric irons, but we still have a great deal of room for expansion.

2. My second suggestion is that you make a careful study of the needs of home managers in order that money and effort may not be wasted in producing tools that are used very little, or are useless.

You know, I am sure, that you can quickly build up a prejudice if you equip a house with pieces of equipment that do not meet the needs of the particular household. Immediately there is set up a wall of prejudice which is difficult to break down. It seems to me that all of us need to study the needs of the home manager in order that we shall put into her hands only the tools that are really efficient for her.

3. May I suggest also that an attempt be made to produce electrically driven machinery which shall be as simple and as cheap as it is possible to make it, consistent with good service. Is it not possible for some plan to be put into operation whereby only safe, durable, and efficient machinery will be offered for sale? Make it fool-proof so that the woman who is buying cannot make a mistake, that whatever piece of equipment she shall buy shall meet the requirements of safety, durability, and efficiency.

Would it be possible—and I am asking this as a question—to put into the hands of the woman, the consumer, the buyer, certain very simple specifications or standards by which she shall be able to judge when she goes into a store, something about the relative efficiency of units, something about electrical washing machines, something about vacuum cleaners, something about relative costs.

There still persists in the mind of our buying public the impression that if you pay the most for something you get the best out of it. That, of course, isn't always true. Is there some way of focussing attention on the efficiency of the piece of equipment rather than encouraging the woman perhaps to use a green stove rather than a gray one? The color may be important, but after all the efficiency of the piece of equipment which she is buying is of tremendous importance and is her real reason for making the purchase. Can you strengthen her hands in some way so that she shall make fewer mistakes in the future, which is, of course, to the good of all of us.

4. Then is it possible to offer women careful training in the selection, in the use, in the care, and probably the simple repair of household equipment? I have stated heretofore that women in this work are particularly successful, more successful than men.

May I just make one suggestion here? Take it for what it is worth. It seems to me as a home economist that you as sellers of electricity and electrical equipment can best serve the home-maker by giving her information which has to do very specifically with your field of work,—the use of electricity in equipping her house, so she may use electricity to the best advantage. There are a great many places where she can get recipes, where she can be taught proper combination of foods, and it would seem to me that you as a group would be rendering a more specialized kind of service for which the home-maker has inadequate opportunities, if you would specialize along the lines of teaching her to use equipment rather than offering cooking schools.

5. May I suggest also that care be exercised in putting into a home only suitable, needed equipment so that the budget can be carried through without undue worry or strain.

6. If I may be permitted to emphasize one special need, it would be the need of the farm home where there is still in many instances an undue, almost an unfair amount of manual work still to be done. If I were pointing out the thing that seems to me to be your large social opportunity, it would be the opportunity to bring to the farm, and to the farm home, electrical equipment and electricity at a rate which would make it possible for the farm homes and the farm to have a chance to participate in this tremendous power that is at the finger tips of most of our urban people in order that the lag behind what we might call our "general culture level" may not be so great. Surely cheap electricity, efficient power-driven tools and equipment would be a great boon to the farm women. At the present moment it may well have an even more far-reaching effect than that of labor saving. Since again and again farm accounts reveal the fact that it was the chickens, the turkeys, the garden that made the difference between loss on the one hand and profit on the other, we might pause to consider whether the release of the woman's time and energy through the use of power machinery and her use of them in some productive effort might not only offset the cost of the machinery, but contribute to farm profits.

Perhaps this may seem a bit indirect so far as the problems of the home manager are concerned, but I think it is important. If it were possible to introduce on our farms substitutes for farm help—those substitutes may be electrical helps—it would rid the farm home-maker of a good many problems, not simply the physical problem of feeding and housing hired help, but the other problems much more serious to all farm women of having to keep in the household the kind of people who are at the present time likely to be available for farm help, who complicate the family relationships, and the problem of child training. If we could get the farm help "out of the house," as one woman said, we would be helping the women a long way in their home-making problem on the farm.

Electricity's Part in Home-Making

We must, of course, acknowledge the limitations of electricity in accomplishing the full program of home-making. A few years ago at an electrical show there was displayed a baby spanking apparatus. I am not even sure that that would be effective on all occasions. (Laughter.)

We know also that we cannot depend upon electrical robots to train up children in the way they should go, to offer us the solace and inspiration of devoted members of our family. Nevertheless, we can use it as a tool in making the machinery of housekeeping operate more effectively and with less human effort. The wise home manager, whenever it is within the range of her budget, will make large use of electricity.

As I see it, the chief aims of every home-maker are as follows: To see to it that insofar as possible her home is economically sound; that it is mechanically convenient; that it is physically healthful—and, of course, it goes without saying that we want our homes morally wholesome. We also want our homes to be mentally stimulating. We want them to be artistically satisfying; we want them to be socially responsible; we want them to be spiritually inspiring, and supporting it all, of course, we want our homes to be founded upon mutual affection and respect.

As I see it, wherever electricity can aid in accomplishing this aim, there is its place in home management. (Applause.)

CHAIRMAN OWENS: Miss Bane has made a real contribution not only to this program but to the industry. Miss Bane, on behalf of the industry I thank you for these valuable and pertinent suggestions, and for your very splendid contribution.

I ask your indulgence for just a moment, please. Is the nominating committee ready to report? Mr. Dick, will you come to the platform, please?

While Mr. Dick is coming to the platform, I think if Miss Bane has not done anything else, she has emphasized in our minds the advantage of having a department in our business in close contact with the home, a Home Service department.

Mr. Dick, Chairman of the Nominating Committee!

Nominations

MR. JACKSON DICK (Georgia Power Company, Atlanta, Ga.): The Nominating Committee has suggested the following names:

T. A. Kenney, Allied Power & Light Company, New York.

H. B. Flowers, New Orleans Public Service, Inc., New Orleans, La.

R. T. Smalley, Kansas Electric Power Co., Lawrence, Kansas.

E. A. Barrows, Narragansett Electric Co., Providence, R. I.

Leavitt Edgar, The Edison Electric Illuminating Co., Boston.

D. C. Green, Electric Bond & Share Co., New York.

Paul Dowling, Pacific Gas & Electric Co., San Francisco, Cal.

S. E. Skelley, Pacific Power & Light Co., Portland, Ore.

V. L. Board, Public Service Company of Colorado, Denver, Colo.

Jos. Gill, Florida Power & Light Co., Miami, Florida.

T. D. Crocker, Northern States Power Co., St. Paul, Minn.

L. B. Herrington, Kentucky Utilities Co., Louisville, Ky.

W. S. Vivian, Middle West Utilities Co., Chicago, Ill.

F. R. Phillips, Duquesne Light Co., Pittsburgh, Pa.

John Coghlan, Pacific Gas & Electric Co., San Francisco, Cal.

Nominations, aside from those submitted by the Nominating Committee, may be made from the floor.

CHAIRMAN OWENS: If there are no other nominations, what is your pleasure with regard to the report of the Nominating Committee? A motion to adopt the report will be in order if there are no other nominations.

MR. MARTIN J. INSULL (Middle West Utilities Co., Chicago, Ill.): I move the report of the Nominating Committee be adopted.

[The motion was seconded, put to a vote and carried.]

CHAIRMAN OWENS: That concludes the program. Thank you very much indeed for your attendance.

[The meeting adjourned at 5:10 p. m.]

PUBLIC POLICY COMMITTEE SESSION

PUBLIC POLICY COMMITTEE SESSION

THURSDAY, JUNE 6, 1929

[The meeting convened at 9 p. m. in the ballroom of the Auditorium and Convention Hall, Atlantic City, N. J., Mr. W. W. Freeman presiding.]

CHAIRMAN FREEMAN: It is a source of regret to all, I am sure, that Mr. Ballard, the Chairman of the Public Policy Committee, who should preside at the session this evening, if he were here, is unable to be with us on account of absence abroad.

Before introducing the first speaker on the program this evening, I wish, in behalf of the Committee, to make acknowledgment of the courtesy extended to our Association in connection with broadcasting of our program of the evening by the National Broadcasting Company, through the courtesy of its President, Mr. Aylesworth. The report of the Committee, and the address, will be broadcasted over a network of twenty stations, and the Committee desires to express its appreciation of this courtesy on the part of the National Broadcasting Company.

It is fitting that the first speaker of the evening should be our President, who, as Chairman of the Committee of Award of the Charles A. Coffin Medal, will present the report for this year. Before calling upon Mr. Arkwright, it is suggested that I announce the winners of this award in past years.

The award has been given each year, beginning with the year 1922, the company winning that year being The Southern California Edison Company. In 1923, Public Service Company of Northern Illinois; in 1924, the Consumers' Power Company; in 1925, the Commonwealth Edison Company; in 1926, the Edison Electric Illuminating Company of Boston; in 1927, Puget Sound Power & Light Company.

I am now glad to make way for President Arkwright to present the award for this year.

PRESIDENT ARKWRIGHT: Ladies and Gentlemen: Before announcing the award, I would like to report to you that in accordance with your direction and authority, we sent a cablegram to Mr. Owen D. Young, at Paris, expressing our congratulations on the successful outcome of the Reparations Conference, and your pride in the part that he has taken in bringing about the happy result.

I have a reply from Mr. Young to that cablegram, which I will read to you:

"P. S. Arkwright, National Electric Light Association, Atlantic City: I send to you and through you, to my friends and associates in the National Electric Light Association, my heartiest thanks for your and their thoughtful message. I regret that I cannot be with you, and I send you all my best wishes for the success of your convention.

(Signed) "Owen D. Young." (Applause.)

REPORT OF CHARLES A. COFFIN PRIZE COMMITTEE

BY P. S. ARKWRIGHT, *Chairman*

(For Committee Personnel, See Appendix 4)

I consider the presentation of this report one of the distinct privileges which goes with the office of President of your Association, for it gives me the opportunity to not only award and congratulate an outstanding Light and Power company for its work during the past year, but also to pay my respects to the memory of a man who in his time was a great leader in our industry—Charles A. Coffin.

Few men knew so well the problems of the producers and distributors of electricity as Mr. Coffin, and few have ever been as helpful as he was to those responsible for the progress of the industry. In the past, the company serving great urban centers or far-flung territories of considerable importance have received this award, but this year the honor is to be bestowed on a company of slightly over 19,000 customers. Its urban territory is separated from any other city of any size by over 600 miles; interconnection is out of the question. One large section of its population is foreign, with a distinctly lower standard of living than that of the native citizens. Yet, despite its comparatively small size, the many indications of difficulties surrounding its growth, this company has grown, has progressed, and has played a part which your Committee feels constitutes a distinguished contribution to the development of light and power for the convenience of the public and for the benefit of the industry.

The Committee hopes this award will be an inspiration to the managers of the smaller companies operating throughout the nation. In every field, general administration, commercial activity, and engineering, a splendid job has been done by an active, aggressive management. I think it is no exaggeration to say that the fact that this company with notable resolution and tenacity, has submitted statements of its accomplishments for five separate years, has in no small measure helped in making its fine record in all fields.

It gives me pleasure to announce the Award of the Charles A. Coffin Medal for 1928 to the El Paso Electric Company. (Applause.)

Will Mr. F. J. Gannon, Manager of the El Paso Electric Company, please come forward?

[Mr. Gannon came forward.]

Mr. Gannon, of the El Paso Electric Company, I congratulate you upon the accomplishments of the company under your management. I present you, on behalf of the Charles A. Coffin Prize Committee of the National Electric Light Association, the Charles A. Coffin Medal, for having made a distinguished contribution to the electric light and power industry, for the convenience of the public and the benefit of the industry. It is my pleasure, also, to present the Certificate of Award and a check for $1,000 for the use of your Employees' Benefit Association.

I extend to you, likewise, my personal congratulations on your fine work.

MR. F. J. GANNON (El Paso Electric Company, El Paso, Tex): In accepting the medal given as the emblem of the Coffin Award, I feel very much like David must have felt when Goliath fell. A small company, comparatively speaking, situated in the far West and little heard of, unleashed a stone from its sling and sent forth its brief to the Coffin Award Committee with considerable hope and prayer. Tonight the prayer has been answered and we feel exactly as David must have felt in the days of old.

Many of you may never have known that El Paso had an electric company, and you probably feel that those of us who live in West Texas are different than those of you who live in the East. As a matter of fact, we who live in El Paso are very much like you people in the East—doing what we can at every opportunity to promote public service. We have generating stations and we are self-reliant. We are six hundred miles from anyone else and do not have the benefit of interconnecting power such as many of you enjoy. The generating stations that we have on the South of the Rio Grande in Juarez do not generate the kind of power that we can advantageously connect to our lines.

The giving of this Award to El Paso Electric Company is an outstanding instance of the benefit of centralized management and the coordination of public service operations in large companies. Had we not been able to secure the advice and help and assistance of the organizations with which we are affiliated, I doubt very much if El Paso Electric Company could have accomplished the things that have made possible our present success.

In accepting this Award, I want to express to the members of the Coffin Award Committee and the members of the National Electric Light Association the deep appreciation of the executives of our company for the recognition they have made of the faithful, excellent and loyal service given by the employees of El Paso Electric Company as well as the people of El Paso, without whose cooperation nothing would have been possible.

REPORT OF THE PUBLIC POLICY COMMITTEE

BY W. W. FREEMAN, *Vice-Chairman*

(For Committee Personnel, See Appendix 4)

I have the honor to submit the Report of the Public Policy Committee for this year as follows:

This year is LIGHT'S GOLDEN JUBILEE. It is fifty years since Edison gave to the world the first practical electric lamp. In this lamp, the electric utilities had their beginning; from it has developed the whole field of electricity's usefulness. It is fitting, indeed, at this time that we express tribute and appreciation to Mr. Edison and that we take some measure of the progress made by these utilities in expanding usefulness and in meeting public obligations in the provision of electric service.

Amid the rapidly expanding and changing character of electrical development, one policy stands out as having been uniformly and consistently followed by all and at all times. This is the policy of growth and expansion. The electrical industry has been progressive; it has not stood still. From the beginning, the men responsible for electrical development have realized the enormous contributions in useful service which electricity has made and will continue to make to the whole national and community well-being, to workers and to homes, to all phases of economic and social life. They understand and assume the obligation to unfold the full possibilities of electric service and translate them into everyday use for all the people, on the farm, in village, and in large city. In its plans, its construction of plants and facilities, its organization and financing, the industry has looked to the future. Not only has it quickly adopted advances, but it has stimulated and searched for them.

Year by year electric service extends; more homes are electrified, domestic use increases and takes on new forms; the service reaches to smaller and smaller towns and on to the farms; electricity is becoming the essential power supply for all purposes; the quantity of power made available for each worker increases. There lie ahead fields of still greater expectation for new and larger uses. The policy of aggressive development and expansion is still essential.

Herbert Hoover made the following statement before the World Power Conference in London, 1924:

"The factor that has been primarily responsible for the tremendous changes of the last century and without which modern civilization could not exist is mechanical power. The form in which in increasing degree such power is being applied is electrical energy—the greatest tool that has come into the hands of man. The degree to which we utilize this tool as a substitute for manual labor will largely determine the rate of our social and industrial progress."

Electrical development is progressing at a rapid pace. During the past seven years electrical service was furnished to nine million homes, bringing the total to 19 millions. No full measure can be taken of the benefit of this in improving family life, effecting economy in expenditure, the saving of time and making for happier living. Electricity has provided a power supply not only for the factories but also for the homes. Thousands of electrical appliances are assuming the burden of housework.

Extension of Service

A distinct characteristic of electric progress in the last few years has been the extension of service to small towns and farms. Transmission lines, constituting a vast network even five years ago, have been still further extended to reach 4000 small towns and villages formerly without electric service. So widespread has the service now become that almost every community with over 1000 inhabitants has electricity, and in many parts of the country, every community, no matter what its size, receives such service. Not only do they enjoy benefits of electricity in their homes, but by it the door of industrial opportunity has been opened to the smallest town having also reasonable transportation facilities. The spread of service to the farm continues, until now 500,000 farms are connected. The objective of electric service for all the people comes nearer and nearer to attainment.

With the development of great interconnected systems and mass production of power, the factories and workers of the nation are increasingly turning to electricity for power supply. The total increase of 9,800,000 h.p. in the nation's industrial enterprises since 1919 has been in electric motors. President Hoover's Committee on Recent Economic Changes in the United States, in its report on May 15, 1929, after emphasizing the widespread higher living standards as characteristic of our national life, pointed out that the rise in the use of power has been three and three-quarter times faster than the growth in population, and then added:

> "The increasing flexibility with which electricity can be delivered for power has enabled manufacturers and farmers to meet high labor costs by the application of power driven specialized machines; and power in the flexible form has penetrated into every section of the United States, including many rural areas.
>
> "The survey shows that as a nation we now use as much electrical energy as all the rest of the world combined.
>
> "Through the subdivision of power, the unskilled worker has become a skilled operator, multiplying his effectiveness with specialized automatic machinery and processes. Thus the unit cost of production has been reduced, the drudgery eliminated from much unskilled work and wages maintained or actually increased."

There has been a clearer crystallization of public understanding of major trends and developments. The far-reaching economic and social benefits of interconnection, mass electric production and large scale development have become better understood. The function and usefulness of the holding company in bringing this about has become more generally understood. Mere size of operations causes less comment; the benefits accruing to the public from them are better comprehended. The public generally realizes that through large scale development electric service is becoming possible to the citizens of the smallest village and to the dwellers upon farms; and that only in this way has there been created the reliable, adequate, and low-cost power supply upon which the nation's industrial development is taking place. Experience has demonstrated the savings in expense, the financial stability, the fuller utilization of investment and resources, the increased efficiencies, and larger capacity for service which follows unification and consolidation. They are accepted as economic necessities. Failure to apply them would indicate lack of progress.

Individual Enterprise

Through the application of these principles, "as a nation we now use as much electrical energy as all the rest of the world combined." And it should not be overlooked that all the rest of the world combined hitherto has, to a very large extent, followed the policy of governmentally owned and politically operated electrical supply, while this nation has followed the precept of the immortal Lincoln that "in all the people can individually do as well for themselves, government ought not to interfere."

The benefit of improved efficiencies, better management, large scale development, and advances in the art, have been shared with the consumer. An outstanding characteristic of the past year has been rate reduction. The general cost of living continues at 70 per cent above pre-war levels; domestic electricity is 25 per cent under pre-war levels. In 1914 the average household used but 268 units of electricity; in 1928, the average used was 456. Beyond this, electricity today will do more than it was possible for it to do then, for scientific advance has provided the consumer with better and additional methods of utilizing it.

Purchase of Security Offerings

Large increases in demand for service; the necessity for large investment in facilities, which is characteristic of the business; the greater cost of furnishing service as it extends to sparsely settled territories, continue to require large sums of money in financing growth. In the year 1928, during this period of intensive Governmental investigation, continued public confidence in private operation was demonstrated by the purchase of one billion six hundred million dollars of security offerings of electric light and power companies.

The year just passed has been particularly noteworthy for the public attention directed to the electric utilities. Their condition, methods, practices, and performances have been a major subject of public discussion, which has ranged from vituperative attack and political abuse to sober and constructive consideration of major questions, and has covered most of the degrees between. Utilities today live under the microscope. In the scrutiny they have undergone, real performance in public service has often been overlooked, faults have been magnified, and motives distorted. But on the whole, discussion has redounded to their benefit and will do so still more when complete information becomes diffused and the public mind better informed.

Federal Investigation

The source of inquiry has largely been the Federal Trade Commission. Up to this time, its investigation has been directed largely to the National Electric Light Association, its Geographic Divisions and to publicity activities. The broad work of the Association toward accomplishment of its object—"to advance the art and science of the production, distribution and use of electric energy for public service," has as yet received slight attention. The local State Information Bureaus have been thoroughly investigated.

Although the Association as well as its Divisions and the State Bureaus were early apprised that there was doubt whether the Federal Trade Commission could compel the furnishing of much of the information sought, a decision was reached at the outset to comply completely and promptly with every request of the Commission. In accordance with this decision, the Commission representatives have been accorded full and free access to all books, records, papers, reports and correspondence of the Association. No request has been refused. No question of right or authority has been raised. The result has been a most rigorous inquiry into every activity of the Association for the last twenty years. Over 100 witnesses have been heard, over 7000 pages of testimony have been transcribed, and 4300 documents and other exhibits have been introduced into evidence. We have voluntarily undergone a microscopic examination which has delved into records from the dust-covered volumes of the past to the fresh ink of the present, and into thousands of scattered incidents arising from one end of the country to the other.

We understand that this phase of the investigation on the Commission side is now practically completed. The Commission as yet has announced no conclusions. The industry has not, as yet, presented evidence in its own behalf.

Public impressions have come almost entirely from newspaper reports.

Sound Policies Followed

Your Committee is confident, as the result of this critical review of the activities of the Association for the last half century, and without claiming perfection, that it will be found that its policies have been sound, its work beneficial to the public and the industry, its ideals consistent with the highest American business standards, its mistakes few and trivial considering the number of individuals involved and the large volume of work accomplished.

An independent press is essential to free government. The National Electric Light Association believes in an uncontrolled and undominated press, free to criticize or commend as conditions may warrant.

The utilities recognize that the furnishing of information regarding their purposes, accomplishments, needs and difficulties is one of the obligations of public service. In recent years, the Association and its member companies have made every effort to inform customers, investors and the public. To that end, the Association has utilized every opportunity for creating a more complete public understanding. On matters of opinion, it has stated its own views; on controversial subjects it has given its own side. Endeavor has been made to correct inaccuracies and misinterpretations. It has done so openly and frankly. Publicity material of the Association has always shown the source so that everyone to whom it was sent has known from whence it came.

There may have been occasional instances of overzeal in distribution, but we may congratulate ourselves that criticism has been directed to excessiveness of publicity rather than to secretiveness.

True and Accurate Information

At the last annual convention, this Association by resolution recommended to its members a continuation of the policy of preparing and diffusing as widely as possible full, accurate, and timely information on all phases of the business. Truth and accuracy were declared to be the standard by which its statements should be judged. Your Committee is glad to be able to report that out of the large volume of publications and informational items circulated by the Association, all of which for recent years has been freely submitted to Commission scrutiny, none has been found which cannot stand that test. The adverse comment which has been made upon Association publicity has not been directed to its truth or accuracy, but rather to its volume and methods of distribution. The same is true, with few exceptions, of the publicity emanating from the local State Bureaus.

The widespread distribution of informational material necessarily involves contacts with those who receive it. From the furnishing of data to schools and colleges come relationships with those who use it. Such contacts are proper, natural, necessary, and desirable for all concerned, if informational service is to be efficient. The relationship necessitates a high standard on both sides. It is inconceivable that the industry should refuse any reasonable request for information helpful to those engaged in public instruction. It is improbable that teachers in our schools or instructors in our universities would accept for their use any material which is not truthful, accurate, and valuable, even if an attempt were made to foist the opposite character upon them. The whole question of cooperation and relationship between education on the one hand and commerce, business and industry on the other, is one of common concern, by no means confined to the utilities. It involves practically every great American industry. The methods must be finally determined by the educational authorities. The electric industry has always cooperated with them in the fullest degree. It desires to continue to do so. It hopes that in the near future, a more definite basis for that relationship will be worked out and declared by those responsible for educational methods. The industry expects to conform with their final policies.

A Leader in Research

The electrical industry has long been recognized as a leader in research. In the laboratories of the electrical manufacturers and in the field experimentation of the operating companies, there has been ceaseless search for new truths, added applications, and further harnessing of this great instrument for the benefit of mankind. This effort has been rich in rewards, shared not alone by the electric industry and its customers, but aiding other industries and reaching into the lives of all the people. With the formulation of the great program for stimulation of Pure Science Research, under the direction of the National Research Council, the National Electric Light Association, in behalf of the electric light and power companies, is glad to announce its full participation in the movement. The National Electric Light Association thus confirms its confidence in the body of men devoting their lives to research who have already given so much and who have in their hands the unfolding of a still richer future.

Ours is a responsibilty for bringing to the American people the best electric service at lowest possible cost which human capabilities can accomplish. To this end the National Electric Light Association and its members rededicate themselves. (Applause).

CHAIRMAN FREEMAN: Just a word of explanation. The program at this time is in cooperation with the National Broadcasting Company. We are going to be favored with several selections from two well known artists. The announcements will be broadcast by Mr. Peterson of the National Broadcasting Company. I will assure you he can do better than I.

[Selection by Mr. Spalding.]

CHAIRMAN FREEMAN: The National Electric Light Association desires and expects to keep in step with the business interests of the nation in respect to the highest standards of ethics and business practice. It is fitting that tonight we should be favored with the presence of a gentleman who perhaps better than anyone else in the country at the present time can speak with a voice of authority and advice as representing the premier business organizations of our country. Undoubtedly the Chamber of Commerce of the United States represents, as does no other organization, the organized business interests in all its branches, of the nation, and if the Chairman of the Board of Directors of that Chamber cannot speak with authority and conviction, it is difficult to imagine anyone else who can.

Mr. Barnes has honored us by selecting as his subject, the topic, "America's Fifty Years of Aladdin."

I have great pleasure in presenting Mr. Julius H. Barnes. (Applause).

AMERICA'S FIFTY YEARS OF ALADDIN

By JULIUS H. BARNES

Chairman of the Board of Directors of the Chamber of Commerce of the United States

This occasion tonight marks the Golden Jubilee of the Electric Light. It provides, as well, a popular testimonial of admiration and affection for the inspired labors and for the simple life of America's foremost inventive genius. Fifty years of spotlight distinction have invested his character with a national regard bordering on reverence. That half century of time spans a period in history of most intense human interest. Certainly no other half century in world history could possibly have equalled the myriad changes of this single era. The contrasts disclosed by a comparison of the living habits of these dissimilar days have clearly widened the horizon of human health, welfare, opportunity and content.

A peculiar interest would attach to that comparison because these changes have come within the span of a single life. When that single life itself, as in the case of Thomas Edison, has been also a potent force in working the miracles in modern science and invention, it acquires a unique distinction. It would be a title clear to fame for a single mind to carry into practical perfection a device for lighting which has been improved but not displaced by fifty years of intensive inventive progress. But Edison's distinction rests not alone upon the idea of a light itself, but on the wider, daring conception that the subtle force of electricity could be harnessed to control, and be distributed flexibly at point of use. Even Edison's painstaking study and even Edison's soaring imagination could not at that early day have visualized that the wire which entered America's homes for lighting would have later become the channel of fluid power which established in every individual home its own power plant. It would be interesting if today there could be preserved the changing images of the inventor's mind as he saw the feed wire, planned for simple lighting alone, drawn upon in the course of time to successively operate the electric iron, the vacuum cleaner, the washing machine, the electric range, the refrigerator and the radio. So, also, it would be interesting to visualize the successive steps, with accelerating speed, by which the flexible power distribution of which he was the pioneer so provide itself in competitive use for industry that it has revolutionized the power plants of our factories.

The Force Behind Progress

Industry has always had its sources of power: the water wheel, fuel generated steam, the combustion engine—but none of these serves industry so directly and with such economy as does the flexible force carried to its point of use through the distribution inspiration of Thomas Edison. His concept of fifty years ago of ready distribution, limited in vision, as it was, of necessity, in that day, is the basis today for American homes freed of household drudgery; of American farms lifted from the shadow of relative isolation; of industry that has put a premium on intelligence and skill and lifted the crushing burden from the bent backs of labor. Flexible power, easily transported, is the moving force in successive inventions that raises steadily the general average of possession and living.

The science of electricity is indeed of world-wide origin and development. The super-intellects of all peoples have contributed to its understanding and its use. We measure the practical unit of electrical resistance today in the name of the German scientist Ohm. We measure the flow of electric current along a wire in the name of a French mathematician Ampere. We measure the force required to cause a current to flow against resistance in the name of the Italian physicist Bolta. We express the unit of electrical power in the name of a Scottish engineer Watt. But in all of America and throughout the world, every shade and variety of electrical service, the finest of subtle pulsations and the most tremendous physical forces are expressed to every understanding with the single name of Edison. No single mind today has contributed so largely to our whole social advance and when, as well, that single life has preserved the simplicities of living unswayed by an adulation which falls to few men in history, it is the reassurance also of the real quality of America. All America does itself honor to honor in this Golden Jubilee the intellectual achievements and the personal qualities of the man whose name is inseparably linked with that subtle fluid energy which is the very life of modern living. His name will be remembered as long as man can speak and as long as man can hear.

A Half Century Ago

Now, half a century of human progress spanned in this field by a single life, and that life the acknowledged leader, must present comparisons of extraordinary popular interest. What were the habits of industry; what were the social customs; what were the popular conceptions and ideals of the world of fifty years ago, and how have they changed for good or ill? Since the daily press of a people probably most accurately reflects the everyday practices and customs which enable us to gage the conditions of their living, it is interesting to go back to the newspaper of half a century ago.

For example in *Leslie's Weekly* of 1879 there is a news item recording a patent granted Thomas A. Edison for electric lighting apparatus—an insignificant item in itself and manifestly conveying at that moment neither to publisher nor to public anything of the vast import which fifty years of history have since recorded.

Something of the coming revolutionary character of this invention is shown shortly thereafter when the New York *Sun* comments editorially on the panic in gas company shares which had been occasioned by the manifest progress in electric lighting. The editorial suggests that the investment in gas manufacture and distribution might be saved "if gas could be made available for cooking, and ladies could thus become expert cooks." As a matter of normal development since, gas has become the universal cooking fuel of our great cities and, of course, every lady in this audience and that of the radio can testify that she has become, and is, an expert cook. Otherwise how account for the spread of the delicatessen and its ready-cooked foods?

Pioneer Advertisers

Advertising in the newspaper of fifty years ago averaged about 20 per cent of its content, and today 60 to 65 per cent, although today's news columns cover home and world news with a completeness which was not possible with the limited communications of those early days. This is why we buy a daily newspaper today for half the price, though with four times the news. The limited advertising of New York newspapers fifty years ago, however, shows a continuity of American business which is extraordinary—Lord & Taylor, Daniels, Stern Bros., Macy's, Hearn's, Altman's, Sloane's. Their vast assortments and their imposing buildings in the very heart of Fifth Avenue fashion today are the half-century outgrowth of dependable merchandising which, at reasonable prices, pioneered the columns of half a century ago. Knox Hats, Cuticura Soap, Worcestershire Sauce, Royal Baking Powder were then taking the first uncertain steps which have made them household names today. Colgate's Soap showed a pioneer initiative in eliminating the depression of summer trade by advertising then that "since the soap improves by age and drying, a supply laid away by families leaving the city would be found improved on their return in the fall."

There was a large advertisement in which all visitors to New York were entreated not to fail to see the electric light "now in use at Nicoll the Tailor's," and which added, further, that they possessed a telephone for customer's use and that steam machinery was used in running sewing machines and all scientific improvements. Here was merchant resourcefulness applied certainly with foresight and vision, though if today's 300,000 daily visitors to New York should attempt to see the electric light in the present shop of Nicoll the Tailor, still on Broadway, it would, of course, require the police reserves.

What the Newspapers Lacked

There were no newspaper advertisements, of course, of automobiles or accessories, the backbone of today's newspaper and magazine support; no office equipment, no sports, no apartment or office buildings, no radio, no airplanes, no public utilities, no banks with page spreads or companies offering securities in nation-wide industries, no foreign securities offered to the American financial market. There was no refrigeration, no advertisement of electric devices or gas appliances. There were no advertisements of summer resorts or hotels. Evidently the American clientele that could travel or take vacations was too small to carry the expense of appeal.

There is an interesting sidelight in the advertisement of the elevated roads of New York, on which the traffic was made to bear what it had to, by charging ten cents fare between 5.30 and 7.30 a.m., and ten cents between 5 and 7 p.m. Between-times, you could travel for a nickel. Think of the working conditions of fifty years ago, which made the morning rush hour of city transit start at 5.30 a.m. and end as early as 7.30 a.m. Those are the hours today at which you could be sure to find a seat. The evening rush hour, which then extended to 7 p.m., is today finished by 6 p.m. The shorter working day, which this so vividly illustrated, not only marks the conquest of extreme drudgery in daily occupation, but it is beginning to be intelligently understood by industry itself that reasonably balanced working hours and reasonable leisure, with adequate wage scales, are the very heart of universal use and buying which maintains industries themselves. In the working hours of that early day the automobile would have lacked a market, not alone for wage scales which had no margin for the purchase of such a modern-day convenience, but a working day which had no time to use or enjoy such a facility, and a working day that left little strength or energy except for bed or dissipation. As early as 1860 we had gasoline, but it was worthless, for invention had as yet found no way to use it.

Strong Men of the Day

The pioneer industry of that day had its strong men whose names and achievements are grafted into American history. The columns teem with the names of Huntington, Harriman, Rockefeller, Carnegie, Morgan, Clark, Armour, Hill, Gould, Fiske and Cooke. The field in which these financiers laid the foundation for industrial leadership and large individual fortune was small indeed. The Stock Exchange recorded a turnover of 100,000 to 200,000 shares a day, against today's 5,000,000. The financial columns showed these men and others possessed of large vision and supreme daring. There run the tales of large risks assumed, success in industrial development, paralleled with gigantic losses, under the standards of that time.

These straws illustrate the way in which social custom and modern industry have, step by step, developed together the earning power which has widened the range of articles of use and convenience in common possession and have created leisure to enjoy and demand more things in everyday life. From the beginning invention has been the life-blood of suggestion, creating new articles of universal aspiration.

America was still a pioneer country with resources yet to be developed, with latent wealth still awaiting the mind and hand that could fashion it to human service. Remember that Edison's electric light was only three years behind the year of the last great tragedy of America's receding frontier in the Indian country; 1876 was the year of Custer's Last Stand, the final tragic resistance of the red Indian to the oncoming wave of American settlement. It still comes as a shock to most of us that the lives of many of this audience have spanned the period between the Indian frontier and today's complex civilization. Measured in changes of customs and habits, measured in the expansion of old industry with the miracle growth of population and buying power, measured in the role of new inventive industry which those early days could not even imagine, this period of fifty years stretches interminably in the imagination.

The Long Record of Time

But in the long record of Time itself, how short the span, indeed! I remember recently hearing this perspective illustrated by Charles F. Kettering, himself an inventor of international eminence. He recalled that last year Roy Chapman Andrews found in the Desert of Gobi, in the heart of Asia, a great dinosaur skeleton, and the geologists looking over the strata in which it was found estimated it had been there eighty million years—quite a long time. So they said, "It is petrified and nothing of any vitality could be existing for eighty million years." "But," added Kettering, "Harvard University had an astronomical laboratory down in Africa, and last year they photographed a nebula—a spiral nebula—and the light that affected the photographic plate in that camera last summer left its source one hundred million years ago. Light travels at the rate of 186,000 miles per second, and if you reduce 100,000 years to seconds and multiply the result by 186,000 miles, you have the distance in statute miles. In other words, that light which affected that photographic plate last summer left its source twenty million years before the dinosaur was born."

Then Kettering goes on to point out that the human race has been conscious of itself only eight thousand years. If you could take the eight thousand years in which the human race has been conscious of itself and put it into that 100,000,000 years, and stir it up and turn it over to a chemist to analyze, he would analyze that thing and report, "That looks to me like pure Time, with the exception of just a slight trace of impurity in it which we call Civilization." If you would take the two thousand years of the Christian era and dissolve it in that 100,000,000 years, the scientist could not find even a trace of it.

The Deathless Quality of Mind

There is just one quality which man possesses which is deathless in itself and which makes the race able to look even pure Time in the face with self-respect. That is the deathless quality of Mind, the divine restlessness of intellect which explores the unchanging mysteries of Nature itself. It is the faculty which enables man to comprehend natural law and harness under that law the forces of nature to man's service. Somewhere back in the misty days of our early race, the element of fire having been discovered by accident, there was mentality enough for the race to see that light and heat were associated by natural law together. There are today the evidences that the early caveman chipped niches in the rock walls of ancient caverns in which fire was evidently built for lighting only. Then rushes were used, soaked with grease and splinters of resinous woods like pine; then the rushlight style of lamps in which wicks soaked up oils from an open dish. Then before the Christian era, through centuries of experimentation, waxed candles had been made from pressed honeycomb, and then the tallow candle followed. Oil lamps originated with sperm oil from the whale fisheries a century and a half after the landing at Plymouth Rock. Then some Edison of a century and a half ago developed the metal chimney which steadied the flame of an open lamp, and then came the glass chimney which made the oil lamp really practicable. Then man's intellect comprehended the possibility of controlling illuminating gas for lighting, and so good a mind as Napoleon's condemned the whole effort to substitute gas in the place of candles as a "grand folly." Sir Walter Scott ridiculed the "mad man" who proposed to light the streets of London with smoke. It was difficult in the early days to get lamp-lighters to approach the gas posts for street illumination to light the gas.

Less than one hundred years ago the Philadelphia Common Council received a petition against the use of gas, stating that its "immense destruction of property was nearly as fatal as gunpowder."

Obstacles to Progress

Always the pioneers of science have had to overcome not only the mysteries of natural law, but to overcome the inertia and opposition of human intellects slower than their own. Curiously enough, too, the study of invention progress shows that invention is rarely the inspiration of a moment, but more largely the laborious product of toilsome study and experimentation. The natural law by which heat and light are inseparable, which was recognized by the caveman who built his little fire in the rocky niche to give him light, was the law which enlisted the painstaking study of Edison to find a practical light that could be carried into every nook and corner. Recognizing that light was inseparable from heat, his early experimentation was toward finding a substance so high in melting point that the heat of a current-producing light would not destroy the substance itself. This early suggested carbon. It would be stimulating to the active minds of today that dread the slow laborious process of observation to read the history of the numerous experiments of Edison to find a practicable carbon for the use of lighting. He sent explorers at great expense over all the world for fibers. The charring of various materials runs through the whole gamut, from tissue paper, through all kinds of thread, lime, celluloid, shavings and cork; and in those early days bamboo fibers gave the best results. Learning that carbon burns in the air, his early lamps were exhausted of air by a hand-pump. It required the inventor's tenacity of purpose to carry through the early obstacles to the success which we celebrate tonight. That nature marked him early for special distinction in this field is indicated by the fact that he experimented with chemicals in his father's cellar at the age of eleven, and at fifteen possessed important books on chemistry and physics, and carried his own experimental apparatus in the baggage car on the train on which he worked as newsboy between Port Huron and Detroit. Something divine and deathless drove him into this field in which, measured in terms of human service, he has a supreme distinction.

What Does It Profit?

We have today bewildered minds that stand by the wayside and call for the return of the good old days before machine civilization. "What does it profit a race," they say, "if living is made soft and easy, and thereby sturdy character is undermined?" "The new security of livelihood must lead to relaxed effort, to lowered standards." "What is the contribution to human welfare that we pile our great temples of industry story on story, reaching high heaven itself?" "What does it mean other than gross materialism that we invent the radio?" they say. Does it mean nothing to them that the intrepid explorers of the Polar South hold daily contact with civilization through this mysterious triumph of invention? Does this daily contact, which includes even the programs of music and light-hearted entertainment from the cities they have left behind undermine the fiber of men who dare the mysterious hazards of the Antarctic wastes? Do our 25,000,000 automobiles, which have made the open road also the open door to health and to family picnics that replace the corner saloon, mean nothing to them except a supposed decadence of individual character? Does the miracle of the motion-picture, seating its daily audience of 14,000,000 and bringing to them through eye and ear the daily news of a now-contracting world, mean nothing to them in quickened intelligence, wider understanding, and the inspiration of limitless opportunity? Does the new invention of the airplane, which makes every interior city a potential world port, spell to them an undermining of the qualities of personal daring and courage? Does it mean nothing to them that modern industry, developing under the profit motive, to be sure, has nevertheless made a direct contribution toward elimination of sickness and suffering, and even held death itself at bay for longer spaces?

For example, the modern refrigerator, the perfected metal and glass containers for perfectly preserved foods, the vacuum cleaner with its daily cleanliness, the automatic heater with its equably preserved temperatures of the home—these are the things, along with advances in professional knowledge, that vanquish countless human tragedies. This is illustrated by the fall in the death rate of the United States from 17 per 1000, the average of twenty years ago to 12 per 1000, the average of these recent years. That means 600,000 less deaths per year than twenty years ago. Resolve that, if you please, into the countless homes that are thus protected against individual sorrow and desolation. Should inventive industry and the trained professional mind take no pride in 600,000 fewer death tragedies in American homes each year?

No Fear for the Sturdy Virtues

And to illustrate to you the intimate interlacing of social service and industry itself, this fall in the rate of deaths, clearly the product of improved hygiene and sanitation, is itself the basis of an universal confidence in life insurance which has directly stimulated the virtues of thrift and self-denial. The unexpected savings to these life insurance companies by a rate of death loss less than had been expected when they made their contracts years ago, constantly falling, has enlarged their resources and created a confidence in these companies, along with the lengthening record of able and trustworthy management, until our people have contracted with these private companies a total of seventy-three billion dollars of life insurance. In half the span of time which we celebrate tonight, the thrift investment of our people in this after-death protection has risen from ten billion to seventy-three billion dollars. Here are private contracts many times the aggregate of all the allied debts and reparations, which through four months of negotiation for their final plan of settlement has fixed the attention of the world, although these debts and reparations rest primarily upon the entire national wealth of several great peoples. Besides these life insurance contracts which are based on the impulse of saving and the affectionate care of those who survive us, marches also the record of extraordinary growth in savings accounts. These are the indicators that dissipate any reasonable fear that easier living conditions will undermine the sturdy virtues of thrift and self-denial and affection and lead only to extravagance and thoughtless waste.

Could you imagine an Edison under any conditions of modern living that would not devote his restless intellectual energy to the study of natural laws and the perfection of inventions of human service? And there are many coming Edisons of smaller stature.

Can you imagine a field of inspirational appeal that can exceed the field of modern business, ranging through invention, research and organization, when that business is conducted with high ideals as well as high standards of business efficiency?

The New Freedom

Is our civilization highly mechanized, or are we beginning for the first time in history to put a proper premium on the superiority of mind over muscle? When we equip office and workshop with invention and power that shorten the working day, has modern industry only contributed an opportunity for profitless idleness or worse? When electrical servants in the home free the afternoon of its ancient tasks, has industry done nothing more than swell the motion-picture audience or added to the window shoppers of our avenues? There is no chorus from the emancipated homes of America that the home is being mechanized, destroying the craftsmanship of former times. There is no insistence from the women of America that we return to the domestic era of the washtub, the stifling range, and the dusty broom. Twenty million American homes connected for electricity evidence no inappeasable aspiration for the days of the kerosene lamp. American homes pay for kilowatt hours, but they buy light, warmth, coolness, relief from drudgery.

So also, 500,000 farms, now connected with electric light and energy, are developing a new definition for the farm unit—a departure from the traditional farmstead, but a farm in which the energy of the factory will be applied to the lightening of farm drudgery as well. Modern industry and particularly the power industry has presented to all of us the priceless gift of leisure hours. Industry does not need to assume the personal responsibility for the use of those precious moments of opportunity. That responsibility rests on the individual. If we believe in democracy at all, if we trust human character, at all, we must profoundly believe that through error and misdirection man will nevertheless learn to use this new freedom wisely.

The Basis of Social Advancement

With profound truth, Herbert Hoover said in 1924, before the World Power Conference:

"The factor that has been primarily responsible for the tremendous changes of the last century and without which modern civilization could not exist is mechanical power. The form in which in increasing degree such power is being applied is electrical energy—the greatest tool that has ever come into the hands of man. The degree to which we utilize this tool as a substitute for manual labor will largely determine the rate of our industrial and social progress. To reduce human labor, to increase its productivity, is the most profound basis of social advancement."

Within the past past month the Committee on Recent Economic Changes, under the chairmanship also of Herbert Hoover, recounts the progress of the five intervening years. This report speaks of the rise in the use of power, three and three-quarters times faster than the growth in population. It emphasizes its increasing flexibility which enables it to penetrate every section of the United States, including rural areas. It speaks of the silent revolution by which through power the unskilled worker has become a skilled operator, multiplying his effectiveness. The survey states that, as a nation we now use as much electrical energy as all the rest of the world combined.

Inevitably we must analyze for ourselves the causes which lie behind preeminence in national progress. There is, then, not disparagement, but inspiration, for ourselves and others, when we find cause and effect securely jointed.

For example, the sixty million horsepower today in America is possible because today 75 per cent of America's factories are electrified, while in Great Britain only 48 per cent are electrified. With that we find that the relative national wealth of the United States and Great Britain runs in exact ratio of the horsepower per capita used in industry, namely 4½ to 1. With that, again, we find as between the United States and Great Britain we have twice as many owned homes, and one-twentieth as many people per capita on public charity.

Distribution of Wealth

The indicators by which our national income rises in throbbing growth until it approaches an annual one hundred billion dollars of new production, show that American industry, with its power service, increases the volume of things to divide among the homes of America. The evidence in America of equable distribution of these earnings under our political and social system rests on such indicators as its twenty-five million automobiles and its nineteen million telephones. Distinctly, the average of human security is steadily advancing. The congested quarters of our cities today show the universal possession of good shoes and stockings by the children of the tenements. The wage-earner of America today may reasonably aspire to own his flivver and a savings account. The working girl of America has established the standard of silk as the proper garb for self-supporting womanhood. The poorhouse is today echoing fewer footsteps within its sparsely tenanted halls.

History will rate America's most significant gift to civilization as its genius for revolutionary organization of industry. America's title of honor in history will rest upon the rise of average welfare under the earnings of highly organized and power-driven industry, and of a social system which distributes and shares those earnings fairly.

But then, industry must not rest content with the progress which has been made. As long as there are still in the world men and women and children who would be happier if there were brought within their reach more and better food, more and better clothing, and until security of employment and earning power enables them to live in better homes, there is a responsibility and inspiration in this power industry which is the direct servant of all industry. All human history has accepted the concept of poverty as unavoidable. "The poor ye have with you always," has scriptural authority. Under the favor of Providence, America may reasonably hope, in the not distant future, it will have shown that poverty—except as result of individual and exceptional misfortune—may be recorded as a vanquished evil. When that day comes, it will rest upon the economic law established by modern industry, directed by brains, driven by power, administered with high intelligence and high ideals. There is a peculiar responsibility resting on this electrical industry. It asks from public regulation, fair and generous treatment and understanding, and it should make sure that its own ethics and standards shall be above reproach. Its record of business enterprise and resourcefulness has invested it with peculiar distinction. It must maintain itself in public confidence by standards and practices that challenge the closest scrutiny. Possessed of the business enterprise which it has shown, and conducting itself so as to enlist the public confidence which it should possess, there stretches before it a limitless future, measured both in business opportunity and the satisfaction of social service.

When Thomas Edison forty-nine years ago established his Pearl Street lighting station in New York City, with 750 h.p. and fifty-nine customers, could he have possibly visualized the 2,100,000 h.p. generated in New York today? When as meter reader and bill collector he answered a complaint of overcharge at 23 Wall Street and convinced the Senior J. P. Morgan of the correctness of his lighting bill, could he have visualized the start of an industry that would dominate all industries?

A Challenge and an Inspiration

But at any scale of industry development, large or small, the qualities of intellectual stature, or earnestness of purpose, of simple sincerity, are the qualities which make his name inseparably connected with this new giant. They are the qualities which this industry may well pray will always mark its leadership. We properly celebrate tonight the Golden Jubilee of an epoch-making invention, and properly invest it with the character of a testimonial to private character and ability of which all America is proud. The history of this individual, and the history of all industry which has developed on the basis of his successive inventions, should give inspiration to American Youth. I said earlier tonight, and I repeat, that the one deathless force in human life—a force from which human progress must inevitably continue to develop—is the power of the human intellect. I recall again a striking assertion of Mr. Kettering in which he states that "Whatever is within the range of the human mind to imagine, that thing can be done."

That note is a challenge and an inspiration, even as it is a characteristic of this industry and the individual whom we are honoring.

CHAIRMAN FREEMAN: I am instructed to announce that those who wish to round out the evening with dancing, will have the privilege of doing so as soon as the floor can be cleared of the seats, and to encourage your cooperation in that regard, a special lighting exhibition will be put on immediately in the exhibition hall. It can be seen to advantage from the gallery which can be reached to my left. Announcement will be made in the exhibition hall as to when this hall will be prepared for dancing.

We thank you, and adjourn this meeting.

[The meeting adjourned at 11.30 p.m.]

REPORTS OF
SPECIAL NATIONAL COMMITTEES 1928-1929

(For Personnel of Committees, See Appendix 4)

Advertising Committee

FRANK LE ROY BLANCHARD, *Chairman*

No Serial Report

Charles A. Coffin Prize Committee

P S ARKWRIGHT, *Chairman*

Report presented at Convention (see p. 177)

Codes and Standards Committee

IRVIN W. DAY, *Chairman*

No Serial Report

Electrification of Steam Railroads Committee

BRITTON I BUDD, *Chairman*

Convention Address by Mr. Budd (see p. 31)

Serial Report, Publication No. 289-118 (see addendum, p. 1571)

Exhibition Committee

E W GOLDSCHMIDT, *Chairman*

Report presented at Convention (see p. 27)

Constitution and By-Laws Committee

R F PACK, *Chairman*

Report presented at Convention (see p. 25)

Finance Committee

SIDNEY Z MITCHELL, *Chairman*

No Serial Report

Lamp Committee

FRANK W SMITH, *Chairman*

Serial Report, Publication No. 289-67 (see p. 188)

Prize Awards Committee

W H ONKEN, JR, *Chairman*

Report presented at Convention (see p. 54)

Public Policy Committee

R H BALLARD, *Chairman*

Report presented at Convention (see p. 178)

Rate Research Committee

L R NASH, *Chairman*

Serial Report (Publication Delayed)

Water Power Development Committee

PAUL A SCHOELLKOPF, *Chairman*

Serial Report, Publication No. 289-124 (see p. 201)

Wiring Policy Committee

J E DAVIDSON, *Chairman*

No Serial Report

LAMP COMMITTEE

Lamp Sales

During 1928 a total of 312,000,000 large tungsten filament lamps were sold in the United States. This is the greatest number of lamps ever sold in any one year and is an increase of 2.3 per cent over the previous year as compared with 3.7 per cent increase of 1927 over 1926.

In addition, 9,900,000 large carbon lamps were sold in 1928, as compared with 12,600,000 sold in 1927, a decrease of 21.4 per cent. The majority of these carbon lamps (77 per cent) were imported. The total sales of large carbon lamps during the past three years have decreased, due to the decrease in importations, the sales of domestic-made large carbon lamps having remained about constant. Most of these imported carbon lamps have been sold through chain stores, which are now selling tungsten filament lamps in greatly increasing quantities.

The sales of miniature lamps, such as those used in flashlights, automobiles and Christmas trees, are not included in the figures above given. The sales for these types of lamps during the past three years have been as follows:

Tungsten Filament Miniature Lamp Sales

	1926	1927	1928
Flashlight	32,700,000	37,380,000	42,880,000
Automobile	116,300,000	116,500,000	132,040,000
Christmas tree	34,350,000	44,350,000	45,245,000
Miscellaneous	4,990,000	6,900,000	8,205,000
Total	188,340,000	205,130,000	228,370,000

Carbon Filament Miniature Lamp Sales

	1926	1927	1928
Christmas tree	12,680,000	13,415,000	25,650,000
Miscellaneous	1,030,000	1,050,000	915,000
Total	13,710,000	14,465,000	26,565,000

Christmas tree lamps are generally supplied with current from central station service. Those that burn eight in series on 115-volt service consume about 5 watts each, a string of eight lamps being about the equivalent of one 40-watt lamp. Of the tungsten filament Christmas tree lamps sold in 1928, about 3,300,000 were of the new 10-watt 115-volt type, so that the 1928 sales of all tungsten and carbon filament Christmas tree lamps were the equivalent of about 9,000,000 40-watt lamps.

Fig. 1 graphically shows the number of large (excluding miniature) lamps sold each year beginning with 1907. It also gives the aggregate lumens of the lamps sold, showing that a much greater amount of light was used than the number of lamps sold would indicate.

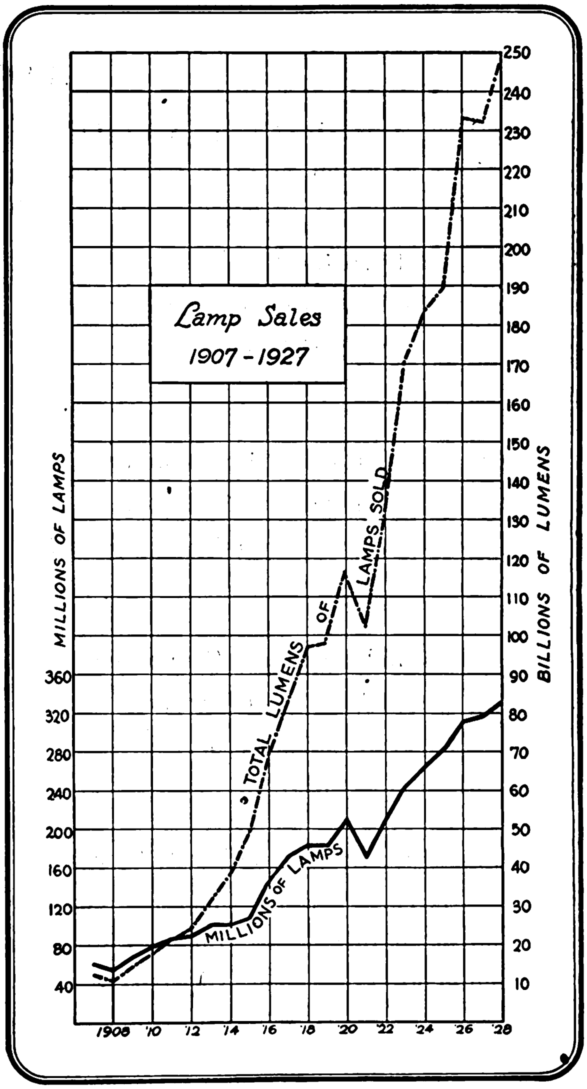


FIG. 1—Number and Aggregate Light Output of Lamps Sold (Excluding Miniature Lamps).

Average Lumens, Watts and Efficiency of Lamps

Table I presents the average lumens, watts and efficiency (lumens per watt) of large lamps sold during the past three years. Similar data for each year, beginning with 1907, are shown graphically in Fig. 2.

Distribution by Voltage

Table II presents the relative demand for lamps during the past three years, divided into voltage groups.

Standard Voltages

Table III shows the distribution of lamp sales classified by voltage groups within the 100-130-volt range (generally called the 115-volt group) for the past three years. These data are also shown graphically in Fig. 3.

Publication No. 289-67, Serial Report, Lamp Committee.

TABLE I.

AVERAGE LUMENS, WATTS AND EFFICIENCY OF LAMPS SOLD (EXCLUDING MINIATURE LAMPS)

	1926	1927	1928
Average lumens...............	747	732	769
Average watts................	59.6	59.0	60.2
Average lumens per watt.......	12.5	12.4	12.8

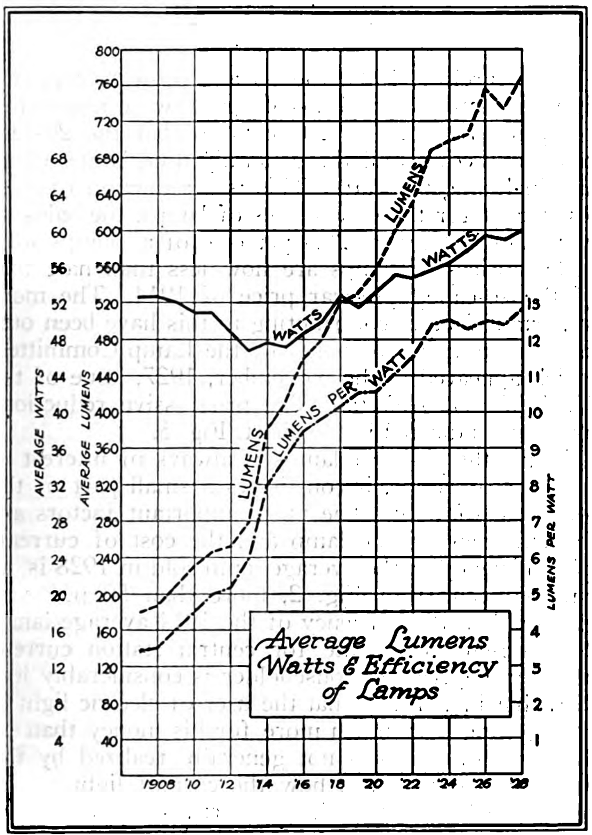


FIG. 2—AVERAGE LUMENS, WATTS AND EFFICIENCY OF LAMPS SOLD (EXCLUDING MINIATURE LAMPS).

TABLE II

DEMAND BY VOLTAGE GROUPS

	1926	1927	1928
115 volt group................	89.6%	89.9%	90.7%
230 volt group................	3.3	3.2	2.9
Street series group...........	1.7	1.6	1.5
Street railway group..........	1.5	1.4	1.5
30 and 60 volt groups.........	3.1	3.1	2.6
Miscellaneous.................	0.8	0.8	0.8
Total......................	100.0%	100.0%	100.0%

It will be noted that the sales of 110-volt lamps decreased slightly in 1928 from the previous year. In earlier years 110 volts was the principal voltage, but it is now yielding gradually to the higher voltages. The 115-volt lamp demand decreased slightly last year, the 120-volt demand being the only one which showed an increase.

Demand by Sizes

Table IV shows the relative demand for the more important sizes of lamps during the past three years.

TABLE III

DISTRIBUTION OF LAMPS BY VOLTAGE WITHIN THE 100-130 VOLT RANGE

	1926	1927	1928
100-109 volts.................	0.1%	0.1%	0.1%
110 volts.....................	12.4	8.9	8.1
111-114 volts.................	....	....	....
115 volts.....................	48.3	49.2	47.9
116-119 volts.................	....	....	....
120 volts.....................	33.8	36.4	38.7
121-124 volts.................	....	....	....
125 volts.....................	4.3	4.3	4.2
126-130 volts.................	1.1	1.1	1.0
Total......................	100.0%	100.0%	100.0%
Aggregate 110, 115 and 120 volts	94.5%	94.5%	94.7%

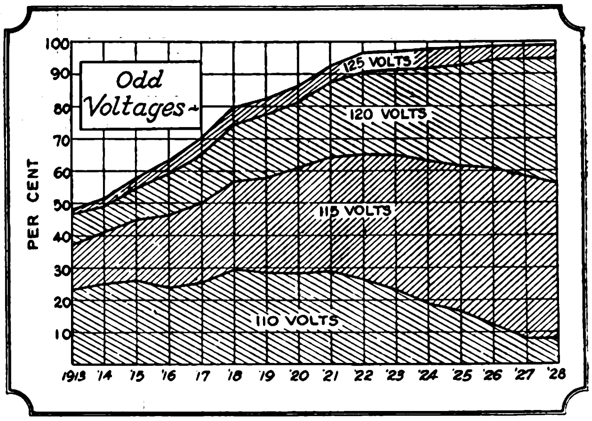


FIG. 3—DISTRIBUTION OF LAMPS BY VOLTAGE WITHIN THE 100-130 VOLT RANGE.

TABLE IV

DEMAND FOR LAMPS BY SIZES

	1926	1927	1928
10 watts......................	3.8%	4.1%	4.1%
15 watts......................	5.0	5.0	4.9
25 watts......................	20.4	21.6	22.4
40 watts......................	15.2	14.4	13.9
50 watts......................	17.3	16.5	15.3
60 watts......................	11.6	12.7	13.1
75 watts......................	4.9	3.4	3.4
100 watts.....................	9.5	10.3	10.7
150 watts.....................	2.1	2.4	2.7
200 watts.....................	3.0	3.0	3.2
300-1000 watts................	1.1	1.0	1.1
Street railway................	1.5	1.4	1.5
Street series.................	1.3	1.5	1.5
Miscellaneous.................	3.3	2.7	2.2
Total......................	100.0%	100.0%	100.0%

Street Series Lamps

The average light output of street series lamps sold in 1928 was 2422 lumens, an increase of 5.6 per cent over 1927. Fig. 4 graphically shows the average light output of street series lamps sold each year, beginning with 1907.

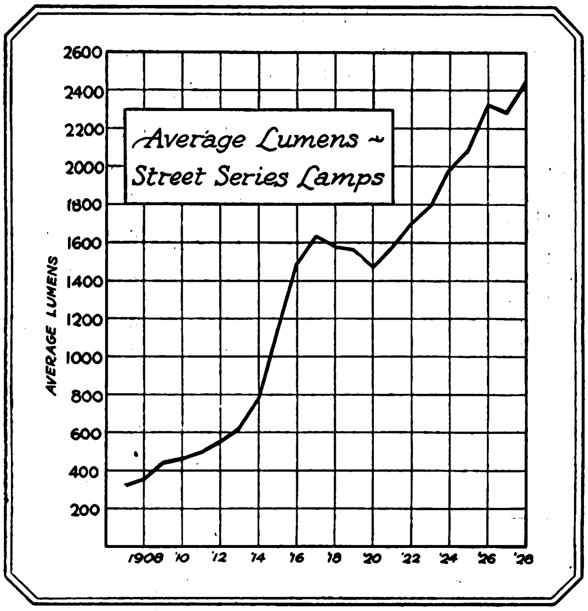


FIG. 4—AVERAGE LIGHT OUTPUT OF STREET SERIES LAMPS SOLD.

The relative demand for the different sizes and ampere ratings of street series lamps during the past three years is shown in Tables V and VI.

TABLE V

DEMAND FOR STREET SERIES LAMPS BY SIZE

	1926	1927	1928
Less than 600 lumens	2.6%	1.6%	1.3%
600 lumens	18.3	18.2	16.3
800 lumens	6.7	7.1	7.5
1000 lumens	30.0	30.0	29.2
2500 lumens	17.7	17.7	19.3
4000 lumens	12.7	12.3	12.5
6000 lumens	9.8	10.2	10.9
10000 lumens	2.2	2.0	2.2
Miscellaneous	....	0.9	0.8
Total	100.0%	100.0%	100.0%

Price Changes

Table VII presents the dates of introduction of the present sizes of the 115-volt group of Mazda lamps for general lighting service, their original list prices and the changes in prices that have occurred to date.

On July 1, 1928, a price reduction averaging 8.8 per cent was made. This was mentioned in the July, 1928, issue of the *N. E. L. A. Bulletin,* in an article contributed by the Lamp Committee.

TABLE VI

DEMAND FOR STREET SERIES LAMPS BY AMPERE RATING

	1926	1927	1928
4.0 amperes	3.0%	3.5%	2.7%
5.5 amperes	3.9	5.7	4.2
6.6 amperes	64.4	64.7	65.7
7.5 amperes	10.1	8.8	8.9
Compensator	18.4	16.6	17.7
Miscellaneous	0.2	0.7	0.8
Total	100.0%	100.0%	100.0%

On March 1, 1929, the 50 and 60-watt standard lighting lamps of the 115-volt group were reduced in list price from 22 to 20 cents so that the 20-cent price now covers all the generally used lamps up to and including 60 watts. This is a reduction of over 9 per cent for these two sizes of lamps, the sales of which, in 1928, were 28.4 per cent of all lamps sold.

The prices of lamps are now less than half that of the so-called pre-war price of 1914. The more important factors contributing to this have been outlined in an article prepared by the Lamp Committee, which appeared in the November, 1927, issue of the *N. E. L. A. Bulletin.* The progressive reductions made are indicated in the chart, Fig. 5.

While the price of lamps is always of interest to the user of lamps, it constitutes a small part of the total cost of light. The more important factors are the efficiency of the lamp and the cost of current. The efficiency of the average lamp sold in 1928 is, as will be seen from Fig. 2, more than 50 per cent greater than the efficiency of the 1914 average lamp. The present retail rate for central station current used by the average householder is considerably less than that in 1914, so that the user of electric light is now getting very much more for his money than he did in 1914. This is not generally realized by the user. Fig. 6 indicates how the cost of light to the retail user has decreased, the chart also showing how the cost of living has increased during this period.

Lamp Developments

75 Watt Inside Frosted Lamp

While there is still a relatively slight demand for the 75-watt lamp, the Mazda manufacturers are now supplying this lamp in the A-23 inside frosted bulb in place of the old PS-22 clear bulb. The list price of the lamp with the inside frosted bulb is 10 cents less than with the old clear bulb (35 cents as compared with 45 cents). It should be noted that the 100-watt lamp is obtainable at the same price and is made in the same bulb.

Projection Lamps

In last year's report mention was made of the 50, 100 and 200-watt 115-volt lamps fitted with the medium prefocus base. There are now also available 500 and 1000-watt lamps fitted with prefocus base (formerly fitted with screw base), the 500-watt lamp having a medium prefocus base and the 1000-watt

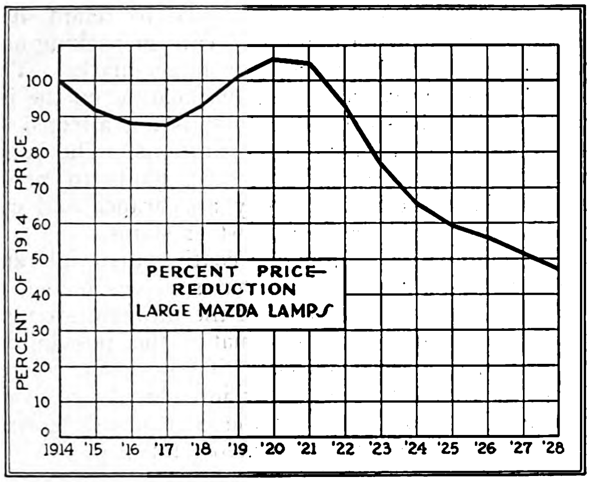


FIG. 5—REDUCTIONS IN PRICES OF MAZDA LAMPS SINCE 1914.

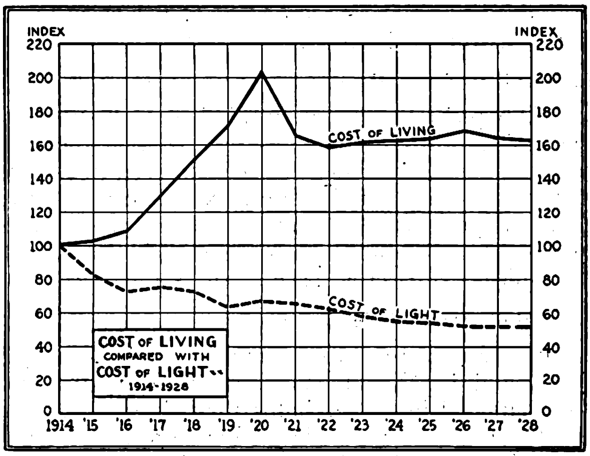


FIG. 6—COST OF LIVING AND COST OF ELECTRIC LIGHT, 1914-1928.

TABLE VII

PRICE TABLE SHOWING DATES OF INTRODUCTION OF MAZDA LAMPS, ORIGINAL LIST PRICES AND CHANGES TO DATE

Size in Watts	10	15	25	40	50(B)	50(C)	60	75	100	150	200	300	500	750	1000
November 16, 1907	.....	.....	.....	$1.50	.....	.....	$1.75	.....	.....	.....	.....	.....	.....	.....	.....
October 1, 1908	.....	.....	$.85	1.10	.....	.....	1.40	.....	.....	.....	.....	.....	.....	.....	.....
November 13, 1908	.....	.....	.85	1.00	.....	.....	1.40	.....	.....	.....	.....	.....	.....	.....	.....
September 1, 1909	.....	.....	.80	.90	.....	.....	1.25	.....	.....	.....	.....	.....	.....	.....	.....
January 1, 1910	.....	.....	.70	.80	.....	.....	1.10	.....	.....	.....	.....	.....	.....	.....	.....
April 1, 1911	.....	.....	.65	.70	.....	.....	1.00	.....	.....	.....	.....	.....	.....	.....	.....
March 1, 1912	.....	$.50	.50	.55	.....	.....	.75	.....	.....	.....	.....	.....	.....	.....	.....
June 1, 1912	$.50	.50	.50	.55	.....	.....	.75	.....	.....	.....	.....	.....	.....	.....	.....
October 1, 1912	.40	.40	.40	.45	.....	.....	.60	.....	.....	.....	.....	.....	.....	.....	.....
July 1, 1913	.35	.35	.35	.35	.....	.....	.45	.....	.....	.....	.....	.....	.....	.....	.....
April 1, 1914	.30	.30	.30	.30	.....	.....	.40	.....	.....	.....	.....	.....	.....	$6.50	$8.00
July 1, 1914	.30	.30	.30	.30	.....	.....	.40	.....	.....	.....	.....	.....	$6.00	6.50	8.00
October 1, 1914	.30	.30	.30	.30	.....	.....	.40	.....	.....	.....	$3.00	$4.00	6.00	6.50	8.00
April 1, 1915	.27	.27	.27	.27	.....	.....	.36	.....	$1.00	.....	2.00	3.00	4.50	6.00	7.00
July 1, 1916	.27	.27	.27	.27	$.28	.....	.36	$.65	1.00	.....	2.00	3.00	4.50	6.00	7.00
April 1, 1917	.27	.27	.27	.27	.27	.....	.36	.65	1.00	$1.50	2.00	3.00	4.50	6.00	7.00
January 1, 1918	.30	.30	.30	.30	.30	.....	.35	.70	1.10	1.65	2.20	3.25	4.70	6.50	7.50
October 1, 1918	.35	.35	.35	.35	.35	.....	.40	.70	1.10	1.65	2.20	3.25	4.70	6.50	7.50
October 1, 1919	.35	.35	.35	.35	.35	$.65	.40	.70	1.10	1.65	2.20	3.25	4.70	6.50	7.50
April 1, 1920	.40	.40	.40	.40	.40	.65	.45	.75	1.10	1.55	2.10	3.15	4.60	6.50	7.50
October 1, 1921	.40	.40	.40	.40	.40	.60	.45	.70	1.00	1.40	1.90	2.80	4.15	5.75	6.70
April 1, 1922	.35	.35	.35	.35	.35	.55	.40	.70	.95	1.30	1.80	2.50	3.75	5.25	6.00
October 1, 1922	.35	.35	.35	.35	.35	.55	.40	.60	.75	1.00	1.30	1.90	2.75	4.00	4.50
May 1, 1923	.32	.32	.32	.32	.32	.50	.37	.55	.70	.90	1.15	1.75	2.50	3.75	4.25
February 1, 1924	.30	.30	.30	.30	.30	.45	.35	.50	.60	.75	1.00	1.60	2.35	3.75	4.00
July 1, 1924	.27	.27	.27	.27	.27	.40	.32	.45	.55	.70	.95	1.50	2.25	3.75	4.00
January 1, 1925	.27	.27	.27	.27	.27	.40	.32	.45	.50	.65	.80	1.25	2.00	3.50	3.75
February 1, 1926	.27	*.27	*.27	*.27	*.29		*.32	.45	*.45	.60	.80	1.25	2.00	3.50	3.75
September 1, 1926	.25	*.25	*.25	*.25	*.27		*.30	.45	*.43	.60	.80	1.25	2.00	3.50	3.75
February 1, 1927	.25	*.25	*.25	*.25	*.27		*.30	.45	*.43	.60	.80	1.25	2.00	3.75	4.00
April 1, 1927	.23	*.23	*.23	*.23	*.25		*.25	.45	*.40	.60	.80	1.25	2.00	3.75	4.00
July 1, 1928	.20	*.20	*.20	*.20	*.22		*.22	.35	*.35	.60	.80	1.25	2.00	3.75	4.00
March 1, 1929	.20	*.20	*.20	*.20	*.20		*.20	.35	*.35	.60	.80	1.25	2.00	3.75	4.00

*New standard line of lamps.

having the new mogul prefocus base. The new mogul prefocus base is the same design (but larger dimensions) as the medium prefocus base.

Intermediate Screw Base

It is hoped that ultimately this base will supersede the candelabra base, but it is realized that there are large numbers of candelabra sockets used in fixtures throughout the United States. No concerted movement has yet started except that the regularly listed so-called "candelabra" lamps are available fitted with the intermediate screw base at the same price.

Short Bulb Street Series Lamps

The 15-ampere (4000 lumen) and 20-ampere (6000 and 10,000 lumen) lamps have, in the past, been supplied in longer bulbs than those of equivalent 6.6-ampere lamps. The 15-ampere lamp is now available in PS-35 (formerly PS-40) bulb and the 20-ampere lamps in a short PS-40 bulb, the prices of these shorter-bulb lamps being lower than the old larger-bulb lamps.

On these three shorter-bulb lamps the light center length has been changed from 9½ to 7 in. To use the shorter lamp requires, in most fixtures, a change in the socket position or the insertion of a 2½-in. socket extension piece screwing into the present socket. The use of the lower price shorter lamp well warrants the slight expense of changing the socket position or of using the extension piece.

The lamp manufacturers advise that the changeover to these new lamps is progressing more slowly than had been anticipated, so that at the present time both types of series lamps are in demand, and the cost per lamp, instead of being lower, is higher. The Lamp Committee, therefore, draws Member Companies' attention to the opportunity, by making a small expenditure for socket change, where this is involved, to materially reduce the renewal cost by using the new and less costly lamps. If Member Companies who have not already done so will fall in line with the general program, it will assist to hasten this simplification project.

An article, supplied by the Lamp Committee, describing this, appeared in the August, 1928, issue of the *N. E. L. A. Bulletin.*

56 Watt Inside Frost Street Railway Lamp

This lamp supersedes the 56-watt lamp in S-21 clear bulb. It has a special filament construction designed to withstand vibration on street cars and will supersede the corresponding size in the straight side clear bulb, for use five in series on 525 to 650-volt circuits.

Inside Coloring

A notable development was the introduction of the inside colored lamp to supersede the outside coated or sprayed finish type previously used. While bulbs of natural colored glass have been used to some extent, their relatively high price has limited their application.

The outside coated colored lamps were not entirely weatherproof under conditions of severe exposure, the colors tending to fade from the action of the elements. The mat surface tended to retain dust and soot and called for unusual care in packing and handling, to avoid scratches or finger-marks. The new process sprays a non-fading coating on the inside of the bulb so that the color is not affected by the weather nor by handling operations. The lamp, having a smooth outside surface, tends to retain its original smooth and glossy appearance and can readily be wiped free from dust or stains.

The elimination of outside coating materials and the foreign matter that the mat surfaces tended to retain has greatly safeguarded the ultimate strength of basing cement and eliminated the possibilities of stained or corroded bases. These inside colored lamps in the wattages so far introduced are available at the same prices as the corresponding sizes and colors of the outside coated lamps.

25 Watt, T-6½ Bulb, Intermediate Base Showcase Lamp

This lamp, illustrated in Fig. 7, made available during the past year, has an overall length of 5½ in. and is listed at 55 cents. The diameter of the lamp is about the same as the intermediate base socket which makes the lamp useful where space limitations prevail. It makes possible the design of extremely neat and compact showcase lighting equipment and has also been found effective for illuminating displays, models, etc., from beneath. It is also desirable for light ornaments of such proportions requiring a small extended light source.

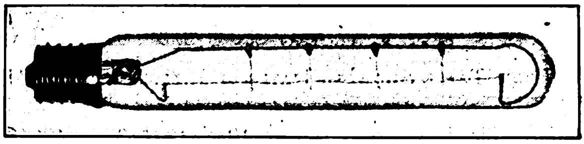


FIG. 7—25-WATT, INTERMEDIATE BASE SHOWCASE LAMP.

An article, calling this lamp to the attention of Member Companies, was published in the *N. E. L. A. Bulletin,* December, 1928.

Very Large Lamps

The most powerful incandescent lamp, so far constructed, consumes 50,000 watts and is illustrated in Fig. 8. Its tungsten ribbon filament requires about 450 amperes at 115 volts. The lamp is so designed that the heated gas in rising passes through a metal chamber equipped with radiating fins to cool the gas to a temperature which will permit the continued operation of the lamp. One feature of this lamp is the sealing of the bulb proper to the metal chamber. This is done with a series of glass rings, fused together, of graduated differences in temperature coefficient, the glass of the bulb having a considerably different expansion-temperature coefficient than that of the metal. The lamp is purely an experimental one.

Lamps in sizes up to 10 kw. are finding rapidly increasing use in lighting for the production of motion pictures and for airport floodlighting service. A novel means of improving the candlepower maintenance of these lamps is being introduced.

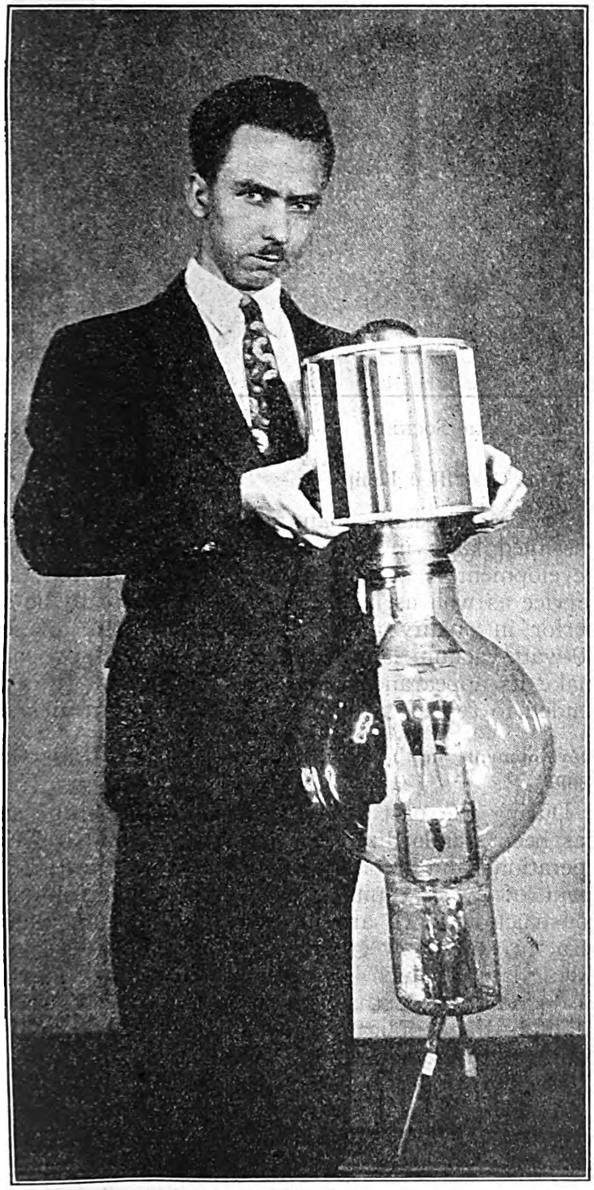


FIG. 8—50-Kw. Lamp, the Largest Incandescent Lamp Ever Made.

An Improvement in the Very High Wattage Lamps

The incandescent lamps used in airport and motion picture studio lighting are not only operated at very high efficiency, but their bulb surface per watt is much less than that of the smaller lamps so that their bulbs tend to blacken more rapidly. The 500-watt lamps for floodlighting service are made in bulbs 5 in. in diameter, while 10-in. bulbs are used for the 10,000-watt lamps for airport floodlight and motion picture studio lighting. The wattage is twenty times as great, but the bulb surface is only quadrupled, so that the watts per unit of bulb surface are five times as great in the 10-kw. lamp as in the 500-watt floodlighting lamp.

The tungsten slowly evaporated from the filament surface clings to the inside of the bulb as a black deposit, where it absorbs both light and heat radiation. Chemical means are employed to minimize this blackening, but on occasion it nevertheless becomes objectionable. The blackening reduces the light output and raises the bulb temperature. If the bulb temperature reaches the softening point of the glass, happily a rare occurrence, the bulb distorts and the lamp fails mechanically, but the light output is usually so reduced by absorption before that time that the lamp has but little remaining value. Fortunately, the deposit on the inside of the bulb does not always adhere strongly to the glass (unless the bulb has been allowed to become so black that it has softened or devitrified), so that the black deposit can normally be removed to a large extent by the proper kind of cleaner introduced in the bulb. This cleaner consists of about a teaspoonful of metallic tungsten powder, which is put inside of the bulb. When the blackening becomes noticeable, the lamp is taken out of its socket and turned about slowly, so that the tungsten powder slides around on the inner surface of the bulb "mopping up" the deposit as it goes along. The bulb can be restored in this way to approximately its original state, and the light output increased nearly to its initial value.

There is a slight decrease in light generated by the filament throughout life by reason of the changes which take place in it during burning, and, of course, this cannot be restored by cleaning the bulb. The cleaning intervals should ordinarily be shorter at first because as the lamp ages in service the tendency to blacken becomes somewhat less. It is expected that it will be found advisable to clean these lamps about four or five times during the course of their life.

Lamps for Sound Pictures

The introduction of sound with motion pictures necessitated the development of small lamps having high efficiency. These lamps have a horizontal coil

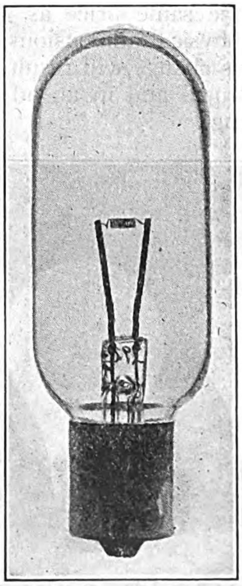


FIG. 9—Horizontal Coil Filament Lamp for Film Sound Recording.

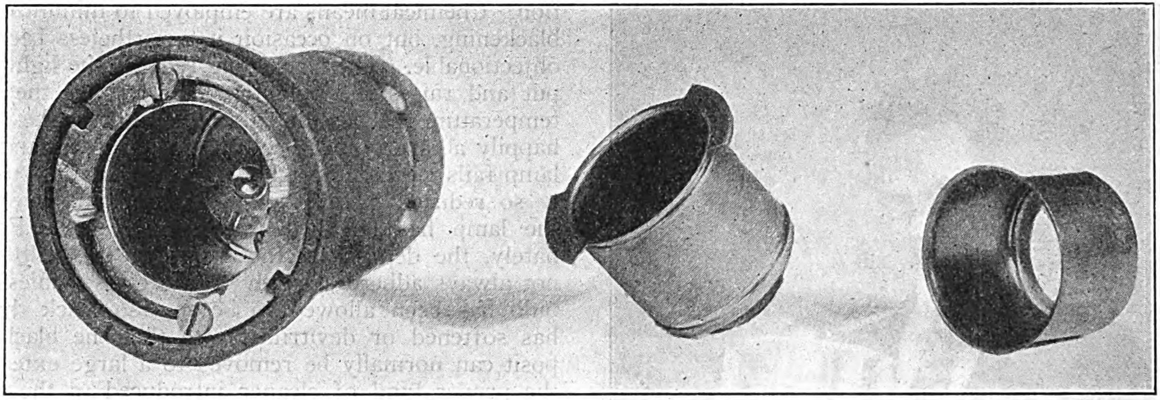


FIG. 10—MOGUL PREFOCUS BASE AND SOCKET.

filament for projecting the sound record on the film through a very small slit and on to the photo-electric cell. Flattened wire supports at each end of the filament are used to allow for expansion and contraction of the filament and to keep it from bowing.

Mogul Prefocus Base

The success of the medium prefocused base lamp and socket for use in projection equipment led to the production of a mogul prefocused socket and base, illustrated in Fig. 10. It can be utilized on any lamp regularly supplied with a mogul screw base and is now standard with the 1000-watt 115-volt T-20 bulb lamp for projection lighting service.

60 Watt A-21 Bulb Lamp

The lamp manufacturers have reduced the overall length of the 60-watt A-21 bulb lamp, illustrated in Fig. 11, making it exactly the same, in length as well as diameter, as the present 50-watt lamp. It is believed that with advancing standards of illumination, many customers who now use 50-watt lamps will be induced to replace them with 60-watt lamps and will be pleased to discover that the 60-watt lamp can be obtained at the same price as the 50-watt, and is identical in physical dimensions. It is, therefore, hoped that this change will result in a shift from 50- to 60-watt lamps, and in an advance in the standards of lighting.

40 Watt Gas-Filled Lamp

The Mazda lamp manufacturers have a 40-watt gas-filled lamp in process of development. If this development is as successful as is anticipated, and service as well as laboratory tests show it to be superior in quality and performance to the present 40-watt vacuum lamp, this new lamp will probably make its appearance some time this year. It is intended to replace the present 40-watt vacuum lamp.

Developments in the Usage of Submerged or Underwater Lamps

During the past year the 1000-watt diving lamp has been standardized for naval rescue and diving operations, and becomes part of the permanent equipment of every capital ship. Civil operations and construction work around piers, docks and marine structures are now greatly facilitated by these same diving lamps, which burn submerged and are capable of operation at depths as great as 300 ft.

Interesting applications of underwater lamps are recorded to include observations and studies of fish and marine organisms, such as reported by Dr. William Beebe and the recent expeditions of the American Museum of Natural History. It is reported that submerged lights attract and lure many specimens to the surface, while in certain localities underwater burning lamps are now used in lieu of bait. In

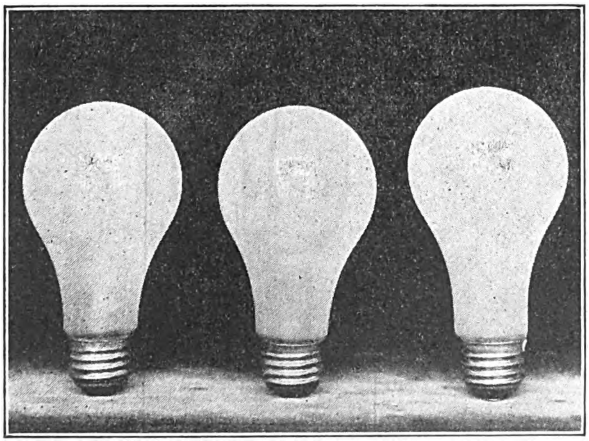


FIG. 11—PRESENT 50-WATT, NEW AND OLD 60-WATT LAMPS.

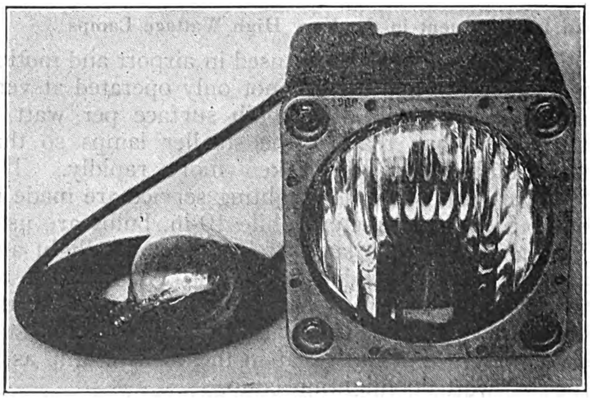


FIG. 12—LIGHTING UNITS OF WATER-TIGHT CONSTRUCTION FOR THE UNDERWATER ILLUMINATION OF SWIMMING POOLS AND FOUNTAINS.

connection with fish hatcheries lamps suspended directly above the water surface attract moths and insects on which the fish feed.

Recent studies of the transmission of light through liquids suggest commercial applications of submerged lamps, not only for the decorative lighting of fountains and streams, but as well for the inspection of oils, liquid soaps, acids and similar fluids.

The underwater lighting of both indoor and outdoor swimming pools and the development of practical units therefor opens quite a large field of application, inasmuch as pools so lighted, consuming perhaps 5 to 10 kw., are quite beautiful and are—to a large extent—free from the probability of drowning accidents or pollution.

Use of Lamps of Proper Voltage

In its report of a year ago your Committee called attention to the cases, all too frequently encountered, in which lamp dealers supply lamps whose rated voltage differs from the announced standard of service of the utility.

The following is quoted from last year's report:

"In cases where dealers are supplying lamps of too high a voltage the cause is generally either the stress of commercial competition, or failure fully to realize the detriment resulting to all parties through that practice, or failure of a wholesaler to supply lamps of correct voltage.

"The class of lighting customers who suffer most by this practice are, in general, the small customers, particularly residence users, who take, without question as to voltage, the lamps offered by the retail dealers.

"Since the lighting voltage in the larger cities of the country is generally either 115 or 120 volts as contrasted with a lighting voltage of 110 or 115 in many of the smaller communities, it is generally found that where a dealer draws his lamp supply from a larger city the lamps, if they are not of the correct voltage, are more likely to be of a voltage higher than the correct voltage, rather than to be lower than the correct voltage. Thus, in general, we find that, when a lamp is not of the proper voltage, it is generally of too high a voltage.

"The disadvantages, which are well known to the companies but not generally known by the consumers, resulting from operation of lamps of too high a voltage, are:

1. The customer receives less light, and at a greater cost per unit of light.
2. The central station loses kilowatt-hour sales due to the decrease in wattage consumption of the lamps.
3. The manufacturer and dealer lose lamp renewal sales.

"It is, therefore, to the best interest of all parties concerned that only lamps of proper voltage be used. A realization on the part of the dealer of the harm resulting from using lamps of improper voltage will almost invariably result in a change to the proper voltage."

Further study and investigation of this subject shows that in the great majority of cases in which

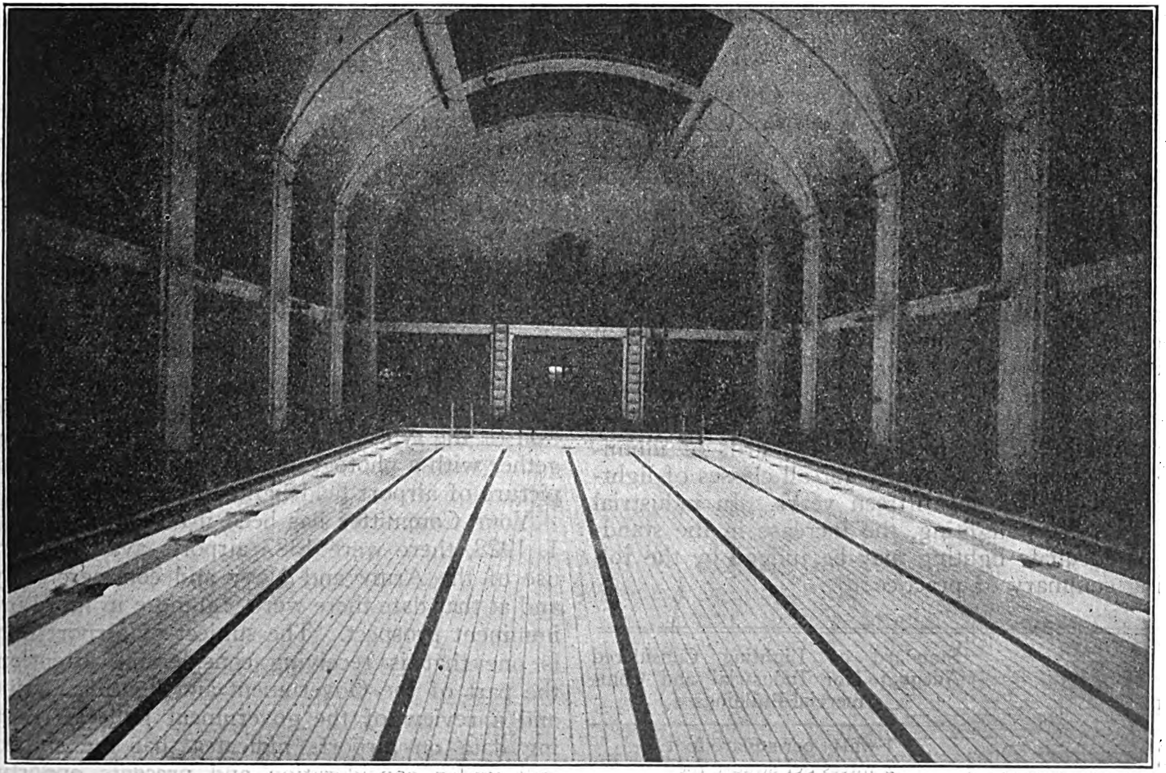


FIG. 13—VIEW OF A SWIMMING POOL LIGHTED FROM BENEATH THE SURFACE

lamps of too high a voltage are supplied, the cause is inadequate or erroneous information, on the part of the user or the distributor, as to the average voltage delivered at the lamp sockets. Lack of knowledge arises either from ignorance or from carelessness, and the remedy is obvious. Erroneous information generally results from improper measurement of voltage, or improper interpretation of voltage readings taken on the customers' premises. For example:—It is a growing practice to regulate the voltage delivered to customers' premises at a value slightly in excess of the system standard in order to allow for voltage drop on customers' wiring. If, perchance, on a system operated with a 115-volt standard, a voltage reading of 117 or 118 volts should be obtained at a lamp socket at a time when there is little or no lighting load in use, or if such a reading were obtained at the service entrance under any condition of load, such indication might be taken as a basis for concluding that the service voltage is too high for the use of 115-volt lamps, and might therefore lead to the recommendation and use of 120-volt lamps; when, as a matter of fact, the voltage drop due to load consumes the excess voltage shown by the reading and there is, therefore, no justification at all for the customer ordering lamps of high labeled voltage. If it is made known to all lamp dealers that the utility will take voltage measurements to check its service in locations where a question has been raised as to the voltage supplied, there will then be no occasion for voltage measurements by people who do not understand the matter, and these cases of improper interpretation will automatically cease.

Some cases of the use of improper lamp voltage result from attempts to compensate for the mechanical rigors of the service by using higher voltage lamps—when the only effective remedy would be to use either the rough service lamp or the vibration resisting lamp or some kind of shock-absorbing socket or lamp mounting. An occasional case of under-voltage operation is found to be due to misdirected effort to economize on the part of the customer, whereby he deliberately orders lamps of higher voltage to save renewal expense, forgetting—or not knowing—that the loss in lamp efficiency which accompanies the increase in lamp life will adversely affect the entire light output of the installation to such an extent as to entirely outweigh the small saving in lamp cost.

It must be remembered that standards of illumination have increased greatly for all classes of lighting service in the last fifteen years. In industrial and commercial lighting, the increase in the standard of adequate lighting may be judged by the following summary of practice:

Year	Standard of Lighting Considered Adequate for Industrial and Commercial Buildings
1913	1 watt per square foot
1920	2 watts per square foot
1929	3 watts per square foot

If the increases in illumination are obtained by increasing lamp wattage without providing additional capacity in the lines supplying the current, the added voltage drop may contribute materially to under-voltage burning of the lamps.

It was hoped that the Voltage Book distributed a year ago would rectify the cases of improper lamp voltage. There has been some improvement, but much still remains to be done. Plans are, therefore, being made for a cooperative effort on the part of the central stations and lamp manufacturers having for an object the discovery and elimination of these remaining conditions of under-voltage burning. This effort will probably develop into a series of meetings, or "voltage conferences," in the larger centers, between the utility and the lamp manufacturers' representatives, following which the latter, having definite information as to the average voltage supplied at the lamp sockets, will correct such cases as may be found in which dealers are not supplying lamps of the correct voltage.

Two cities (of 100,000 population or thereabouts) have already been covered in this manner, with very satisfactory results. In the first one, the operating standard was 110 volts, and as all the larger lamp dealers had to carry 115-volt lamps for all the surrounding territory, they simplified their stocks by supplying 115-volt lamps in their home city also. The corrective measure in this case was the decision of the utility to postpone no longer its change from 110-volt supply to the much more universal standard of 115-volt supply. In the second city a few complaints of high voltage led to voltage tests, which did indicate in certain localities a higher than normal operating voltage. In some districts in this same city prevailing voltages were somewhat below normal. While, in general, the normal voltage was approximated in service, yet the reports of the few higher than normal voltages mentioned above gave rise to misconception and to the use of lamps of too high voltage. The result of the investigation was to establish the nominal operating voltage as the correct voltage for lamp supply.

Airport Lighting

Your Committee has been following with a great deal of interest the subject of airport lighting, and presented in its report last year a general description of the types of lamps used for this service, together with a photograph of a landing floodlight and picture of airport field lighted by floodlight.

Your Committee has been informed that on Oct. 1, 1928, there were 1387 airports available for the use of the Army and Navy and commercial flyers, and at that date there were 900 more in more or less imminent prospect. The subject of airport lighting is one that is receiving considerable attention on the part of the Government and lighting engineers, and a review of the government bulletins containing data on airports indicates that the subject is still under consideration and presents opportunity for considerable study and research.

In several cities special markings and signs for the aid and safety of aviation are being placed on conspicuous large objects, such as gas holders, railway stations, tops of hotels, etc. These aeronautical lighthouses serve a valuable purpose and will undoubtedly increase as aviation becomes more popular.

The Assistant Secretary of War and the Director of the Aeronautics Department of Commerce have both suggested that the utility companies might further cooperate by marking the roofs of their buildings, gas holders and other structures, with the name of the town and with directional arrows pointing to the nearest airport. They point out that the smaller the town, the greater value these markers will have. Specifications for such markings can be secured from the Director of Aeronautics of the Department of Commerce. The Aeronautic Branch of the Department of Commerce has issued Aeronautics Bulletin No. 16 entitled "Airport Rating Regulations," which bulletin contains specifications of rating on night lighting equipment.

At the International Civil Aeronautical Conference recently held in Washington, the fact was emphasized and has since been subscribed to by all air transport companies that commercially feasible air transportation necessitated night flying and safe night landing. Since the last Committee Report the transcontinental air way has been equipped with 1000-watt airway beacons over the last remaining section west of Salt Lake City, and thousands of miles of other routes have been similarly marked. The Department of Commerce specifies that a pair of directional beacons be added to the rotating route beacon, and these direction lights provided either with a distinguishing color, or to flash a dot and dash code. Privately owned rotating beacons must be equipped with a fixed projector pointing in the direction of the nearest airport. These developments greatly expand the consumption of lamps and lighting power and will, undoubtedly, have a beneficial effect in extending central station lines in rural communities.

In order to provide flexibility of airport landing field illumination, there have been recommended a plurality of individual projector units, usually arranged in banks or groups of three to ten, remotely controlled and operated in accordance with the wind direction. Such an arrangement insures against trouble from individual outages and extends the areas floodlighted. A typical modern airport has a connected load of twenty-four 3-kw. lamps, in addition to the boundary and marker lights and hangar floodlighting. Illuminated wind Tees are also coming into usage, so that each major airport now represents a connected load on the order of 100 kw.

Red obstacle lights placed on every prominent structure near an air terminal make up a considerable addition to the field lighting itself.

Two new lamps have been developed for the airport floodlighting projectors designed to operate on voltage transformers at the units. These are the 1½- and 3-kw., 32-volt prong base lamps.

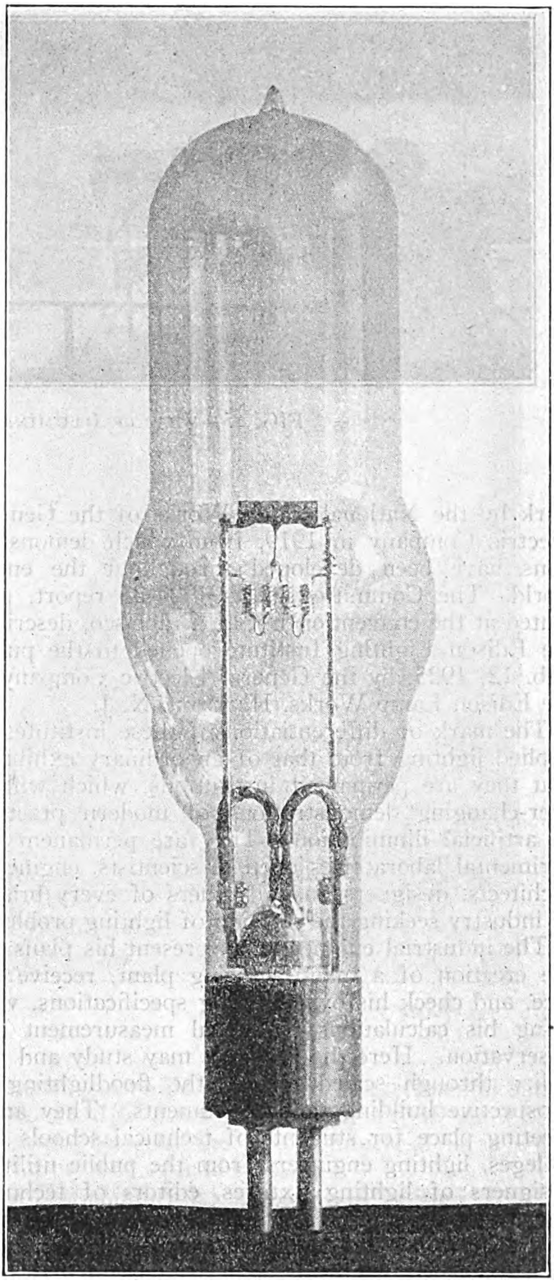


FIG. 14—THE 3-KW., 32-VOLT GT-38 BULB MAZDA LAMP RECENTLY DEVELOPED FOR AIRPORT FLOODLIGHTING.

Lighting Demonstrations

On May 30, 1929, there was opened in Grand Central Palace, New York City, under the auspices of the Westinghouse Lamp Company, another permanent institute for the advancement of the art of modern lighting. With the creation of this lighting institute, there is brought to the central station companies and others interested in the promotion of better lighting the third important demonstration of this kind in this country. The Lamp Committee presented to the Association at the 1920 Convention at Pasadena a lighting demonstration patterned after the first demonstration of its kind, made at Nela

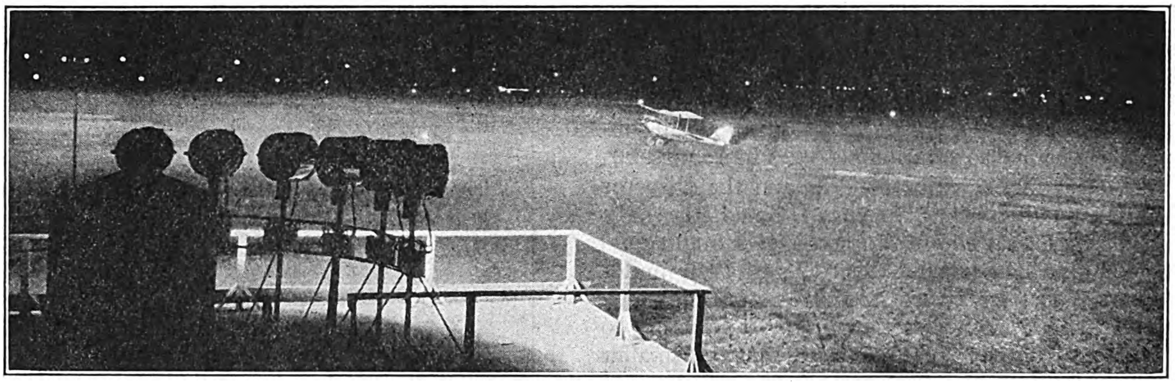


FIG. 15—VIEW OF ILLUMINATED RUNWAYS ON A LIGHTED AIRPORT.

Park by the National Lamp Works of the General Electric Company in 1919, from which demonstrations have been developed throughout the entire world. The Committee in its 1924-25 report, presented at the convention in San Francisco, described the Edison Lighting Institute opened to the public Feb. 12, 1925, by the General Electric Company at the Edison Lamp Works, Harrison, N. J.

The mark of differentiation of these institutes of applied lighting from that of an ordinary exhibit is that they are permanent institutions, which will be ever-changing demonstrations of modern practices of artificial illumination. They are permanent experimental laboratories open to scientists, engineers, architects, designers and all others of every branch of industry seeking the solution of lighting problems.

The industrial engineer may present his plans for the erection of a manufacturing plant, receive advice, and check his own lighting specifications, verifying his calculations by actual measurement and observation. Here the architect may study and visualize through scaled models the floodlighting of prospective buildings and monuments. They are a meeting place for students of technical schools and colleges, lighting engineers from the public utilities, designers of lighting fixtures, editors of technical and business magazines, merchandising managers of central stations, and dealers in lamps and equipment, each to inspect, study or have demonstrated to him, according to his individual interest, any of a thousand applications of lighting, whether it be in the home, the commercial or the industrial field.

The Westinghouse Lighting Institute occupies the seventh floor of the Grand Central Palace, an entire city block of 40,000 sq. ft.

Artificial light produced by electricity has become so commonplace in its fifty years that it is accepted with hardly a thought of its existence. This complete acceptance has been largely the result of a standardization in lamp manufacture that, in a sense, has stultified the development of application methods. The electric lamp is used for what are considered satisfactory results without an adequate appreciation of what would be possible if greater knowledge existed in the application of light.

It is this theory of application that makes the Nela

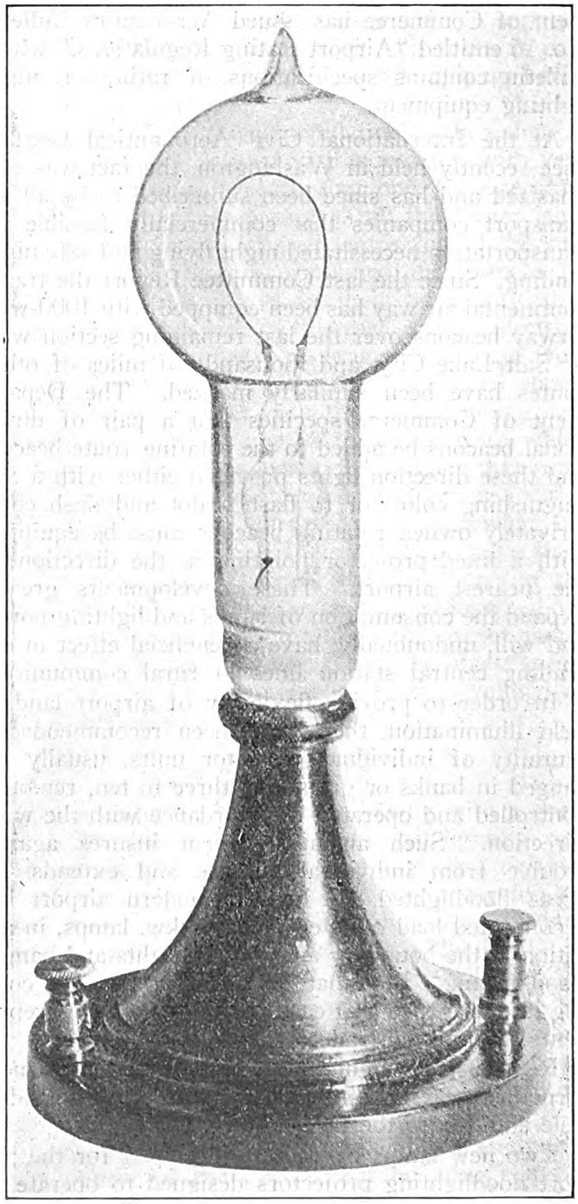


FIG. 16—REPLICA OF EDISON'S EXPERIMENTAL LAMP OF OCT. 21, 1879 (THE ORIGINAL WAS DESTROYED).

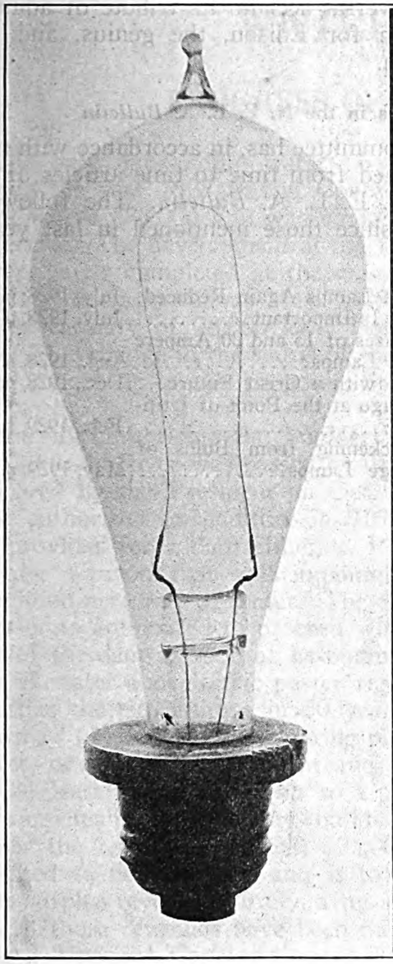


FIG. 17—THE FIRST COMMERCIAL LAMP, 1881.

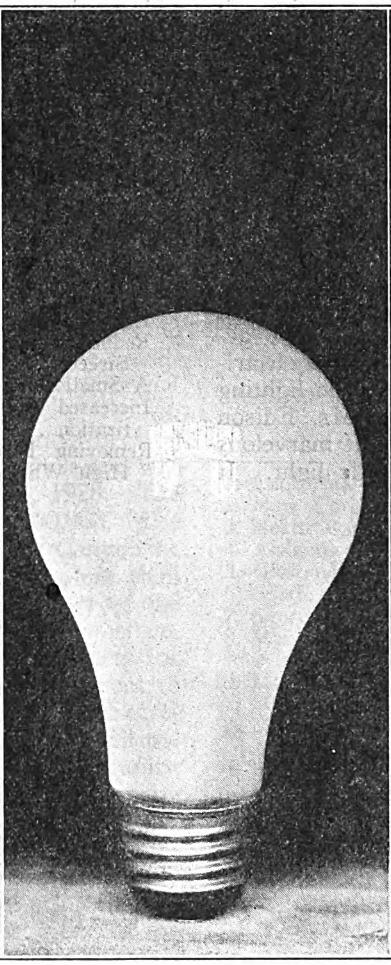


FIG. 18—PRESENT DAY 60-WATT LAMP.

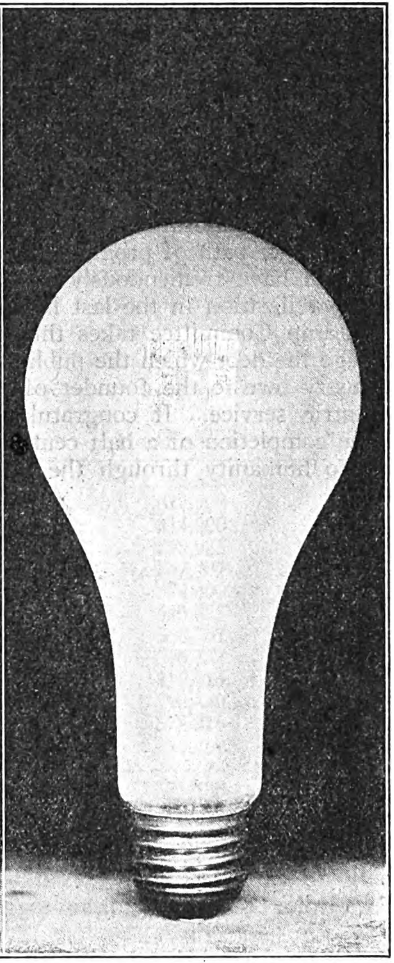


FIG. 19—PRESENT DAY 100-WATT LAMP.

School of Lighting, the Edison Lighting Institute, and the new demonstration opened by the Westinghouse Lamp Company in May of this year, unique in the history of applied lighting. All three of these large scale permanent institutes are open to the public and are free to all visitors.

The Lamp Committee is following with interest the success of such demonstrations for promoting the art and practice of better lighting. Institutes of this kind should certainly have a marked influence, not only in raising lighting standards, but also in encouraging the tendency toward the use of proper light intensities for industrial, commercial and home lighting purposes, through demonstrations of their utilitarian value in each field of their application.

Fiftieth Anniversary of the Incandescent Lamp

Oct. 21 of this year marks the fiftieth "birthday" of the incandescent lamp of Thomas A. Edison, who developed not only the first practical lamp, but a completely new system of generation and distribution of electric current for the lamp.

Much has and more will appear in the press and literature of the day regarding these remarkable inventions and the development of the industry. Fig. 16 illustrates a replica of Edison's experimental lamp of Oct. 21, 1879, and Fig. 17, 18 and 19 show the differences between the first commercial lamp sold and the present equivalent lamps.

The first commercial lamp, shown in Fig. 17, consumed about 100 watts and was rated to give 16 c.p. horizontally, equivalent to about 170 lumens. It blackened considerably during its life, the average amount of light throughout life being about 65 per cent of initial. It sold for $1.25 and was a marvel of the age.

The lamp shown in Fig. 18 is about the average size now used. It is rated at 690 lumens, its average lumens throughout life being 93 per cent of initial. It thus gives over five times the amount of light given by the lamp of 1881 and consumes about 40 per cent less current. Its list price is 20c., less than one-sixth that of the 1881 lamp.

Consuming about the same wattage as the first commercial lamp, the lamp illustrated in Fig. 19 is rated at 1340 lumens, its average lumens throughout life being 92 per cent of initial. It thus gives an average throughout life of over eleven times the amount of light given by the lamp of 1881. Its list price is 35c., less than one-third the 1881 lamp.

Mr. Edison, who is perhaps best known through his development of the incandescent lamp, although this is only one of his vast number of wonderful achievements, was presented, on Saturday night, Oct. 20, 1928, with the Congressional Medal, the highest honor the Government pays to any citizen. This event is well remembered by everyone. The resolution of Congress aptly stated that the Medal was bestowed in commemoration of his achievements in illuminating the path of progress through his inventions which have tremendously accelerated the advance of civilization in the last half century.

The Lamp Committee takes this occasion to acknowledge the debt which the public and the electrical industry owe to the founder of electric lighting and electric service. It congratulates Mr. Edison upon the completion of a half century of marvelous service to humanity through the electric light. It adds to the universal acclaim its tribute of admiration and esteem for Edison, the genius, and for Edison, the man.

Articles in the N. E. L. A. *Bulletin*

The Lamp Committee has, in accordance with past practice, published from time to time articles of interest in the N. E. L. A. *Bulletin*. The following have appeared since those mentioned in last year's report:

Price of Mazda Lamps Again Reduced	July, 1928, p. 400
Home Lighting Is Important	July, 1928, p. 439
Reduction in Sizes of 15 and 20 Ampere Street Series Lamps	Aug., 1928, p. 492
A Small Lamp with a Great Future	Dec., 1928, p. 750
Increased Voltage at the Point of Utilitization	Feb., 1929, p. 108
Removing Blackening from Bulbs of High Wattage Lamps	May, 1929, p. 309

WATER POWER DEVELOPMENT

PROGRESS OF WATER POWER DEVELOPMENT IN 1928

The only outstanding water power development during the year 1928 was at Conowingo, in Maryland, where 378,000 h.p. was completed and placed in service. The development at the falls of the Ohio River, partly completed at the close of 1927, came into full operation about May 1, 1928, with an installed capacity of 78,000 kw. There has been no observable change in the status of the Muscle Shoals development or in the proposed St. Lawrence development.

The bill authorizing the Boulder Dam project on the Colorado River was passed by Congress and was approved by the President on Dec. 21, 1928. The total authorized expenditure is $165,000,000. The bill provides for a dam either at Black Canyon or Boulder Canyon that will impound not less than 20 million acre feet of water. The Secretary of the Interior is authorized to proceed with the construction of the dam as soon as he obtains contracts for sale of water and electric power rights sufficient to amortize the expenditure in 50 years. The Secretary may (1) build the generating plant and sell the power, or (2) build the plant and lease the units, or (3) lease the power rights to a private company or municipality which may build its own plant. Under the terms of the bill, $25,000,000 is to be allocated to flood control and is to be repaid only from surplus revenues, if any, after all prior charges against those revenues have been met. The cost of the All-American Canal, estimated at $38,500,000, is to be a charge upon the land benefited by it, and is not to be paid for from the revenues derived from the sale of water or power rights from the dam. The act becomes effective within six months if ratified by the seven Colorado Basin States, or after six months on ratification by six of those States.

U. S. Geological Survey

The U. S. Geological Survey reports that on Jan. 1, 1929, the developed water power in the United States amounted to 13,571,530 h.p. The increase in the last year was 1,275,530 h.p. or 10.4 per cent. The largest item in this increase was the Conowingo development of the Philadelphia Electric Company which comprised about 30 per cent of the increase. The figures for recent years are as follows:

Date	Horsepower	Increase Per cent
1921, November	7,926,958	
1924, March	9,086,958	14.6 (2.3 yr.)
1925, March	10,037,655	10.5
1926, Jan. 1	11,176,596	11.3 (.8 yr.)
1927, Jan. 1	11,720,938	4.9
1928, Jan. 1	12,296,000	4.9
1929, Jan. 1	13,571,530	10.4

The average annual increase was 8.1 per cent.

The 13,571,530-h.p. hydraulic electric power existing on Jan. 1, 1929, is divided between 3375 plants, of which 1605 are public utility plants with capacity of 11,886,336 h.p. (8,867,229 kw.) and 1770 miscellaneous industrial plants with capacity of 1,685,194 h.p. The public utility plants average 7406 h.p. each and the industrial plants 952 h.p. each.

The distribution among the States is as follows:

State	Horsepower	Per cent of U. S. Total
1. California	2,226,529	16.4
2. New York	1,813,500	13.3
3. North Carolina	814,000	6.0
4. Alabama	799,085	5.9
5. Washington	747,407	5.5
6. South Carolina	574,000	4.2
7. Georgia	543,685	4.1
8. Maine	538,761	3.9
9. Wisconsin	516,732	3.8
10. Maryland	415,815	3.1
11. Montana	393,440	2.9
12. Michigan	378,315	2.8
All others	3,810,260	28.1
	13,571,530	100.0

The present status of water-power development in the United States as summarized by the Federal Water Power Commission and the Geological Survey is as follows:

	Horsepower
1. Total water power in United States (50% of time)	55,000,000
2. Corresponding capacity that will be installed	75,000,000
3. Probably 75% of this is under Federal jurisdiction	41,250,000
4. Installed Jan. 1, 1929	13,571,530
5. Licensed by Federal Water Power Commission	6,656,000
6. Constructed under F. W. P. Com. license	2,506,696
7. Under preliminary permit from F. W. P. Com.	4,856,000
8. Applications not acted upon	10,000,000

The following is a statement of electric energy generated in the United States in hydraulic plants 1920 to 1928 inclusive:

Year	Kw-Hr.	Per cent Increase
1920	16,150,000,000	...
1921	14,970,000,000	—7.3
1922	17,207,000,000	15.0
1923	19,343,000,000	12.4
1924	19,969,000,000	3.2
1925	22,356,000,000	12.0
1926	26,189,000,000	17.1
1927	29,875,000,000	14.0
1928	34,696,000,000	16.1

Average of 8 years about 10 per cent.

Publication No. 289-124, Serial Report, Water Power Development Committee.

The following gives an idea of how the power and energy for 1928 is distributed between the hydro and steam sources of supply:

	Capacity (Average of year) Kw.	Output Kw-hr.	Average Kw.	Capacity Factor
Hydro ..	7,658,000	34,696,000,000	3,960,616	51.7
Steam ..	20,852,000	53,154,000,000	6,067,808	29.1

In the operation of systems including both water power and steam stations, as a general rule, the water power stations are favored and, therefore, operate under higher capacity factors.

Economics of Power Use

There is a wide difference in the cost of producing hydro-electric power in different plants. The principal variable factors in hydro-electric power costs are size of the development, continuity and dependability of water supply and physical features affecting location of the plant. The plants at Niagara Falls and those proposed on the St. Lawrence and Colorado Rivers involving many thousands of kilowatts may be capable of producing energy and delivering it to the station bus bars at an overall cost of from 2 to 4 mills per kw-hr., but the greater number of water power plants scattered over the country develop energy at cost of two or three times this amount. We may safely say that the greater part of the hydro energy generated in the United States costs between 5 and 10 mills per kw-hr. at the generating station bus bars.

The principal variable factors in steam-electric power costs are size of plant, cost of coal and cost of condensing water. The largest and most favorably located steam electric plants operating under high load and plant factor conditions may produce energy at an overall cost as low as 4 mills per kw-hr. but the greater number of steam plants develop energy at a cost of 6 to 10 mills per kw-hr. at the station bus bars. Load factors affect costs in both classes of stations.

We may roughly class all electric energy in two categories, namely (1) low-cost hydro energy from favorably located plants and (2) all other energy, whether generated by water or steam power. The question has been raised as to who shall get the benefit of the low-cost energy. Three solutions have been proposed: 1st, to let the producer sell it for what he can get for it; 2nd, to let the government tax it to bring the cost up to that of steam-produced energy, and 3rd, to let the consumer get the benefit of it.

Experience has shown that the first of these alternatives, namely, to let the producer sell it for what he can get, automatically gives a low price aside from any public regulatory agencies to which the producer may be subject. Such hydro developments are always very large and must be developed, for the most part, all at one time. The result is a large amount of power for which a market must be found at the earliest practicable date, within a definite small radius. Such power has always been sold at a low price and a low margin of profit. Companies exploiting such power developments have generally not fared so well as those developing the higher cost steam power which can be produced by extending the plants at rates just sufficient to take care of the demand.

The second suggestion, that the government shall tax the output for the benefit of all the people until neither the producer nor consumer gets benefit from it, cannot be justified from any point of view, although it is favored by certain legislators and others who ignore the fact that such tax operates to deprive the public of the principal benefit that can come from low cost water power. Such a tax on power at its source is a direct burden on industry and an indirect burden on the consumer of the products of industry. It is, in effect, a tariff to equalize costs and would serve to deprive certain portions of the public of the natural advantages of their location. It would be as logical, and as fair, to use a similar expedient to equalize the cost of fuel, natural gas or coal or oil, as between communities. There are certain fundamental industries that cannot exist without this low-cost energy, and which have been built up on the basis of cost of energy much below that of steam-produced energy. This second proposal would destroy them.

The third alternative, that the consumer should get the benefit of low-cost power, will scarcely be questioned by anyone who looks at the matter from the point of view of the greatest good to the greatest number. This brings up the question as to how the benefits can best be apportioned to the "consumer." In this country it has been the general practice to base rates to all consumers on the cost of service. As opposed to this practice there are some people who advocate a policy of favoring the domestic consumer by making domestic rates very low at the expense of commercial and industrial users.

The advantage of the practice of distributing the benefits of low-cost hydro energy equitably to all consumers is that it gives industrial rates sufficiently low to make it possible for large industries to be built up, producing abrasives, metal alloys, aluminum, bleaching materials, etc., at much lower cost than they can otherwise be produced. This is passed along to the ultimate consumer everywhere when he purchases automobiles, kitchen utensils, cutlery, soap, newspapers, tools, etc., etc. Furthermore, this low-cost energy is fundamental to the growth and expansion of that class of basic industry. A saving of a few dollars a year to the individual householder in cost of energy for domestic use through subsidizing that service at the expense of industrial users is not to be compared with the advantages of steady employment, regular wages and the consequent higher standard of living.

In Canada we have two fairly large examples of different ways of using cheap water power. For about fifteen years Ontario Province has been operating to favor the domestic consumer at the expense of the commercial and industrial user, whereas for about five or six years Quebec Province has followed a policy of using its cheap water powers to stimulate industrial growth. While the Quebec policy has not been in existence long enough to obtain full effect, it was thought that a comparison of the growth of industry in Quebec and Ontario might give some indication of the results obtained under the different policies. Mr. W. M. Carpenter, Research Statistician of the National Electric Light Association, has compiled the following table from data furnished by the Bureau of Statistics, Ottawa, Canada. The table shows results which are certainly worth consideration by statesmen, financiers and economists in this country.

COMPARISON OF GROWTH OF POWER AND BUSINESS IN ONTARIO AND QUEBEC

Percentage Increases, 1925 to 1927

	Quebec	Ontario
	Per cent	Per cent
Population	3.3	2.7
Electric Power		
Main primary h.p.	23.9	6.0
Capital invested	31.7	10.3
Kilowatt-hours generated	61.3	28.2
Manufacture		
Capital invested	21.2	10.8
Employees	16.6	11.9
Salaries and wages	20.1	15.6
Value added by manufacture	26.5	17.2
"Value added," per capita	22.5	14.1
"Value added," per employee	8.5	4.8
Business and Wealth		
Bank debits to individual accounts	49.2	30.3
Building permits in cities	65.8	33.4

RÉSUMÉ OF WORK OF THE WATER POWER DEVELOPMENT COMMITTEE OF THE N. E. L. A.

For several years the National Electric Light Association has had a Water Power Development Committee. The reports of this committee, usually annual, constitute a very instructive current history of the development of water power in this country. They give much valuable data respecting the potential and developed water powers of the country, and discuss comprehensively the many problems, physical, economical and political, which have affected water power development.

Without doubt, the work of this committee has had a constructive influence on water power development.

The following summary of the reports describes briefly the epochs through which water power development has passed.

Prior to 1901

Up to the Roosevelt administration in 1901, water-power development was controlled principally by economic factors. The use of electricity was rather limited and long-distance transmission of power had just been begun, the amount of water power developed was less than 2,000,000 h.p., and most of it was on the smaller streams not under Federal control, and was not used for producing electricity. The acts of May 18, 1896, and March 3, 1899, both bearing on the protection of navigation, made it necessary for proponents of power developments on navigable streams to obtain consent of Congress and approval of plans by the Secretary of War and the Chief of Engineers.

The acts of May 14, 1896, and Feb. 15, 1901, authorized the Secretary of Interior to grant revocable permits for power projects on public lands, and the act of Feb. 1, 1905, authorized the Secretary of Agriculture to grant them on forest reserve lands.

Projects not on navigable streams or public lands or in forest reserves were developed under State laws.

1901 to 1920

During the Roosevelt administration the doctrine of conservation came into prominence, and greatly exaggerated values were claimed for water power resources. All public lands that might be used for water power development were withdrawn from entry. The General Dam Act of 1906 was enacted to control developments on navigable streams, and this was followed by the General Dam Act of June 23, 1910. Specific authorization by Congress was still required for each project on a navigable stream. Neither of the General Dam Acts satisfied the views of the more ardent conservationists who originated them, and on account of their opposition very few projects were able to secure congressional authority. By 1920 the total water power developed in the United States amounted to about 7,750,000 h.p., of which about 2,000,000 was under Federal jurisdiction and 5,750,000 h.p. under State jurisdiction.

Of the 2,000,000 h.p. under Federal jurisdiction, practically all, except the Niagara Falls projects, the Keokuk project on the Mississippi River and the Hales Bar project on the Tennessee River, was developed on western streams under the acts of 1891 and 1905, which did not require special authorization of Congress for each project. This was a period of rapid growth in the use of electricity, and long-distance transmission of power became practicable, making it possible to develop more or less remote water powers and sell the output in distant markets.

1920 to Date

On June 20, 1920, the Federal Water Power Act was enacted after ten years struggle in Congress to procure legislation that would define Federal policy with respect to water power in a way more satisfactory to the various schools of thought than the General Dam Act of 1910 or the legislation affecting public and forest reserve lands. The Federal Water Power Act established a commission consisting of the Secretary of War, the Secretary of Interior and the Secretary of Agriculture. This commission was authorized to issue licenses for water power developments on all streams under Federal jurisdiction on public lands and in the forest reserves on terms intended to fully protect the public interest.

High fuel prices and transportation difficulties resulting from the war, together with the accumulation of many practicable water-power developments which had been waiting to procure Federal authority, caused great activity to follow the passage of the Federal Water Power Act.

At the end of 1928 water-power development in the United States had increased to about 13,571,530 h.p., 5,821,530 h.p. more than in 1920. Of the total power installed, about 4,507,000 h.p. was under Federal jurisdiction.

The Water Power Development Committee cooperated with the Federal Power Commission in drafting regulations under the act and in trying to make it effective, and for a time it appeared that the various schools of thought on water power would be satisfied, but for the past three years there have been efforts by some interests to obtain special legislation that would exempt certain projects from the jurisdiction of the Federal Power Commission.

The reports of the Water Power Development Committee indicate reasons for this condition, which are worth attention.

The report of 1926 states:

"There are pending in Congress various bills affecting the Colorado, Tennessee and other rivers. For the most part these bills seek to obtain special legislation. On the Tennessee and on the Colorado various kinds of publicly owned projects are proposed, and in connection therewith it is sought to suspend the jurisdiction and authority of the Federal Power Commission over these streams. On the Colorado it is proposed to suspend the jurisdiction of the Commission until 1929, and on the Tennessee until 'Congress has taken final action for the control, operation or disposition of Dam No. 2 at Muscle Shoals.' No one can forecast when Congress will take final action on Muscle Shoals, although in March it took a long step toward clearing up the whole problem by voting to negotiate private leases for this famous project for a period of fifty years. Leases were under negotiation by a special committee of Congress when this report was written.

"It is a matter of regret that Congress has been asked to exempt these rivers from the provisions of the Federal Water Power Act. The act was designed to establish a uniform policy to govern the development and utilization of water power throughout the country. It has been so accepted by the industry and the public alike, and its essential soundness is attested by the extensive developments undertaken and projected under its terms. The act should be consistently applied to all streams, large or small, in all sections of the country. Exemption of certain projects from its provisions and from the jurisdiction of the Federal Power Commission must of necessity weaken and impair it. If such exemptions are continued they will ultimately destroy the act.

"Secretary of Commerce Hoover has very clearly recognized this in a recent discussion of the Colorado River problem, in which he stated: 'It seems to me that we should not depart from the national policy established by the Water Power Act. The handling of power (on the Colorado) should be placed in the hands of the Federal Power Commission to give licenses for the use of the water for power purposes under the Water Power Act without imposing a new system of allocation.'

"Special water power legislation for individual streams has its only excuse in political or local expediency, and is a return to the conditions which the people and Congress sought to end by the Federal Water Power Act. It is earnestly to be hoped that Congress will follow Mr. Hoover's view and neither on the Colorado nor elsewhere depart from the national policy which the Federal Water Power Act established and which has now been tested by six years of experience and achievement."

The report of 1927 states:

"Water powers nearest the available markets have now largely been developed and put into service. So, too, have the more distant water powers requiring the lowest investment. Utilization of resources not yet developed must necessarily be expected in some cases to entail higher investment costs, longer and more expensive transmission lines, and higher prices for lands and rights of way. A good proportion of the best hydro developments have already been made.

Water Power Versus Steam

"Contrasted with this, there is a downward trend in the cost of energy produced by steam. Notable improvements in plant design have been effected during recent years that have resulted in marked improvement in efficiency and a substantial reduction in the cost of producing energy. While water power will never cease to be a great national asset, the achievements in steam production have created a noticeable tendency to postpone the development of power by water. Indeed, there are already instances where water powers, selected for development two or three years ago, have been deferred for the present and steam plants installed instead. There are other instances where steam in recent months has been brought in to supplement water power to a degree that a few years ago would have been regarded as unnecessary.

"On most of the great streams of the country the development of water power is completely held up pending the enactment of necessary legislation that, in turn, has become involved in the meshes of politics. But industry declines to wait, and engineers, fighting to bring down costs, have improved the development of power by steam to the point where more than one large water power project has lost its place in the sun, and projects that were considered attractive five years ago no longer appeal to capital. Economic and natural laws are inexorable, and neither the romance of 'white coal' nor popular interest in natural resources can make capital develop a water power where an equivalent amount of energy can be produced from steam for less money."

The report of 1928 gives the following table indicating how much of the total water power of the United States was developed at that time, how much was probably economically feasible of development and how much was not then feasible:

	Horsepower	Per cent
1. Total water power in U. S. available 50% of time.............	55,000,000	100
2. Total developed water power, January, 1928	8,800,000	16
3. Development probable in next 10 to 15 years	5,900,000	10.7
4. Development probably feasible if political controversies be adjusted	11,000,000	20
5. Probably not now economically feasible	29,300,000	53.3

NOTE: A discrepancy will be noted between the figures in the above table and those previously given for developed water power. The figures previously given represent the installed capacity, while those in the table represent the power available 50 per cent of the time.

The report then continues:

"Until developed, water power produces nothing; when developed it continues to produce indefinitely, not being depleted by use, as are most other resources. The importance of developing the water powers that are feasible of development needs no argument. In fact, for the past twenty years the importance and value of water power resources have been so extravagantly urged upon the public by conservation enthusiasts, government operation advocates and others that no sane and reasonable policy of dealing with the development of water power has been able to exist for long. In June, 1920, after twelve years' discussion in Congress, the Federal Water Power Act was made a law and established policies for dealing with water powers under Federal jurisdiction. While not completely satisfactory to anybody, the act was workable, and great activity in water power development followed its passage. Eight years of operation have demonstrated that, whatever else may be said of the act, it certainly is adequate to protect the public interest under all conditions. In spite of this fact, it has been subject to attacks which have increased each year until it has become, temporarily at least, inoperative with respect to many of the larger and more feasible power prospects."

No subject before the country has had so much misinformation published about it as water power. The reports of the Water Power Development Committee stand out for their accuracy and soundness and are worthy of nation-wide study.

Water Power Policy

In October, 1928, the United States Chamber of Commerce appointed a "National Water Power Policies Committee" consisting of the following members:

Frederic A. Delano, *Chairman,* Washington, D. C.
Thomas S. Baker, *President,* Carnegie Institute of Technology, Pittsburgh, Pa.
Arthur S. Bent, *President,* Bent Brothers, Inc., Los Angeles, Cal.
Frank P. Glass, *Editor,* Montgomery *Advertiser,* Montgomery, Ala.
Lafayette Hanchett, *President,* Utah Power & Light Company, Salt Lake City, Utah.
David C. Henny, *Consulting Engineer,* Portland, Ore.
Horace W. King, *Professor Hydraulic Engineering,* U. of Mich., Ann Arbor, Mich.
Alexander Legge, *President,* International Harvester Company, Chicago, Ill.
Charles H. MacDowell, *President,* Armour Fertilizer Works, Chicago, Ill.
Frank I. Mann, Bois d'Arc Farm, Gilman, Ill.
Harold G. Moulton, *President,* Brookings Institution, Washington, D. C.
R. E. Norton, *Vice-President,* C. H. Geist Securities Corporation, Philadelphia, Pa.
Warren Olney, Jr., *Attorney,* San Francisco, Cal.
Lewis B. Stillwell, *Consulting Engineer,* New York, N. Y.
Harry Taylor, *Maj. Gen., Ex-Chief of Engineers, U. S. A.,* Washington, D. C.

The purpose of the committee is set forth in the following language in the letter of invitation to serve on the committee:

"The importance to the public welfare of proper development of the country's resources in water powers has long been recognized by the United States Chamber of Commerce. The Chamber earlier had a representative committee which considered the situation as it existed before the Federal Water Power Act, and made recommendations as to Federal policies, which were supported by our membership in referendum vote, and which proved very similar to most of the features subsequently incorporated in the Federal Water Power Act.

"In the opinion of our Board of Directors the time has come for the Chamber to have a committee to consider the present situation as to water powers and their development and to submit a report with recommendations respecting the policies which should now be followed, in the light of experience and events since 1920. In accordance with the Chamber's procedure, the whole subject will be placed before this committee, without suggestions or commitments of any kind. The purpose is to obtain the independent judgment of a representative committee. The committee will consequently be entirely free to decide for itself both the features of the water power situation which it will select for special treatment in its report and the recommendations of public policy which it will make. We desire the committee to have this independence of judgment not only as to the general subject before it, but also in regard to special problems, such as have arisen with respect to the development at Muscle Shoals."

It is understood that the United States Chamber Committee is planning to make its report in the fall of 1929. Obviously, the power industry should cooperate with the Chamber Committee by furnishing any data that the committee may desire.

On March 25, 1929, the report of the Joint Water Power Committee of the Senate and House of Representatives of the Sixty-sixth General Assembly of the State of Tennessee was submitted.

This report is well worth study. It gives a clear and unbiased analysis of the water power situation and recommends a policy for the State of Tennessee.

The following concluding paragraphs of the report are worth quoting:

"We doubt whether most of us appreciate the difficulties and expense in the development of water power in this basin. There is an impression that if power can be developed from water it costs nothing. Let us consider the Tennessee. At times she rages in flood with an immense volume of water. At other times there is less than a foot of water in the channel. The fall of the river is gradual, only a few feet comparatively all the way from Knoxville to the Ohio. It is difficult to provide storage in this section of the river because the banks are low and because of the immense amount of land which would be flooded by high dams. Then for nearly every hydro-electrical development we would have to have also a steam plant, a duplication in capital expenditure. Homes and factories don't want electricity merely when there happens to be plenty of water in the river. You couldn't get by with that kind of service. They expect to have it whenever the switch is turned. Also, generally, a hydro-electric development costs vastly more than a steam power plant of the same capacity because there are the flood lands to be acquired, the dams to be built, the generating machinery to be provided, etc. It is better, in our judgment, however, from the standpoint of the State, for the water power to be utilized. We save the coal. We have a much bigger investment to be taxed and the water power man has the urge to bring in industries to use his power. If he has a steam plant, when the demand for power goes off, when the factories close for the day, he doesn't burn any more coal. But if he has a hydro plant the power which is not sold is wasted. Therefore, he searches the country over to bring in industries to use his product. He makes a very low rate for power which may be developed at night and for which there is no other demand, and brings in certain kinds of industries which demand cheap power and which can afford to run at night. And then, insofar as the developments reduce the hazard from flood and promote navigation, they also benefit the public.

"We are certain that the great preponderance of the sentiment of the people of our State favors the earliest possible development of our rivers for purposes of flood control, navigation and power, and also that it favors the development of power by a public utility so that distribution to serve our citizens everywhere as far as possible may be insured. We are convinced that the great preponderance of the sentiment favors development and distribution by private capital, subject to the sovereign control of the State, providing a fair incentive and a reasonable return, and power to our people at the lowest reasonable cost. And we are convinced that there is no reason why these developments should not be carried forward at the earliest possible date, knowing as we do that the sovereign power of the State and of its people is ample to protect against any attempted exploitation."

The views of the power industry with respect to a national policy on water power may be deduced from the reports of the Water Power Development Committee of the National Electric Light Association.

Since the matter is now under active consideration, it seems pertinent to summarize those views in concluding this report.

The outstanding principles are:

1. Whenever the market will justify and the cost will not exceed that of steam or other development, water power resources should be developed to the fullest practicable extent and in the shortest possible time.
2. The greatest benefit from the large water-power developments of the country, such as the St. Lawrence, Tennessee, Columbia, etc., will be the growth and general prosperity of the adjacent territory which will be due to the industrial growth that naturally follows these developments.
3. In general, the greatest utilization can be secured for water-power developments when they are part of large central station systems. This is specially true if there are other uses of the water, such as irrigation, navigation and flood control, all of which result in variable rates of output whose inequalities can usually be tolerated in or absorbed by a large interconnected system of steam and water power plants.
4. Special charges or taxes assessed against water power development by Federal or State governments limit the extent to which water power can be used to foster industrial development; consequently such charges should not be imposed.
5. Regulation by public agency should be provided (as it now is in practically every State) to secure proper service at fair rates to all consumers.
6. The Federal Water Power Act in its present form can be administered so as to promote the development of all water power for which a market exists, and it provides ample safeguards for the public interest. Water powers for which no market exists should be withheld from development until economic conditions warrant bringing them into use.
7. The tendency to exempt from the jurisdiction of the Federal Water Power Commission any projects over which the Federal Government has jurisdiction is unsound and leads to undesirable delay and inefficiency in the development of feasible water powers.

REPORTS OF
GENERAL NATIONAL COMMITTEES 1928-1929

(For Personnel of Committees, See Appendix 4)

Civic Development Committee

JOHN B REYNOLDS, *Chairman*

Serial Report (Publication Delayed)

Educational Committee

FRED R JENKINS, *Chairman*

Serial Report, Publication No. 289-122 (see p. 208)

Insurance Committee

W H SAWYER, *Chairman*

No Serial Report

Membership Committee

HOWARD K MOHR, *Chairman*

Annual Report (see p. 274)

Rural Electric Service Committee

CHARLES F STUART, *Chairman*

SERIAL REPORTS

PUB. NO.	
289-12	Developing Electric Service for the Farm—As Exemplified by the Organization and Methods of the Wisconsin Power & Light Co. (see p. 225).
289-65	Developing Electric Service for the Farm—As Exemplified by the Organization and Methods of Alabama Power Co. (see p. 240).
289-61	Building the Load on the Farm (see p. 255).

REPORT OF EDUCATIONAL COMMITTEE

Permanent and lasting results of employee education can only be obtained by carrying out a carefully defined plan which includes liberal cooperation of the company. The best results are obtained where such a plan is recommended by a representative committee and receives executive approval.

The operation of such a plan to be successful must be placed in charge of some one as educational director, either as his full time job or as a part-time job depending upon the size of the company, to see that proper publicity within the company is given to all approved courses, and to cooperate with departments and employees in the organization of groups or classes, and to advise in individual cases.

The committee continues to believe that our relations with our customers and the public depend to a very large degree upon the education and training of the employees to the end that they may conduct the company business in an efficient, courteous and businesslike manner.

The results of the work of the Educational Committee during the last Association year ending June 30, have exceeded that of any previous year. A total of 3379 of the various courses now offered by the committee were distributed, as against 2197 for the previous year, an increase of 54 per cent. This increase is largely due to the new Meter Courses conducted for the Engineering National Section. We believe, however, that there would be a very much larger distribution if all member companies were familiar with the advantages of using these courses, and would formulate some definite plan of employee education as already adopted by a large number of member companies.

The following is a list of member companies who have sent in fifty or more subscriptions during the year ending June 30:

Public Service Electric & Gas Co., Newark, N. J.	343
Jersey Central Power & Light Co., Asbury Park, N. J.	189
Gulf States Utilities Co., Beaumont, Tex.	164
Consumers Power Co., Jackson, Mich.	128
West Penn Power Co., Pittsburgh, Pa.	81
Lawrence Gas & Electric Co., Lawrence, Mass.	77
Associated Gas & Electric Co., Ithaca, N. Y.	77
Blackstone Valley Gas & Electric Co., Pawtucket, R. I.	73
Public Service Company of Colorado, Denver, Colo.	65
Monongahela West Penn Public Service Co., Fairmont, W. Va.	58
New York & Queens Electric Light & Power Co., Flushing, N. Y.	54

The committee particularly wishes to acknowledge the interest and cooperation of the Engineering National Section Meter Committee in the preparation and promotion of the Meter Courses, and of the Accounting National Section in the preparation and promotion of the Advanced Accounting Course.

Educational Conference

To stimulate interest in educational work the chairman of the Southwestern Geographic Division called an educational conference last January in Dallas immediately following the meeting of the Executive Committee of that division. This conference was attended by many executives and educational representatives of the companies, as well as others interested. It was the pioneer conference on education, and both educational and executive representatives stated they learned more about employee education there than they thought was possible. This is to be an annual meeting, and will prove a real stimulus to the work.

The program of this conference, which continued for the greater part of one day, included a presentation of the Educational Courses of the association by the chairman, addresses by educational directors, addresses by executives, and a general discussion of educational methods and results within the companies represented at the meeting.

It is recommended that the chairmen of all Geographic Divisions conduct an educational conference following an Executive Committee meeting along the same lines as the Dallas conference.

The increased use of the Educational Courses is largely due to the work and experience of the Geographic Division representatives, many of whom have given their services to this committee for several years.

On the following pages will be found a brief description and outline of the courses offered by this committee, together with a sample page from each of the various courses.

Pub. No. 289-122 Serial Report Educational Committee.

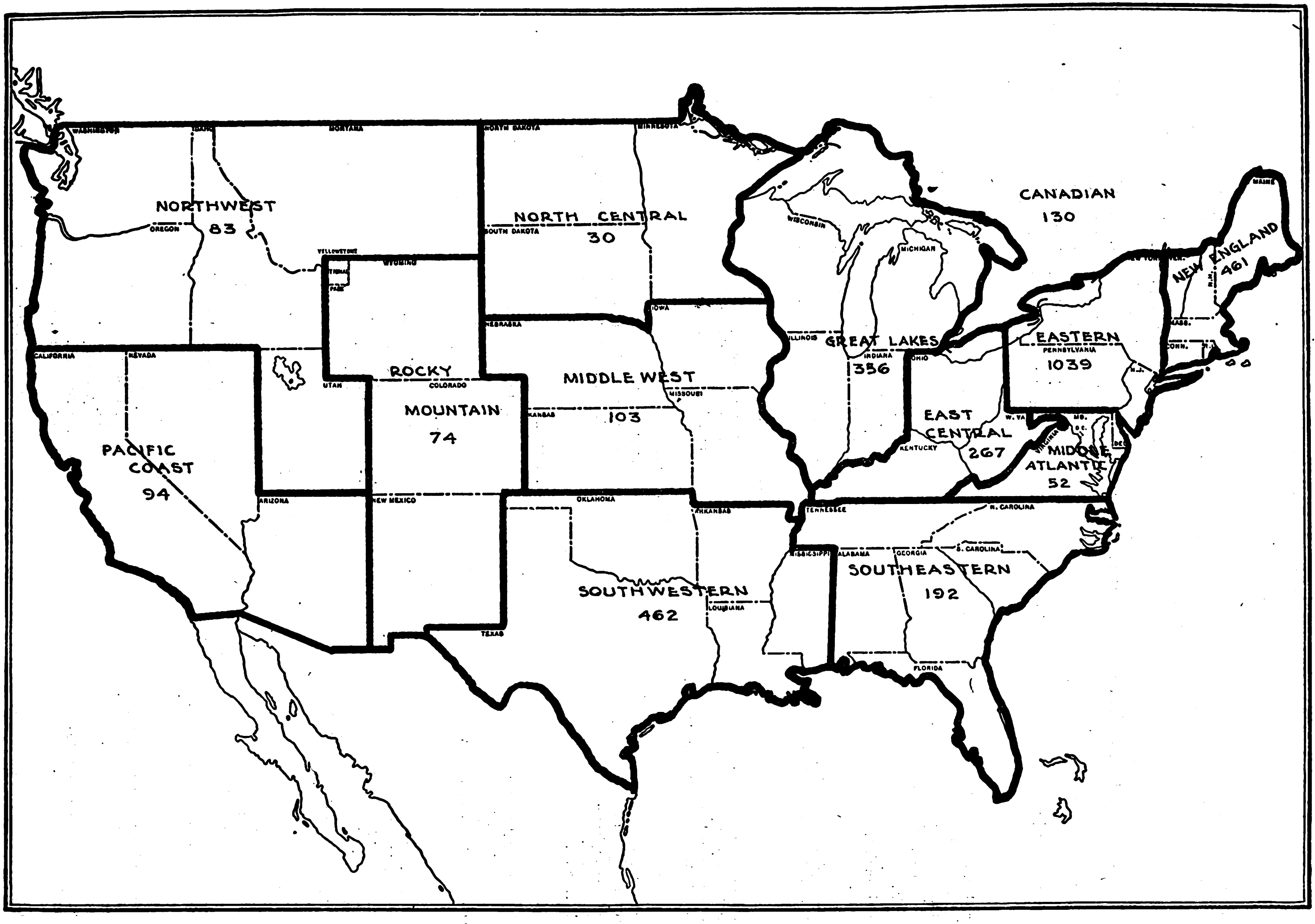

CANADIAN
130
NEW ENGLAND
461
MAINE
N.H.
MASS.
CONN.
R.I.
NEW YORK
EASTERN
PENNSYLVANIA
1039
N.J.
DEL.
MD.
D.C.
MIDDLE ATLANTIC
52
VIRGINIA
W. VA.
EAST CENTRAL
267
OHIO
KENTUCKY
GREAT LAKES
356
INDIANA
ILLINOIS
MICHIGAN
WISCONSIN
MINNESOTA
NORTH CENTRAL
30
NORTH DAKOTA
SOUTH DAKOTA
NORTHWEST
83
WASHINGTON
IDAHO
MONTANA
OREGON
YELLOWSTONE
ROCKY MOUNTAIN
74
WYOMING
COLORADO
UTAH
MIDDLE WEST
103
IOWA
NEBRASKA
MISSOURI
KANSAS
PACIFIC COAST
94
CALIFORNIA
NEVADA
ARIZONA
NEW MEXICO
OKLAHOMA
ARKANSAS
TEXAS
LOUISIANA
SOUTHWESTERN
462
TENNESSEE
N. CAROLINA
S. CAROLINA
GEORGIA
ALABAMA
MISSISSIPPI
FLORIDA
SOUTHEASTERN
192

FIG. A-1—DISTRIBUTION OF COURSES BY GEOGRAPHIC DIVISIONS FOR YEAR ENDING JUNE 30, 1929.

ELEMENTARY COURSE IN BOOKKEEPING AND ACCOUNTING

Published for the Accounting National Section

The purpose of this elementary course, which consists of seven lessons, is to teach the principles of accounting as applied in accounts, books of account, and business forms; also to familiarize the student in the recording of transactions from business forms, and the method of arriving at a final conclusion as set forth in the balance sheet and the profit and loss statement.

A trading business is represented in all these lessons because the fundamental principles are more easily set forth in this line than in production. While these principles are the same yet the presentation is more complicated in a business engaged in manufacture or production.

It is necessary that the student understand and appreciate the importance of these elementary lessons and a knowledge of the fundamentals of bookkeeping before subscribing to the Advanced Course in Electric Utility Accounting.

First Lesson

Introduction—Bookkeeping.
Why Study Bookkeeping?
Method of Earning Income.
Bookkeeping Terms.
Assets.
Liabilities.
Proprietorship.
Income.
Cost.
Fundamental Equations.
Transactions and Their Connection with Bookkeeping.
Purpose of Bookkeeping.
The Account—a Bookkeeping Device.
The Ledger—A Group of Accounts.
Accounts Needed for Recording Cash Sales and Purchases.
Cash Account.
Method of Proving Cash.
Purchases Account.
Sales Account.
Method of Recording Transactions.
The Trial Balance, a Bookkeeper's Device.

Second Lesson

Accounts with Persons.
Accounts with Customers.
Accounts with Creditors.
Accounts with Operating Expenses.
Expense Account.
Accounts with the Proprietor.
Capital Accounts.

Third Lesson

Short-cut Method.
Purchases Record.
Purchases Journal.
Sales Journal.
Cash Record.
Cash Book.
The General Journal—Its Use.
Donald D. Sells, retail hardware merchant, practice set.
H. A. Popp, retail coal dealer, practice set.

Fourth Lesson

The Purchase Invoice.
The Sales Ticket.
The Sales Invoice.
Receipts, Issued and Received.
Reports to the Instructor.
Method of Proving Cash.
The Trial Balance.

Fifth Lesson

Fiscal Period.
Method of Ascertaining the Profit and Loss.
Merchandise Inventory.
The Balance Sheet.
Statement of Profit and Loss.
Relation Between the Balance Sheet and Statement of Profit and Loss.
Closing the Ledger.
Balancing and Account.
The Post-Closing Trial Balance.
Closing Process.
The Profit and Loss Account—A Supplementary Account.

Sixth Lesson

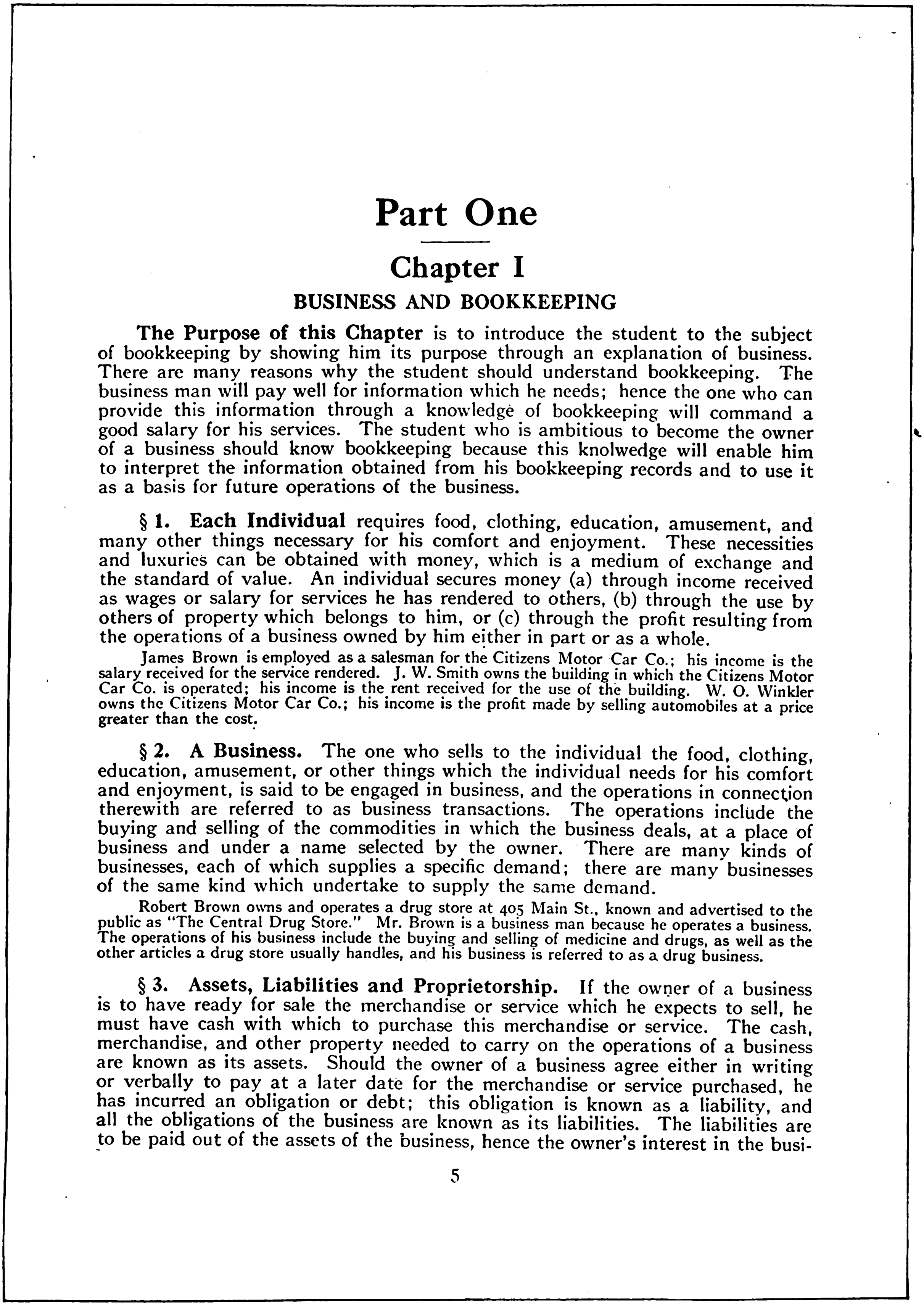
Vouchers in Connection with Purchases.
Vouchers in Connection with Sales.
Vouchers in Connection with Services.
Vouchers in Connection with Banking Transactions.
Reconciliation of Bank Account.
Vouchers Regarded as Cash.
Indorsement of Notes, Drafts or Checks.
The Promissory Note.
The Commercial Draft.

Seventh Lesson

Accounts with Fixed Assets.
Accounts with Notes and Drafts.
Notes Receivable Account.
Notes Payable Account.
Interest—The Use of Money.
Accounts with Interest.
Classification of Accounts.
Asset Accounts.
Liability Accounts.
Capital Account.
Income Account.
Cost or Expense Accounts.

Price for the full course of seven lessons including correspondence service and certificate is $16.00.

Descriptive folder giving full details and outline furnished upon application.



Part One

Chapter I

BUSINESS AND BOOKKEEPING

The Purpose of this Chapter is to introduce the student to the subject of bookkeeping by showing him its purpose through an explanation of business. There are many reasons why the student should understand bookkeeping. The business man will pay well for information which he needs; hence the one who can provide this information through a knowledge of bookkeeping will command a good salary for his services. The student who is ambitious to become the owner of a business should know bookkeeping because this knolwedge will enable him to interpret the information obtained from his bookkeeping records and to use it as a basis for future operations of the business.

§ 1. **Each Individual** requires food, clothing, education, amusement, and many other things necessary for his comfort and enjoyment. These necessities and luxuries can be obtained with money, which is a medium of exchange and the standard of value. An individual secures money (a) through income received as wages or salary for services he has rendered to others, (b) through the use by others of property which belongs to him, or (c) through the profit resulting from the operations of a business owned by him either in part or as a whole.

James Brown is employed as a salesman for the Citizens Motor Car Co.; his income is the salary received for the service rendered. J. W. Smith owns the building in which the Citizens Motor Car Co. is operated; his income is the rent received for the use of the building. W. O. Winkler owns the Citizens Motor Car Co.; his income is the profit made by selling automobiles at a price greater than the cost.

§ 2. **A Business.** The one who sells to the individual the food, clothing, education, amusement, or other things which the individual needs for his comfort and enjoyment, is said to be engaged in business, and the operations in connection therewith are referred to as business transactions. The operations include the buying and selling of the commodities in which the business deals, at a place of business and under a name selected by the owner. There are many kinds of businesses, each of which supplies a specific demand; there are many businesses of the same kind which undertake to supply the same demand.

Robert Brown owns and operates a drug store at 405 Main St., known and advertised to the public as "The Central Drug Store." Mr. Brown is a business man because he operates a business. The operations of his business include the buying and selling of medicine and drugs, as well as the other articles a drug store usually handles, and his business is referred to as a drug business.

§ 3. **Assets, Liabilities and Proprietorship.** If the owner of a business is to have ready for sale the merchandise or service which he expects to sell, he must have cash with which to purchase this merchandise or service. The cash, merchandise, and other property needed to carry on the operations of a business are known as its assets. Should the owner of a business agree either in writing or verbally to pay at a later date for the merchandise or service purchased, he has incurred an obligation or debt; this obligation is known as a liability, and all the obligations of the business are known as its liabilities. The liabilities are to be paid out of the assets of the business, hence the owner's interest in the busi-

5

FIG. 1—SAMPLE PAGE FROM LESSON 1 OF THE ELEMENTARY COURSE IN BOOKKEEPING AND ACCOUNTING.

ADVANCED COURSE IN ELECTRIC UTILITY ACCOUNTING

Published for the Accounting National Section

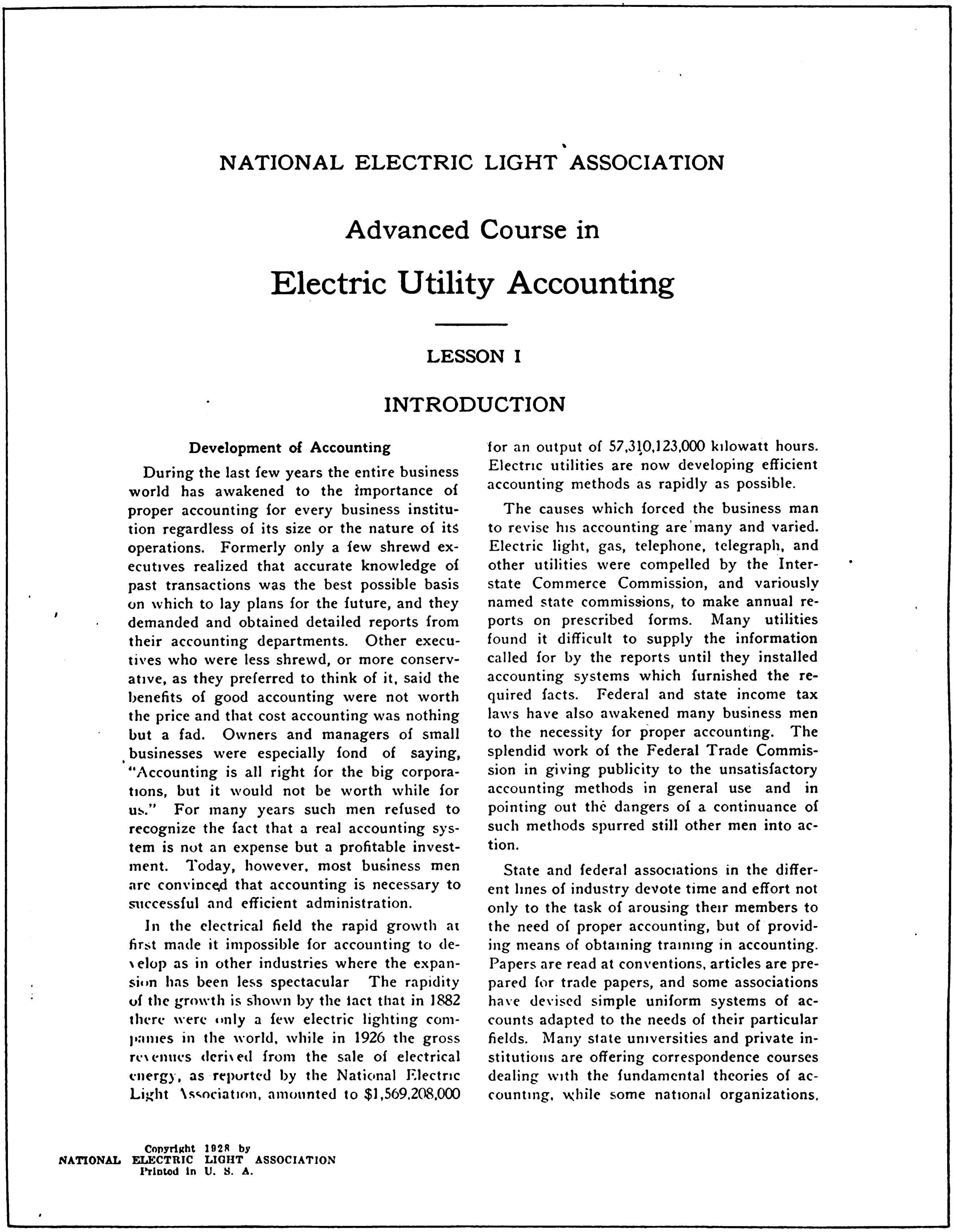
This course has just been through a complete revision by a special committee of the Accounting National Section. The demand for such a course has arisen because of the general nature of accounting instruction that is available for our industry. The necessity for instruction has been emphasized by reason of the rapid growth of our member companies, which causes a considerable demand for a suitably trained personnel. There is a continuous and persistent demand for information on accounting matters.

This revised edition is in conformity with the Association of Railways and Utility Commissioners' Uniform Classification of Accounts, which was approved by the association at the New York convention in 1923, and contains the best practices of our most progressive companies.

Lesson 1—Introduction
Lesson 2—The Uniform Classification of Accounts
Lesson 3—Accounts and Vouchers Payable
Lesson 4—The Corporate Form of Business Organization
Lesson 5—Corporate Books and Accounts
Lesson 6—Operating Expense Accounts
Lesson 7—Income Accounting
Lesson 8—Fixed Capital Accounting
Lesson 9—Bonds
Lesson 10—Financial Statements
Lesson 11—Payroll Accounting
Lesson 12—Stores Accounting
Lesson 13—Customers' Accounting
Lesson 14—Branch Office Accounting
Lesson 15—Applications and Reports to State Authorities.
Lesson 16—Corporate Combinations
Lesson 17—Holding Companies
Lesson 18—Insurance
Lesson 19—Sinking Funds and Reserves
Lesson 20—Budgets
Lesson 21—Accounting Efficiency
Lesson 22—Internal Check System
Lesson 23—Analysis of Accounting Reports
Lesson 24—Auditing—Part One
Lesson 25—Auditing—Part Two

Price for the full course of twenty-five lessons including correspondence service and certificate is $35.00.

Descriptive folder giving full details and outline furnished upon application.



NATIONAL ELECTRIC LIGHT ASSOCIATION

Advanced Course in Electric Utility Accounting

LESSON I

INTRODUCTION

Development of Accounting

During the last few years the entire business world has awakened to the importance of proper accounting for every business institution regardless of its size or the nature of its operations. Formerly only a few shrewd executives realized that accurate knowledge of past transactions was the best possible basis on which to lay plans for the future, and they demanded and obtained detailed reports from their accounting departments. Other executives who were less shrewd, or more conservative, as they preferred to think of it, said the benefits of good accounting were not worth the price and that cost accounting was nothing but a fad. Owners and managers of small businesses were especially fond of saying, "Accounting is all right for the big corporations, but it would not be worth while for us." For many years such men refused to recognize the fact that a real accounting system is not an expense but a profitable investment. Today, however, most business men are convinced that accounting is necessary to successful and efficient administration.

In the electrical field the rapid growth at first made it impossible for accounting to develop as in other industries where the expansion has been less spectacular The rapidity of the growth is shown by the fact that in 1882 there were only a few electric lighting companies in the world, while in 1926 the gross revenues derived from the sale of electrical energy, as reported by the National Electric Light Association, amounted to $1,569,208,000 for an output of 57,310,123,000 kilowatt hours. Electric utilities are now developing efficient accounting methods as rapidly as possible.

The causes which forced the business man to revise his accounting are many and varied. Electric light, gas, telephone, telegraph, and other utilities were compelled by the Interstate Commerce Commission, and variously named state commissions, to make annual reports on prescribed forms. Many utilities found it difficult to supply the information called for by the reports until they installed accounting systems which furnished the required facts. Federal and state income tax laws have also awakened many business men to the necessity for proper accounting. The splendid work of the Federal Trade Commission in giving publicity to the unsatisfactory accounting methods in general use and in pointing out the dangers of a continuance of such methods spurred still other men into action.

State and federal associations in the different lines of industry devote time and effort not only to the task of arousing their members to the need of proper accounting, but of providing means of obtaining training in accounting. Papers are read at conventions, articles are prepared for trade papers, and some associations have devised simple uniform systems of accounts adapted to the needs of their particular fields. Many state universities and private institutions are offering correspondence courses dealing with the fundamental theories of accounting, while some national organizations,

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FIG. 2—SAMPLE PAGE FROM LESSON 1 OF THE ADVANCED COURSE IN ELECTRIC UTILITY ACCOUNTING.

COURSE IN PRACTICAL ELECTRICITY

Published for the Commercial National Section

This course has undergone a thorough revision during this summer, and has been brought up to date in every respect.

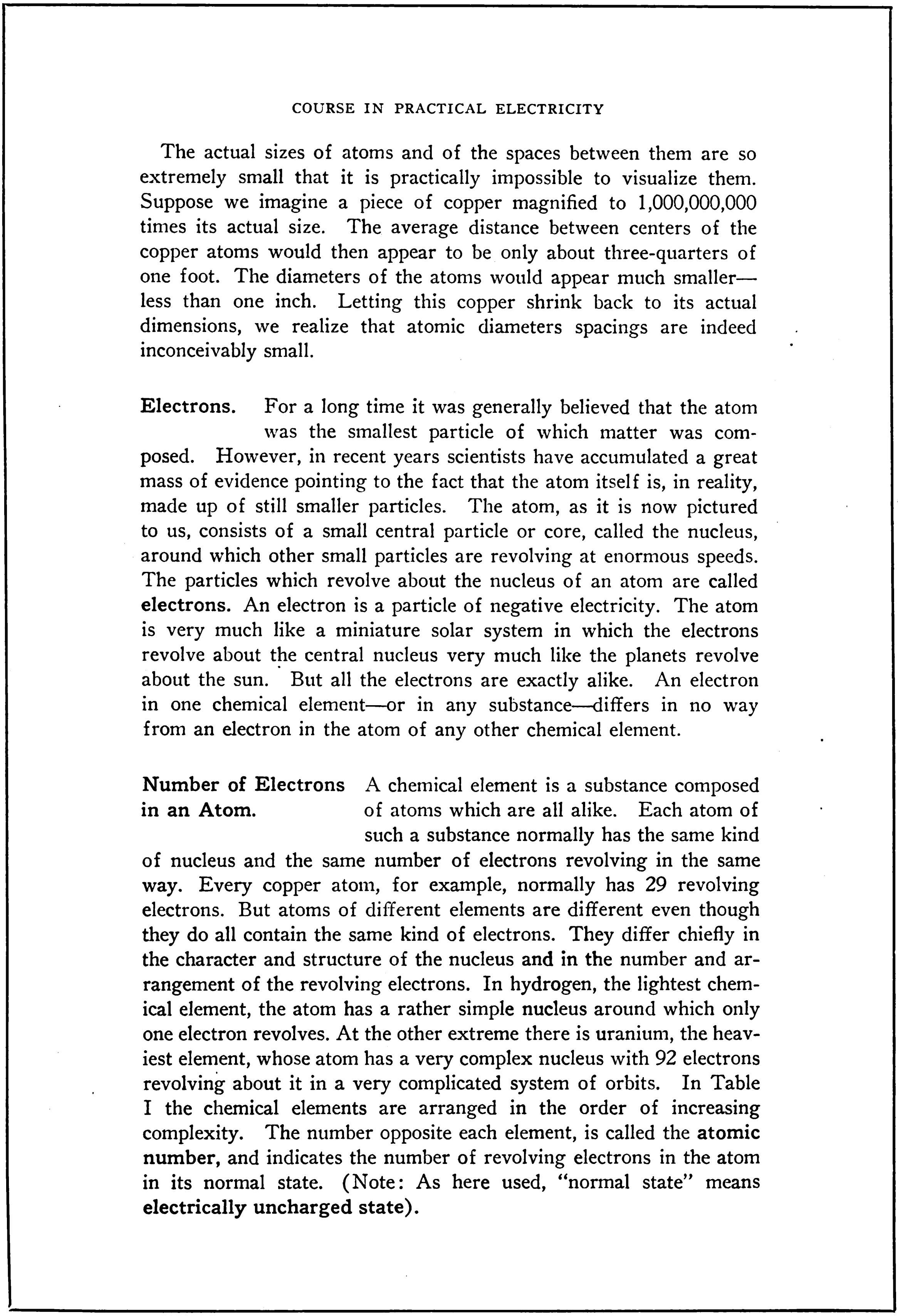
A knowledge of the fundamental principles of magnetism and electricity and an understanding of the principles of the operation of electrical apparatus is absolutely necessary for the employee who succeeds in almost any branch of the Central Station business.

This Course in Practical Electricity has been especially prepared for electric utility employees. It is written in good plain English without higher mathematics and without unnecessary technical expressions, and is specially adapted for employees in any branch of our business requiring a general knowledge, enabling them to intelligently perform their duties.

Lesson 1—Fundamental Principles of Electric Circuits
Lesson 2—Magnetic Effects of Electric Circuits
Lesson 3—Batteries and Electro-Chemistry
Lesson 4—Electrical Generators—A. C. and D. C.
Lesson 5—Alternating-Current Circuits
Lesson 6—Transformers and Regulators
Lesson 7—Motors—A. C. and D. C.
Lesson 8—Measuring Instruments
Lesson 9—Rectifiers, Lightning Arresters
Lesson 10—Lighting and Heating
Lesson 11—Central Station Systems

Price for the full course of eleven lessons including correspondence service and certificate is $12.00.

Descriptive folder giving full details and outline furnished upon application.



COURSE IN PRACTICAL ELECTRICITY

The actual sizes of atoms and of the spaces between them are so extremely small that it is practically impossible to visualize them. Suppose we imagine a piece of copper magnified to 1,000,000,000 times its actual size. The average distance between centers of the copper atoms would then appear to be only about three-quarters of one foot. The diameters of the atoms would appear much smaller—less than one inch. Letting this copper shrink back to its actual dimensions, we realize that atomic diameters spacings are indeed inconceivably small.

Electrons. For a long time it was generally believed that the atom was the smallest particle of which matter was composed. However, in recent years scientists have accumulated a great mass of evidence pointing to the fact that the atom itself is, in reality, made up of still smaller particles. The atom, as it is now pictured to us, consists of a small central particle or core, called the nucleus, around which other small particles are revolving at enormous speeds. The particles which revolve about the nucleus of an atom are called **electrons.** An electron is a particle of negative electricity. The atom is very much like a miniature solar system in which the electrons revolve about the central nucleus very much like the planets revolve about the sun. But all the electrons are exactly alike. An electron in one chemical element—or in any substance—differs in no way from an electron in the atom of any other chemical element.

Number of Electrons in an Atom. A chemical element is a substance composed of atoms which are all alike. Each atom of such a substance normally has the same kind of nucleus and the same number of electrons revolving in the same way. Every copper atom, for example, normally has 29 revolving electrons. But atoms of different elements are different even though they do all contain the same kind of electrons. They differ chiefly in the character and structure of the nucleus and in the number and arrangement of the revolving electrons. In hydrogen, the lightest chemical element, the atom has a rather simple nucleus around which only one electron revolves. At the other extreme there is uranium, the heaviest element, whose atom has a very complex nucleus with 92 electrons revolving about it in a very complicated system of orbits. In Table I the chemical elements are arranged in the order of increasing complexity. The number opposite each element, is called the **atomic number,** and indicates the number of revolving electrons in the atom in its normal state. (Note: As here used, "normal state" means **electrically uncharged state**).

FIG. 3—SAMPLE PAGE FROM LESSON 1 OF THE COURSE IN PRACTICAL ELECTRICITY.

ELECTRICAL METERMEN'S COURSES

Published for the Engineering National Section

The Electrical Metermen's Courses as offered by the Educational Committee were prepared in cooperation with the Meter Committee of the Engineering National Section, recognizing the demand of many years' standing for an elementary course in direct-current watthour metering and single-phase alternating-current metering.

This course is prepared in three parts. Part 1 applies to both the D. C. and A. C. courses, and covers subject matter necessary for these courses. Grouping these lessons into three parts makes it possible to offer two courses, either of which may be selected by the employee. Parts 1 and 2 represent a Direct-Current Meter Course, Parts 1 and 3 a Single-Phase Alternating-Current Meter Course, with Parts 1, 2 and 3 covering both Direct-Current and Alternating-Current Meters.

Part 1—Elementary Theory

Lesson 1—Electricity
Lesson 2—Electromotive Force, Current and Resistance
Lesson 3—Electric Circuits
Lesson 4—Magnetism
Lesson 5—Magnetic Circuits
Lesson 6—Direct and Alternating Currents
Lesson 7—Induced Electromotive Forces
Lesson 8—The Dynamo-Electric Generator

Part 2—Direct-Current Meters

Lesson 1—The Direct-Current Motor
Lesson 2—Direct-Current Watthour Meter—Commutator Type
Lesson 3—Direct-Current Watthour Meter—Mercury Type
Lesson 4—Full Load and Light Load Adjustments
Lesson 5—Potential Circuit of Commutator Type Meters
Lesson 6—Bearings
Lesson 7—Watthour-Meter Test Methods and Formulas
Lesson 8—Standards
Lesson 9—Test Procedure

Part 3—Single-Phase Alternating-Current Meters

Lesson 1—Alternating-Current Units
Lesson 2—Alternating-Current Motor and Watthour Meter
Lesson 3—Induction Watthour-Meter Characteristics
Lesson 4—Commercial Types of Induction Watthour Meters and Types of Magnetic Circuits
Lesson 5—Full Load, Light Load, and Lag Adjustments
Lesson 6—Bearings
Lesson 7—Watthour-Meter Test Methods and Formulas
Lesson 8—Standards
Lesson 9—Test Procedure

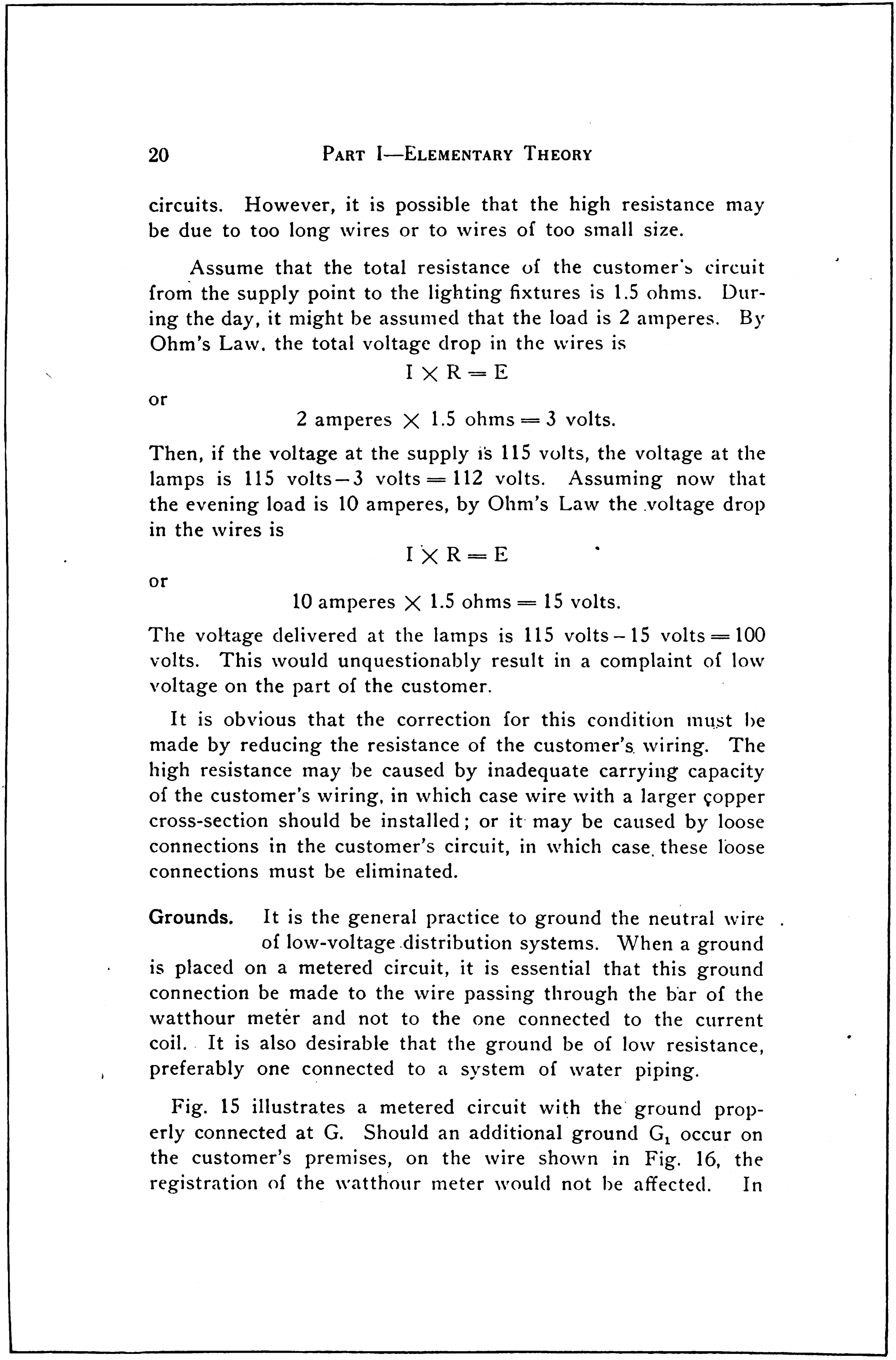
In addition there is included a supplementary booklet—Arithmetic for Electrical Metermen—which consists of a review of the arithmetic that is considered essential to a meterman.

Price for Parts 1 and 2 including correspondence service and certificate is $12.00.

Price for Parts 1 and 3 including correspondence service and certificate is $12.00.

Price for Parts 1, 2 and 3 including correspondence service and certificate is $18.00.

Descriptive folder giving full details and outline furnished upon application.



20 PART I—ELEMENTARY THEORY

circuits. However, it is possible that the high resistance may be due to too long wires or to wires of too small size.

Assume that the total resistance of the customer's circuit from the supply point to the lighting fixtures is 1.5 ohms. During the day, it might be assumed that the load is 2 amperes. By Ohm's Law, the total voltage drop in the wires is

$$I \times R = E$$

or

$$2 \text{ amperes} \times 1.5 \text{ ohms} = 3 \text{ volts.}$$

Then, if the voltage at the supply is 115 volts, the voltage at the lamps is $115 \text{ volts} - 3 \text{ volts} = 112$ volts. Assuming now that the evening load is 10 amperes, by Ohm's Law the voltage drop in the wires is

$$I \times R = E$$

or

$$10 \text{ amperes} \times 1.5 \text{ ohms} = 15 \text{ volts.}$$

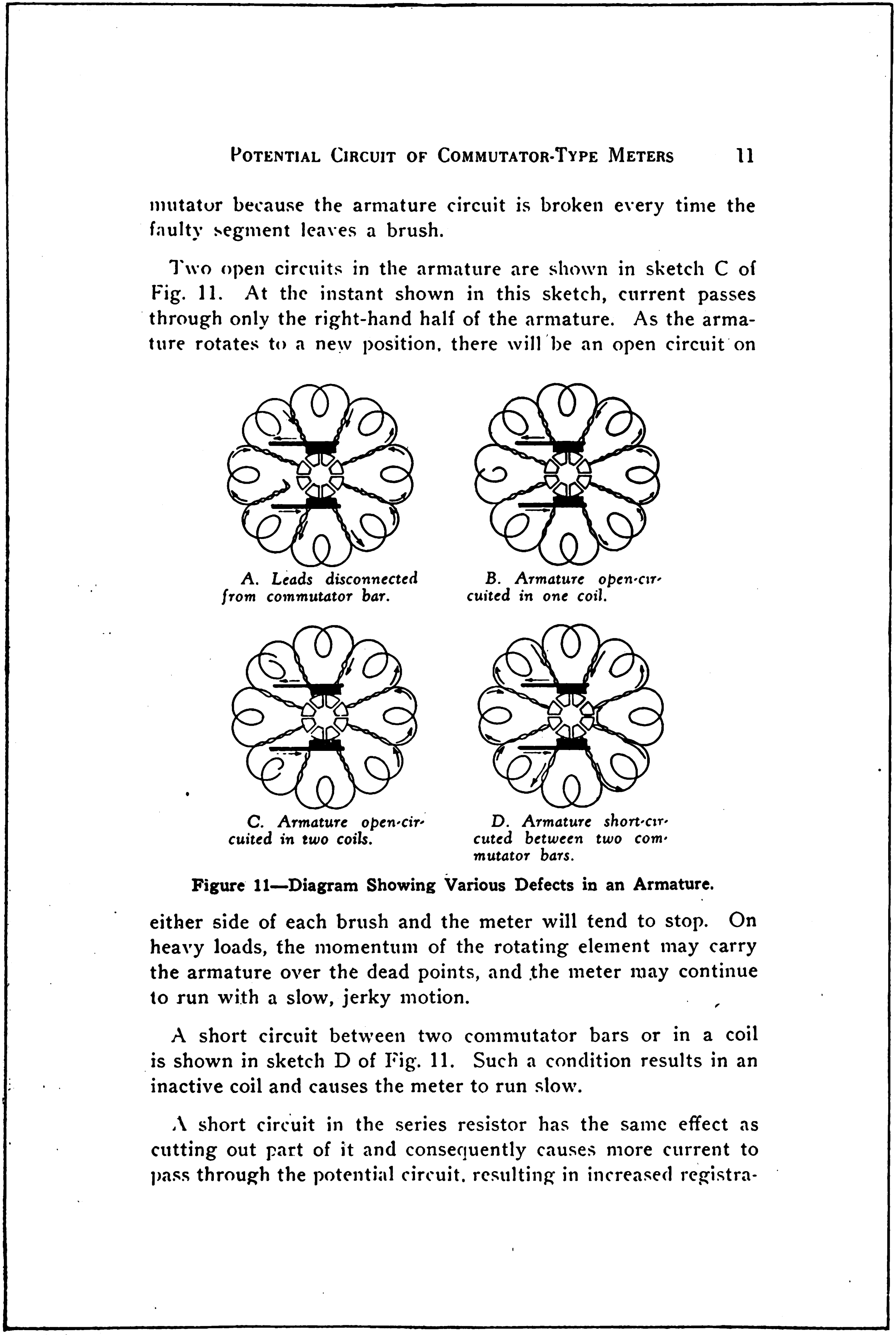
The voltage delivered at the lamps is $115 \text{ volts} - 15 \text{ volts} = 100$ volts. This would unquestionably result in a complaint of low voltage on the part of the customer.

It is obvious that the correction for this condition must be made by reducing the resistance of the customer's wiring. The high resistance may be caused by inadequate carrying capacity of the customer's wiring, in which case wire with a larger copper cross-section should be installed; or it may be caused by loose connections in the customer's circuit, in which case these loose connections must be eliminated.

Grounds. It is the general practice to ground the neutral wire of low-voltage distribution systems. When a ground is placed on a metered circuit, it is essential that this ground connection be made to the wire passing through the bar of the watthour meter and not to the one connected to the current coil. It is also desirable that the ground be of low resistance, preferably one connected to a system of water piping.

Fig. 15 illustrates a metered circuit with the ground properly connected at G. Should an additional ground G_1 occur on the customer's premises, on the wire shown in Fig. 16, the registration of the watthour meter would not be affected. In

FIG. 4—SAMPLE PAGE FROM PART 1 OF THE ELECTRICAL METERMEN'S COURSES.



POTENTIAL CIRCUIT OF COMMUTATOR-TYPE METERS 11

mutator because the armature circuit is broken every time the faulty segment leaves a brush.

Two open circuits in the armature are shown in sketch C of Fig. 11. At the instant shown in this sketch, current passes through only the right-hand half of the armature. As the armature rotates to a new position, there will be an open circuit on either side of each brush and the meter will tend to stop. On heavy loads, the momentum of the rotating element may carry the armature over the dead points, and the meter may continue to run with a slow, jerky motion.

A. Leads disconnected from commutator bar.

B. Armature open-circuited in one coil.

C. Armature open-circuited in two coils.

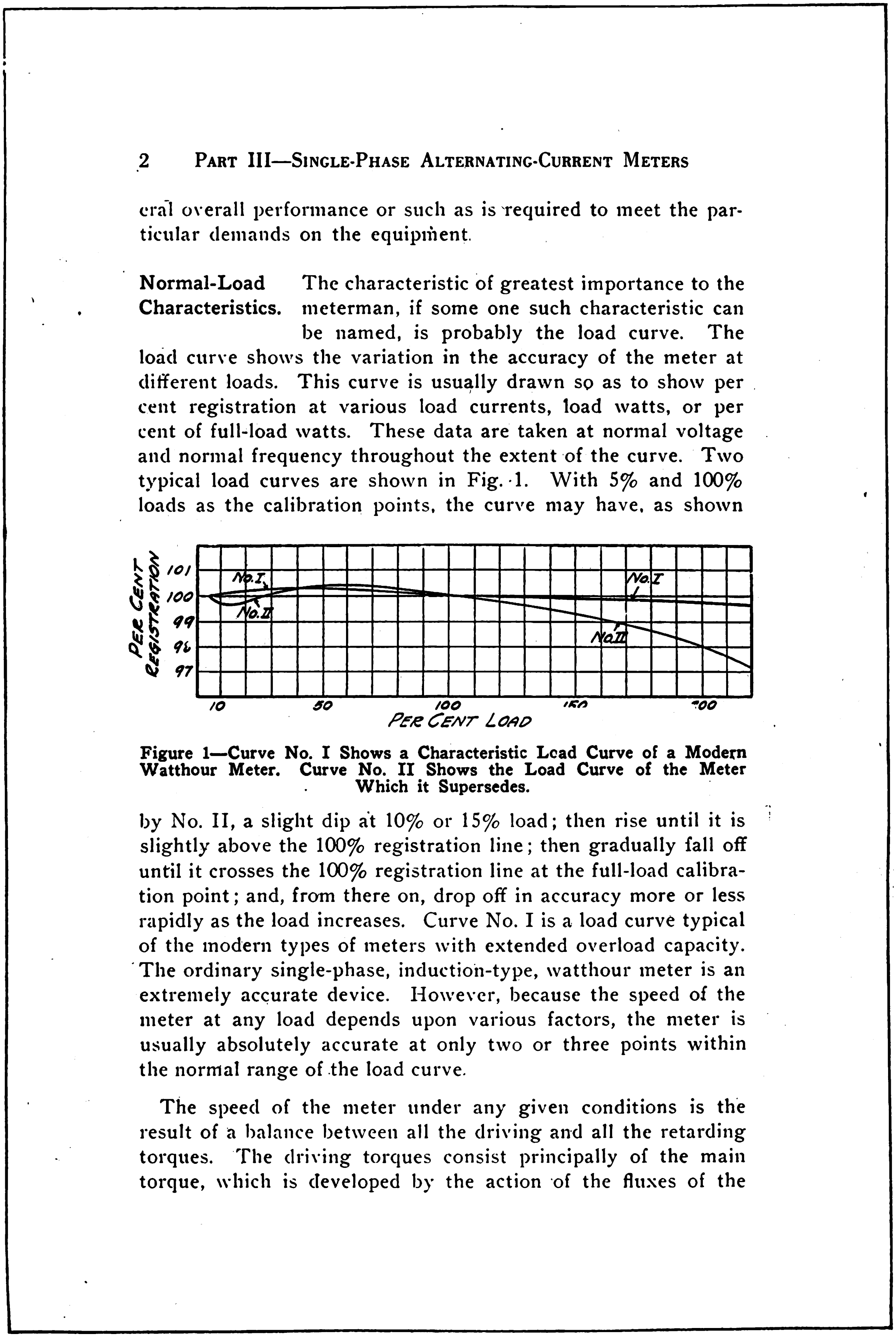
D. Armature short-circuted between two commutator bars.

Figure 11—Diagram Showing Various Defects in an Armature.

A short circuit between two commutator bars or in a coil is shown in sketch D of Fig. 11. Such a condition results in an inactive coil and causes the meter to run slow.

A short circuit in the series resistor has the same effect as cutting out part of it and consequently causes more current to pass through the potential circuit, resulting in increased registra-

FIG. 5—SAMPLE PAGE FROM PART 2 OF THE ELECTRICAL METERMEN'S COURSES.



2 PART III—SINGLE-PHASE ALTERNATING-CURRENT METERS

eral overall performance or such as is required to meet the particular demands on the equipment.

Normal-Load Characteristics. The characteristic of greatest importance to the meterman, if some one such characteristic can be named, is probably the load curve. The load curve shows the variation in the accuracy of the meter at different loads. This curve is usually drawn so as to show per cent registration at various load currents, load watts, or per cent of full-load watts. These data are taken at normal voltage and normal frequency throughout the extent of the curve. Two typical load curves are shown in Fig. 1. With 5% and 100% loads as the calibration points, the curve may have, as shown by No. II, a slight dip at 10% or 15% load; then rise until it is slightly above the 100% registration line; then gradually fall off until it crosses the 100% registration line at the full-load calibration point; and, from there on, drop off in accuracy more or less rapidly as the load increases. Curve No. I is a load curve typical of the modern types of meters with extended overload capacity. The ordinary single-phase, induction-type, watthour meter is an extremely accurate device. However, because the speed of the meter at any load depends upon various factors, the meter is usually absolutely accurate at only two or three points within the normal range of the load curve.

Figure 1—Curve No. I Shows a Characteristic Load Curve of a Modern Watthour Meter. Curve No. II Shows the Load Curve of the Meter Which it Supersedes.

The speed of the meter under any given conditions is the result of a balance between all the driving and all the retarding torques. The driving torques consist principally of the main torque, which is developed by the action of the fluxes of the

FIG. 6—SAMPLE PAGE FROM PART 3 OF THE ELECTRICAL METERMEN'S COURSES.

LIGHTING SALES COURSE
MERCHANDISE SALES COURSE
POWER SALES COURSE

Published for the Commercial National Section

The Educational Committee offers three specialized Commercial Courses covering Lighting, Merchandise, and Power Sales. These courses were prepared by specialists in their respective lines, and are published because of an increased demand for special courses on these three main branches of our business.

These courses are especially adapted for groups and classes of employees of commercial departments. They are also used generally in combination classes with employees of manufacturers, dealers, electrical contractors, and jobbers.

There never was a time in the history of our business when it was more necessary than now that the industry be represented by efficient, courteous, and well-trained salesmen.

Each course is divided into two parts. Part 1 is the same for all courses, and consists of five lessons on the principles of commercial engineering as required in our business. Part 2 of each course specializes in one of the above branches of commercial work.

Part 1

Lesson 1—Salesmanship
Lesson 2—Public Relations
Lesson 3A—Elements of Electricity
Lesson 3B—Elements of Electricity
Lesson 4—Principles of Rates
Lesson 5—Wiring for Light and Power

LIGHTING SALES COURSE

Part 2

Lesson 1—Illuminants
Lesson 2—Principles of Illumination
Lesson 3—Residence Lighting
Lesson 4—Store and Window Lighting
Lesson 5—Office Building, Church and School Lighting
Lesson 6—Industrial Lighting
Lesson 7—Outdoor Lighting

MERCHANDISE SALES COURSE

Part 2

Lesson 1—Advertising
Lesson 2—Merchandising
Lesson 3—Electric Heating and Household Appliances
Lesson 4—Industrial Applications
Lesson 5—Selling Campaigns

POWER SALES COURSE

Part 2

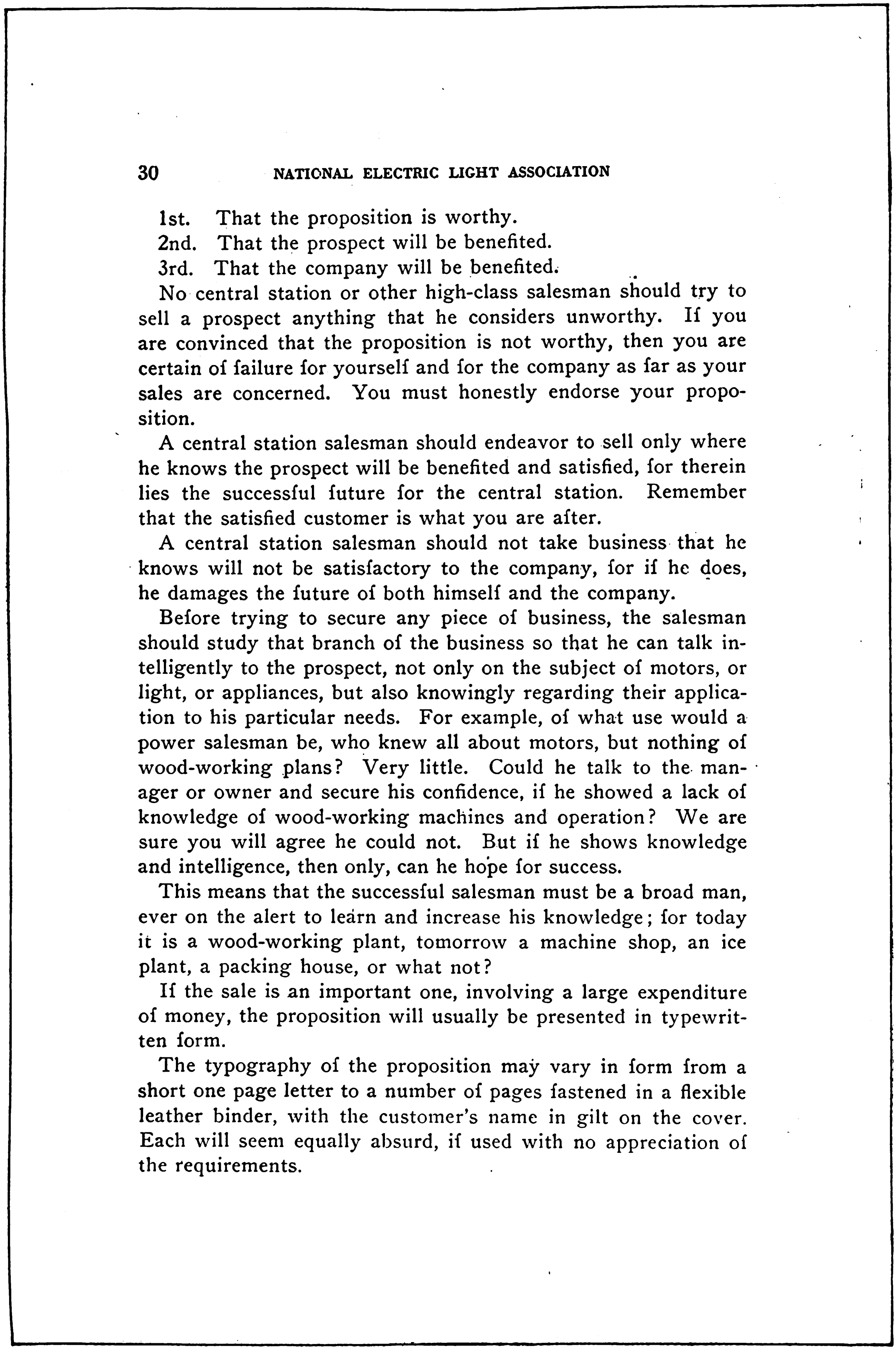
Lesson 1—Electric Motors
Lesson 2—Motor Applications
Lesson 3—Steam, Oil and Gas Engines
Lesson 4—Isolated Plants
Lesson 5—Industrial Heating

Price for the Lighting Sales Course of twelve lessons complete with correspondence service and certificate is $12.00.

Price for the Merchandise Sales Course of ten lessons complete with correspondence service and certificate is $12.00.

Price for the Power Sales Course of ten lessons complete with correspondence service and certificate is $12.00.

Descriptive folder giving full details and outline furnished upon request.



30 NATIONAL ELECTRIC LIGHT ASSOCIATION

1st. That the proposition is worthy.
2nd. That the prospect will be benefited.
3rd. That the company will be benefited.

No central station or other high-class salesman should try to sell a prospect anything that he considers unworthy. If you are convinced that the proposition is not worthy, then you are certain of failure for yourself and for the company as far as your sales are concerned. You must honestly endorse your proposition.

A central station salesman should endeavor to sell only where he knows the prospect will be benefited and satisfied, for therein lies the successful future for the central station. Remember that the satisfied customer is what you are after.

A central station salesman should not take business that he knows will not be satisfactory to the company, for if he does, he damages the future of both himself and the company.

Before trying to secure any piece of business, the salesman should study that branch of the business so that he can talk intelligently to the prospect, not only on the subject of motors, or light, or appliances, but also knowingly regarding their application to his particular needs. For example, of what use would a power salesman be, who knew all about motors, but nothing of wood-working plans? Very little. Could he talk to the manager or owner and secure his confidence, if he showed a lack of knowledge of wood-working machines and operation? We are sure you will agree he could not. But if he shows knowledge and intelligence, then only, can he hope for success.

This means that the successful salesman must be a broad man, ever on the alert to learn and increase his knowledge; for today it is a wood-working plant, tomorrow a machine shop, an ice plant, a packing house, or what not?

If the sale is an important one, involving a large expenditure of money, the proposition will usually be presented in typewritten form.

The typography of the proposition may vary in form from a short one page letter to a number of pages fastened in a flexible leather binder, with the customer's name in gilt on the cover. Each will seem equally absurd, if used with no appreciation of the requirements.

FIG. 7—Sample Page from Part 1 of the Lighting, Merchandise and Power Sales Courses.

32 NATIONAL ELECTRIC LIGHT ASSOCIATION

monly used where a very broad distribution of light is desirable as in the case of street lighting.

Since with both prismatic reflectors and refractors the light is reflected by or passed through clear glass only, the absorption is low and the efficiency of such glassware is of the highest order.

Opal-Glass Reflectors. Opal glass finds considerable application in illumination practice both as a reflecting and transmitting medium. In general there are two types of opal glass, classed as dense and light. The properties of opal glass can be most readily understood if we regard it as common glass, in which fine white particles are, so to speak, held in suspension. When a ray of light strikes this surface, part of the light is reflected directly, as in the case of a polished-metal surface. The remainder of the light travels through the glass in straight lines until it strikes the white particles, or any minute air bubbles which may be present, whence it is dispersed in all directions, some of it being thrown back and reflected as shown in Figure 20, A, and the remainder being transmitted through and out in all directions. If by chance any of the light passes through the glass and fails to strike any of the white particles, it goes out in a line parallel to the one along which it entered. Thus, if a lamp were enclosed in a ball of opal glass, through which on an average, say, one ray in a hundred could pass without strik-

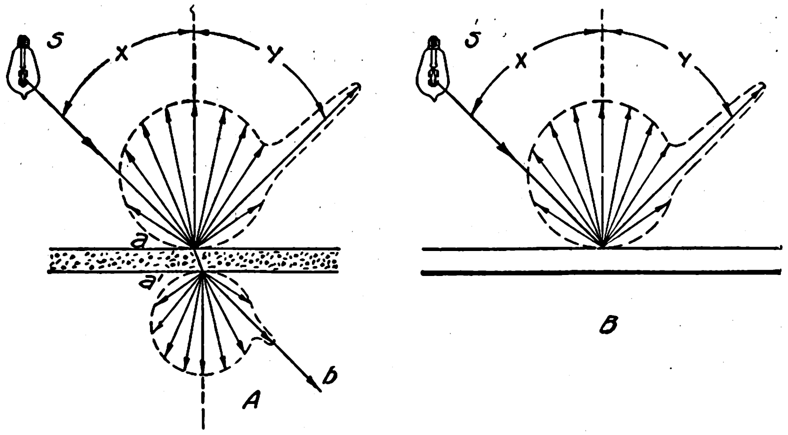
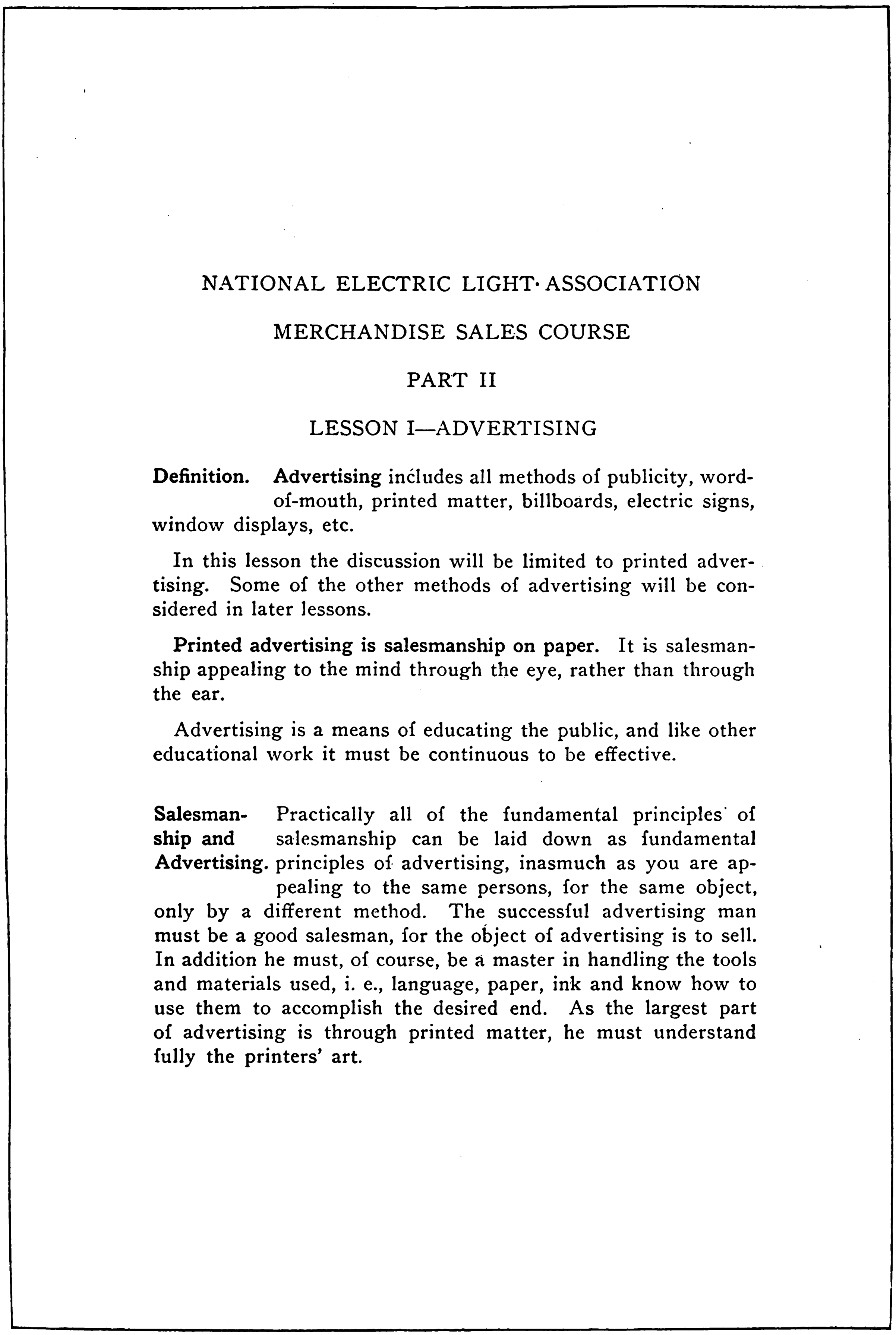


Figure 20
A—Reflection and Transmission of Opal Glass
B—Reflection from Porcelain-Enameled Steel

FIG. 8—SAMPLE PAGE FROM PART 2 OF THE LIGHTING SALES COURSE.



NATIONAL ELECTRIC LIGHT ASSOCIATION

MERCHANDISE SALES COURSE

PART II

LESSON I—ADVERTISING

Definition. **Advertising** includes all methods of publicity, word-of-mouth, printed matter, billboards, electric signs, window displays, etc.

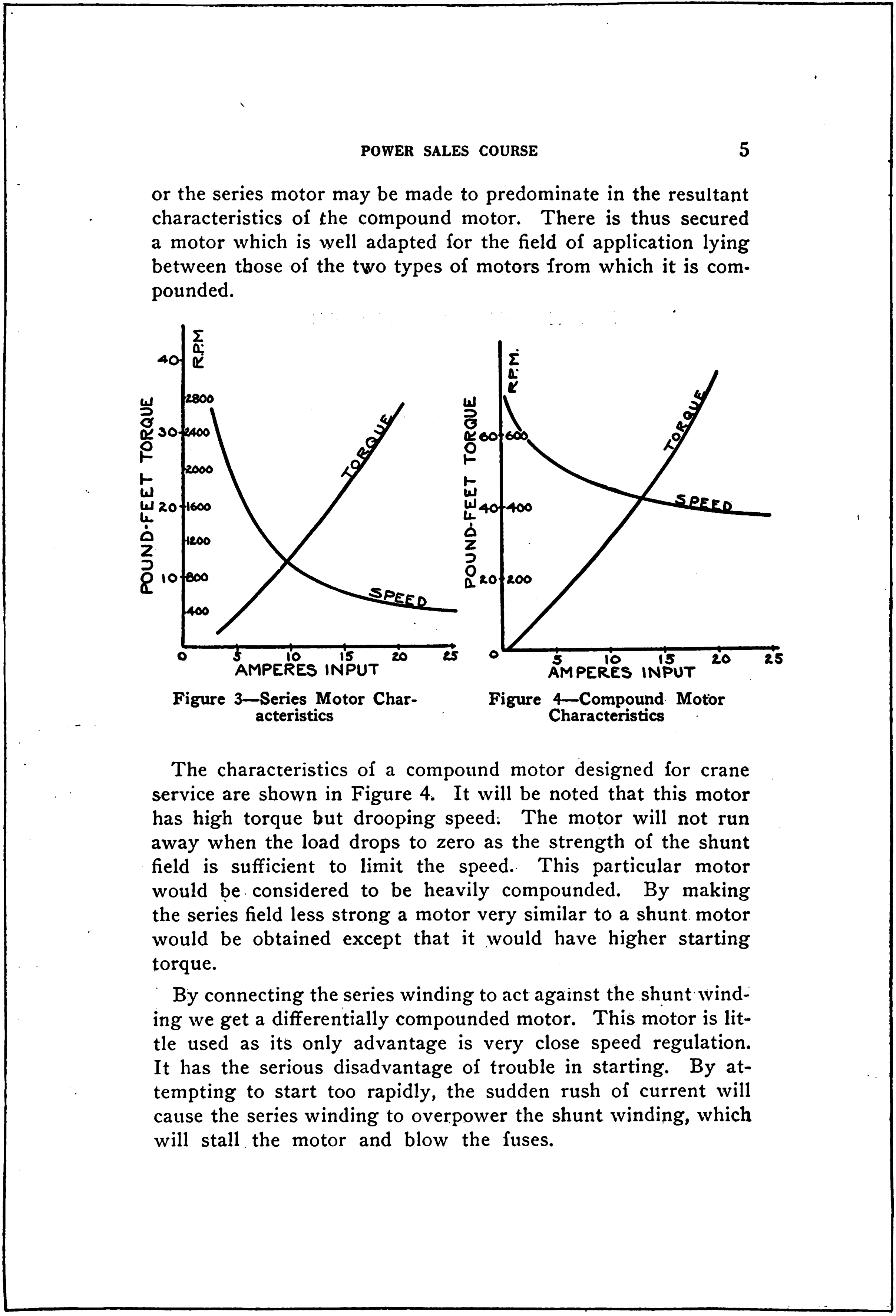
In this lesson the discussion will be limited to printed advertising. Some of the other methods of advertising will be considered in later lessons.

Printed advertising is salesmanship on paper. It is salesmanship appealing to the mind through the eye, rather than through the ear.

Advertising is a means of educating the public, and like other educational work it must be continuous to be effective.

Salesmanship and Advertising. Practically all of the fundamental principles of salesmanship can be laid down as fundamental principles of advertising, inasmuch as you are appealing to the same persons, for the same object, only by a different method. The successful advertising man must be a good salesman, for the object of advertising is to sell. In addition he must, of course, be a master in handling the tools and materials used, i. e., language, paper, ink and know how to use them to accomplish the desired end. As the largest part of advertising is through printed matter, he must understand fully the printers' art.

FIG. 9—SAMPLE PAGE FROM PART 2 OF THE MERCHANDISE SALES COURSE.



POWER SALES COURSE 5

or the series motor may be made to predominate in the resultant characteristics of the compound motor. There is thus secured a motor which is well adapted for the field of application lying between those of the two types of motors from which it is compounded.

POUND-FEET TORQUE
R.P.M.
40
30
20
10
2800
2400
2000
1600
1200
800
400
TORQUE
SPEED
0
5
10
15
20
25
AMPERES INPUT

Figure 3—Series Motor Characteristics

POUND-FEET TORQUE
R.P.M.
60
40
20
600
400
200
TORQUE
SPEED
0
5
10
15
20
25
AMPERES INPUT

Figure 4—Compound Motor Characteristics

The characteristics of a compound motor designed for crane service are shown in Figure 4. It will be noted that this motor has high torque but drooping speed. The motor will not run away when the load drops to zero as the strength of the shunt field is sufficient to limit the speed. This particular motor would be considered to be heavily compounded. By making the series field less strong a motor very similar to a shunt motor would be obtained except that it would have higher starting torque.

By connecting the series winding to act against the shunt winding we get a differentially compounded motor. This motor is little used as its only advantage is very close speed regulation. It has the serious disadvantage of trouble in starting. By attempting to start too rapidly, the sudden rush of current will cause the series winding to overpower the shunt winding, which will stall the motor and blow the fuses.

FIG. 10—Sample Page from Part 2 of the Power Sales Course.

DEVELOPING ELECTRIC SERVICE FOR THE FARM

AS EXEMPLIFIED BY THE ORGANIZATION AND METHODS OF THE WISCONSIN POWER AND LIGHT COMPANY

In order to make available practical information on how electric light and power companies may organize to develop electric service on the farm, the Rural Electric Service Committee has undertaken issuance of a series of reports which reflect in detail how this class of business is being handled by a number of companies.

This is the first of the series. It portrays in detail the rural electric service department of the Wisconsin Power and Light Co., Madison, Wis.; how it was organized; how it fits in with the rest of the organization; how it operates, and results achieved. In the near future similar reports regarding rural electric service departments in other companies will be issued.

It should be understood that the Rural Electric Service Committee of the National Electric Light Association in presenting these reports does not pretend to recommend the plan of organization and operation of any one company. It merely presents the methods of these companies for what they may be worth to others undertaking the organization and operation of such departments.

The Wisconsin Power & Light Company operates in 25 of the 71 counties of the State of Wisconsin, covering all of eight counties and parts of seventeen.

There is grown in this territory approximately 30 per cent of the canning peas, 60 per cent of the tobacco and 70 per cent of the dry beans produced in the State.

Farms served from company lines July 1, 1928	5,142

This is slightly over three times the number served Jan. 1, 1926.

Farms served through wholesale connections	2,150
Total farms served	7,292

This is 14.6 per cent of the farms in company territory.

Average kilowatt-hours per farm Jan. 1, 1928	52

The average energy consumption per farm has increased 44.4 per cent in two years.

The statistics given in Table I have been compiled from data made available by the Wisconsin State Department of Agriculture:

TABLE I

SIGNIFICANT AGRICULTURAL CHARACTERISTICS OF THE TERRITORY SERVED BY THE WISCONSIN POWER & LIGHT COMPANY

Area of territory	12,500 sq. miles
Number of farms	50,000
Average size of farm	125 acres
Farms operated by tenants	10,000
Farms having radio sets	23 per cent
Farms having running water in the house	13 per cent
Farms having furnaces	26 per cent
Number of cows	610,000
Average cows per farm	12
Average yearly milk production per cow	5,100 lb.
Number of silos	32,500
Number of cheese factories	830
Number of butter factories	160
Number of condenseries	30
Number of milk receiving stations	270
Number of swine	589,000
Average swine per farm	12
Annual egg production	30,000,000 doz.
Average annual egg production per farm	600 doz.
Canning peas	33,000 acres
Number of pea canneries	50
Tobacco	18,000 acres
Dry beans	8,500 acres
Pickle salting and receiving stations	80

Publication No. 289-12, Serial Report, Rural Electric Service Committee.

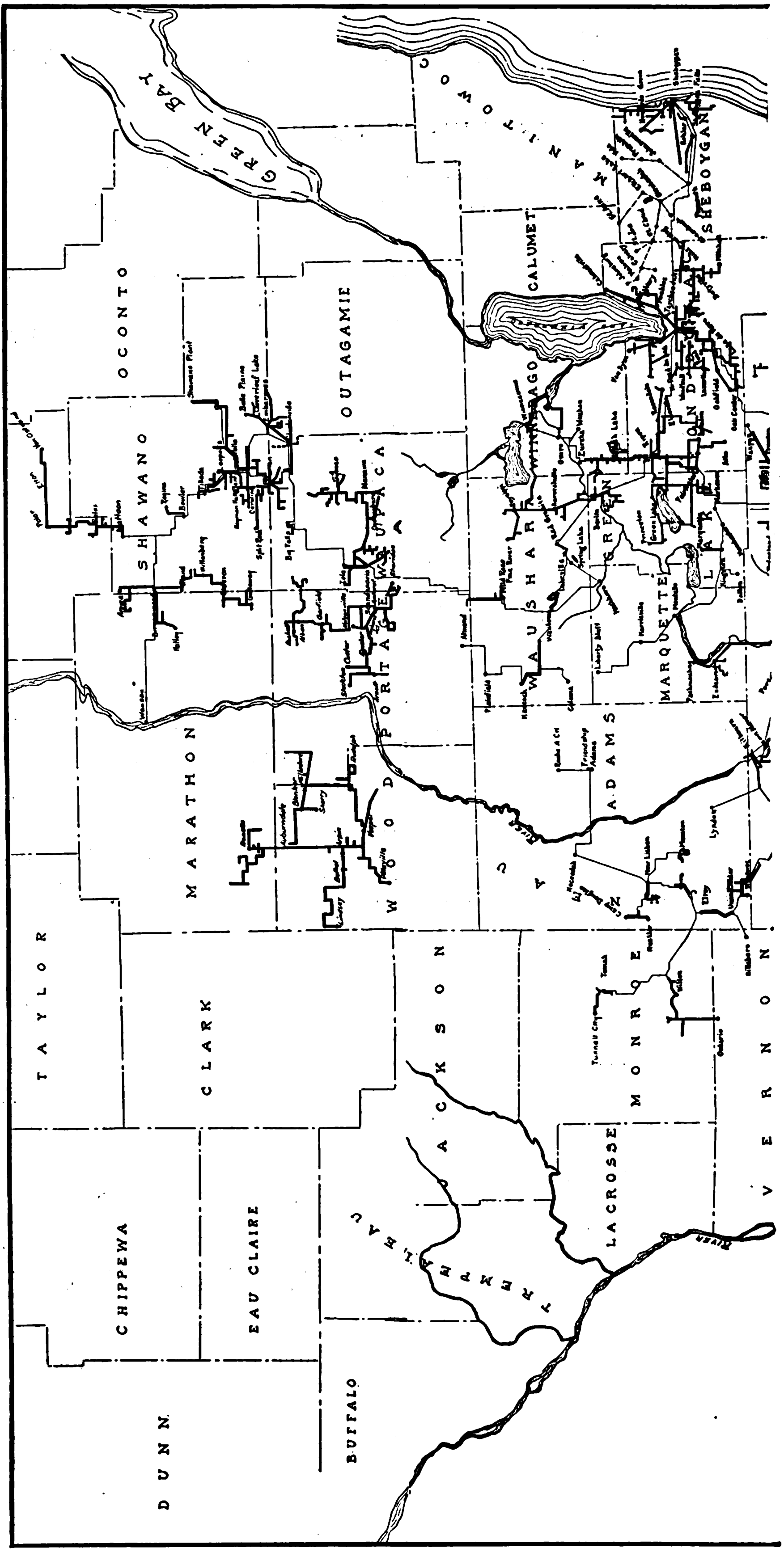

GREEN BAY
OCONTO
MANITOWOC
SHAWANO
OUTAGAMIE
CALUMET
SHEBOYGAN
WINNEBAGO
WAUPACA
FOND DU LAC
WAUSHARA
GREEN LAKE
MARATHON
PORTAGE
WOOD
ADAMS
MARQUETTE
JUNEAU
TAYLOR
CLARK
JACKSON
MONROE
VERNON
CHIPPEWA
EAU CLAIRE
LACROSSE
TREMPEALEAU
BUFFALO
DUNN
River

FIG. 1A—NORTHERN PART OF TERRITORY SERVED BY WISCONSIN POWER AND LIGHT COMPANY.

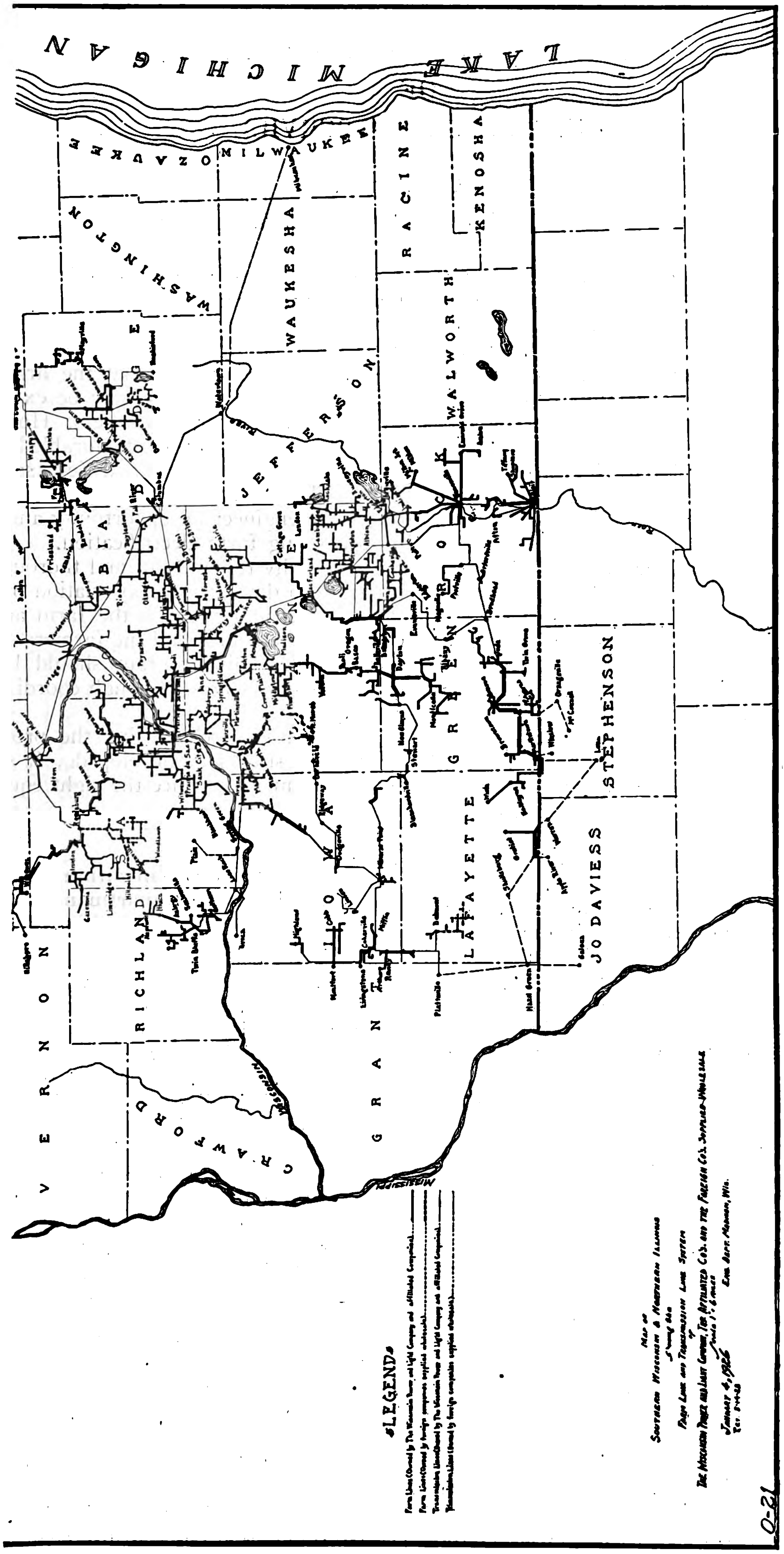

LAKE MICHIGAN
OZAUKEE
MILWAUKEE
WASHINGTON
WAUKESHA
RACINE
KENOSHA
WALWORTH
JEFFERSON
DODGE
COLUMBIA
DANE
GREEN
ROCK
STEPHENSON
JO DAVIESS
LAFAYETTE
IOWA
GRANT
RICHLAND
VERNON
CRAWFORD
SAUK
Wisconsin
Mississippi
LEGEND
Farm Lines (Owned by The Wisconsin Power and Light Company and Affiliated Companies)
Farm Lines (Owned by foreign companies supplied wholesale)
Transmission Lines (Owned by The Wisconsin Power and Light Company and Affiliated Companies)
Transmission Lines (Owned by foreign companies supplied wholesale)
Map of Southern Wisconsin & Northern Illinois showing the Farm Line and Transmission Line System of The Wisconsin Power and Light Company, The Affiliated Cos. and the Foreign Cos. Supplied Wholesale
January 4, 1926
Scale 1" = 8 miles
Eng. Dept. Madison, Wis.
0-21

FIG. 1B—SOUTHERN PART OF TERRITORY SERVED BY WISCONSIN POWER AND LIGHT COMPANY.

ESSENTIALS FOR DEVELOPMENT OF RURAL ELECTRIC SERVICE

BY G. C. NEFF,
Vice-President, Wisconsin Power & Light Company

It should be clearly recognized that, primarily, rural electrification means electricity at work on the farm. A substantial current consumption per farm is necessary before either the farmer or the utility can realize potential possibilities. In this connection line building and the adding of farm customers are only necessary steps leading toward the final goal—an electrified agriculture.

To be successful in developing its farm load a utility company must be guided by executives who believe that farm electrification can pay its own way, that there is a load on the farm sufficient in amount to justify the expenditure which is required for distribution lines, that the farmers can afford to pay the necessary charges for this service, and that they can profit by its use. Aggressive executive support is essential.

Utility executives should appreciate that farm electrification is a big job, that it calls for the expenditure of large sums of money in distribution systems, and therefore should be willing to so organize their company that this large expenditure will be wisely made, and new business resulting from such expenditure will be profitable to both the utility and the farmer.

The farm electric service activities of the company should be carried on by a separate rural service department properly coordinated with the general operating organization and headed by an agriculturally trained man who reports to an operating executive who has a voice in developing the policy of the company, for in work of this kind many questions of policy will arise which require definite and prompt decisions.

The utility company should adopt an extension policy under the operation of which the utility will bear the cost of the entire farm distribution system under average conditions. This policy will not in any way impair the farmer's credit, which in many cases is needed to secure the equipment necessary to properly electrify his farm.

The utility company should develop and adopt a simple uniform rate schedule especially designed to meet farm conditions and so constructed that the farm customer who uses only a little energy must pay a relatively high price for the service rendered but not enough to make this low consumption profitable to the utility. Farm electrification cannot be developed on a permanent basis if the average consumption per customer is low, and it is desirable to bring this fact to the attention of both the farmer and the utility each month through the monthly bill. A proper rate schedule will do this and encourage the farmer and the utility company to cooperate in building the farm load.

The engineering department should be impressed with its responsibility in farm electrification development. It is essential that the first cost of farm lines be low so that they may be extended to reach the greatest number of farmers. However, the cost must be sufficient to provide durable lines which give close voltage regulation and few service interruptions. This is distinctly an engineering problem and offers the engineer an opportunity and responsibility in developing farm electrification.

A carefully thought out and thoroughly organized program to develop an appreciation of the possibilities of electric service on the farm among both the company's personnel and the farmers of the territory is essential. This program should be independent of merchandise sales, although coordinated with this activity.

A plan for merchandising the proper equipment to farmers should be developed. It should be easy for the farmer to secure the right equipment.

Company Organization and How Rural Service Department Was Fitted into This Plan

The Wisconsin Power & Light Company serves approximately 250 cities and villages in an area of 12,500 square miles located in central and southern Wisconsin. This territory is divided into four divisions. Each division organization is headed by a division manager who reports to the operating vice-president. Each division is divided into districts. The district organization is headed by a district manager who reports to a division manager. Service to the people in the entire 12,500 square miles of area is rendered through 18 district organizations. The general scheme of operation is to consider each district manager a general manager of all company activities in that district. Each division manager is considered as a general manager of all company activities in his division.

In addition to the organization just described there are 15 department heads who devote their entire time to some specific phase of the company's business. These department heads report to the operating vice-president. The department heads work directly with the people in the district offices who are actively carrying on the work in which the department head is interested. No department head can issue an executive order to any one in the field, but if the field

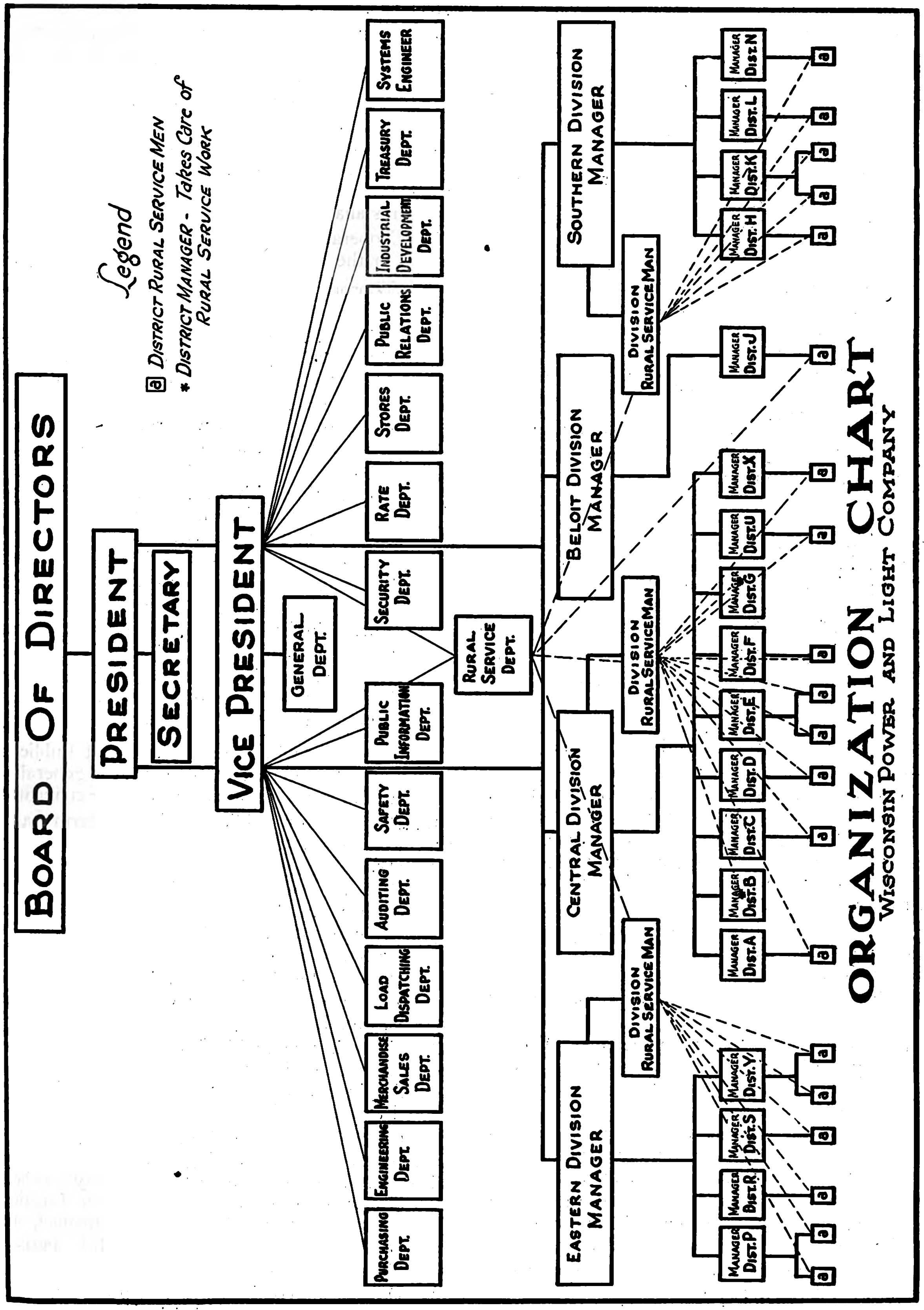

BOARD OF DIRECTORS
PRESIDENT
SECRETARY
VICE PRESIDENT
GENERAL DEPT.
Legend
a DISTRICT RURAL SERVICE MEN
* DISTRICT MANAGER - Takes Care of RURAL SERVICE WORK
PURCHASING DEPT.
ENGINEERING DEPT.
MERCHANDISE SALES DEPT.
LOAD DISPATCHING DEPT.
AUDITING DEPT.
SAFETY DEPT.
PUBLIC INFORMATION DEPT.
SECURITY DEPT.
RATE DEPT.
STORES DEPT.
PUBLIC RELATIONS DEPT.
INDUSTRIAL DEVELOPMENT DEPT.
TREASURY DEPT.
SYSTEMS ENGINEER
RURAL SERVICE DEPT.
EASTERN DIVISION MANAGER
CENTRAL DIVISION MANAGER
BELOIT DIVISION MANAGER
SOUTHERN DIVISION MANAGER
DIVISION RURAL SERVICE MAN
DIVISION RURAL SERVICE MAN
DIVISION RURAL SERVICE MAN
MANAGER DIST. P
MANAGER DIST. R
MANAGER DIST. S
MANAGER DIST. Y
MANAGER DIST. A
MANAGER DIST. B
MANAGER DIST. C
MANAGER DIST. D
MANAGER DIST. E
MANAGER DIST. F
MANAGER DIST. G
MANAGER DIST. U
MANAGER DIST. X
MANAGER DIST. J
MANAGER DIST. H
MANAGER DIST. K
MANAGER DIST. L
MANAGER DIST. N
a
ORGANIZATION CHART
WISCONSIN POWER AND LIGHT COMPANY

FIG. 2—ORGANIZATION OF RURAL ELECTRIC SERVICE DEPARTMENT, WISCONSIN POWER AND LIGHT COMPANY, AND RELATION TO REST OF ORGANIZATION.

work is not satisfactory to the department head it is called to the attention of the vice-president, who works through the division managers and district managers and sees that such steps are taken as are necessary to bring about proper operating conditions. Such a plan permits of close contact between the department head and the field men and at the same time gives to each employee only one person from whom to receive orders.

The head of the Rural Service Department is one of the above described department heads, and his work is carried on in accordance with the above described plan. In each division office there is a man in charge of rural service work who is responsible to the division manager and who has charge of the rural service work in the division. With the exception of two of the small districts where the district manager personally takes care of the ural service work, each district has one or more district farm service men. These district farm service men work under the district managers.

The Rural Service Department is organized and functions in the same general manner as any other department of the company.

Organization Diagram

Fig. 2 shows the general organization of the company, and, in addition, shows in detail the Farm Service organization of the company.

Activities of the Rural Service Department

1. Took the responsibility for the development of a uniform set of rates and rules and regulations for rural service in cooperation with the Rate Department.

2. Conferred with farm leaders on the above matter.

3. Took an active part in presenting the rates, rules and regulations before the State Commission.

4. After adoption by the commission conducted an educational campaign among company employees and farmers for the purpose of explaining the new rates, rules and regulations.

5. Takes the initiative in the revision of rates, rules and regulations relating to farm service before the commission.

6. Looks after all complaints by farmers to the commission.

7. Interprets disputed points in the rules. Within the company the head of the Rural Service Department is the authority, with final appeal to the vice-president possible.

8. Distributes all commission rulings and interpretations and company interpretations with reference to rural service to division and district offices.

9. Canvasses rural customers on old rates with view to securing change to new schedule and arranges for refund when change is made.

10. Canvasses non-customers on established rural lines to sell them electric service.

11. Answers all inquiries from prospective rural customers, holds community meetings with interested farmers, canvasses all possible routes for new line extensions.

12. Secures easements for new rural lines, and in many instances stakes out and prepares the work order for new lines.

13. Keeps a check on new rural line construction to see that there is no undue delay between the signing of the application and the starting of service.

14. Lays out farm wiring systems, estimates wiring costs and in some instances takes contract for wiring installation.

15. Cooperates with merchandise department and dealers in the sale of equipment to farmers by:

(a) Thoroughly discussing with prospective customers possible uses of electricity and reporting prospects to proper place.

(b) When calling on old customers discussing further uses and reporting active prospects.

(c) Observation and comparison of different makes of equipment with recommendations as to what is best suited to needs of the territory.

(d) Cooperation with merchandising men in recommending equipment for special conditions and in making sales where considerable farm knowledge is required.

(e) Securing list of prospects from exhibitions, demonstrations, with addresses.

(f) Furnishing selling information to merchandising department.

(g) Cooperating with merchandising department in the preparation of sales literature and equipment advertising copy.

16. Cooperates with the Department of Public Information in the preparation of copy for general advertising and news releases on rural electrification.

17. Prepares for publication in the farm papers authentic, constructive articles on the rural uses of electricity.

18. Cooperates with the publishers of "Electricity on the Farm" in the preparation of editorial material. A copy of this publication is distributed to each rural customer each month.

19. Purchased and distributed, by personal call, to each rural customer a copy of C. R. E. A. Bulletin, Vol. IV, No. 1.

20. Keeps in touch with C. R. E. A. and all other known sources of information regarding the use of electricity in agriculture. Such information is distributed to the men in the company.

21. On the call of the vice-president of the company, held a series of meetings attended by division and district managers where the company's policies on rural electrification were discussed, the functions of the Rural Service Department explained, and means and methods for developing this business thoroughly discussed.

22. During the coming winter two of a series of district meetings to be attended by all company employees will be devoted to rural electrification. The

programs for these meetings will be in charge of the Rural Service Department.

23. Cooperation with State and National C. R. E. A., State, Division and National Committees of N. E. L. A., and other organizations for general advancement of the rural electrification movement.

24. At least an annual call on every rural customer to list all electrically operated equipment, make inquiry regarding satisfaction of service and discuss additional possibilities.

25. Service to individual farmers, particularly in reference to the selection and installation of equipment. Especial attention is paid to keeping installed equipment in proper operating condition. This has materially reduced emergency calls.

26. Exhibition and demonstration of electrical equipment at fairs and other gatherings. A demonstration truck is being prepared for rural use. Silo filling with a 5 h.p. motor will be shown at special demonstrations this year.

27. In some districts meter reading is done by the rural service men.

28. Recording the company's progress in rural electric development largely through the collection of statistics covering number of farms served, amount of current used, revenue, miles of line built, equipment used. All rural lines built are recorded on a map used only for this purpose.

Procedure in Establishing Service

The original application for electric service is entirely informal and usually consists of a call by some interested farmer, who inquires about rates and conditions under which extensions are made. If satisfied with explanation, he invariably represents his community as a particularly profitable place for the company to make an extension. "All those fellows will be big users," is the usual claim.

If the maps show that extension is feasible, company representative goes over the ground checking distances by speedometer and interviewing the farmers. If he finds the extension impracticable, the matter is dropped and the original inquirer is so notified.

But if there is sufficient interest, a meeting is called at a schoolhouse, church or home in the community. The whole project is discussed as a community enterprise and as applied to any prospect's special conditions. All hear the same story and realize that they are being treated alike. No special inducements or individual deals are made. At this meeting an approximate estimate of the probable cost of the extension is announced with a statement of the number of customers required to put it on free basis. Also the contributions required from customers if a smaller number are secured.

Where there is good chance of getting enough for free basis the original agreements are signed on this basis. As many as possible are signed at the meeting. Then a company man, preferably accompanied by a leading farmer, canvasses all of the remaining prospects, signing them up on a free basis.

If the number of signers multiplied by 400 is not less than the estimated cost of the line, the company proceeds to stake it out and prepare the work order. But if it is impossible to get this number of customers, the original agreements are taken back to the signers with a statement of the contribution needed to make up the deficit. The maximum amount of this contribution is definitely stated in an amended agreement for service.

Where the conditions make it obviously impossible to build an extension on a free basis, the contribution probably required is included in the original agreement. No customer should ever be asked for more than he has agreed to contribute. The estimate should take care of that.

The work thus far has been done by the rural man. If he has the engineering ability, he now stakes out the line and prepares the work order. Otherwise this is done by another representative from the district office.

Easements for the line are now secured from each property owner across or along whose land the line will pass. These legal documents must be signed before a notary, so some one in each district, often the rural man, holds such a commission. The easements are recorded by the Register of Deeds of the County in which the property lies.

The work order for a rural line extension is just like any other construction work order, and passes through the same routine, being approved by the district manager, division engineer, division superintendent, chief engineer, vice president and general manager and president. Accompanying it to the chief engineer's office, however, is a map showing it in relation to roads and all possible conflicts with lines of other utilities. This gives the engineering department the information needed in arranging for joint poles, transpositions, moving telephone lines, etc.

There is also a detailed description of the way the line will be built. This is made the basis of the Railroad Commission's permit to make the extension. A State highway man also goes over the line as staked out, learns how tree interference is to be avoided, to what extent anchors and crossings may interfere with the road and, finding these matters satisfactory or suggesting changes that will make them so, he gives the Commission's approval.

While these formalities are going on, the purchasing agent secures the necessary materials. Then, in accordance with some local or general program, construction begins. At the same time each individual customer lets a wiring contract either to the company or some contractor. The rural man may even secure the contracts and turn them over to a local contractor to fulfill, the company paying for the work and collecting from the customer. In any case, the rural man will decide and mark the spot on customer's premises at which the company's service drop will end.

When line construction and transformer installation is complete, connect orders are made in the local office for each customer. The meter department proceeds to carry out these orders. But if the meter man finds the premises wired in flagrant violation of company rules and the State Electrical Code he refuses to set the meter and calls the defects or dangerous conditions of the wiring to the owner's attention. This calls for corrections by the contractor.

When the meter is finally set, service begins. If the interval to the next meter reading date is not about one month, the service charge and first energy step are prorated on the first bill.

Rates and Contract Form for Rural Service

A few farms in all parts of the territory were formerly served by the smaller utilities now merged in the Wisconsin Power & Light Company. As each such company was purchased, its rural rates were continued until there were 69 different rates in effect. Aside from the resultant complications in billing and bookkeeping, this was a constant source of argument and irritation where neighboring farmers received identical service at quite dissimilar rates. The rates of many of these small companies were entirely inadequate. In some other cases, schedules were applied which were not at all fitted to farm conditions. Therefore, the creation of a new rural rate acceptable to the company, attractive to farmers, fitted to their needs, and uniform for all, was the first step in the extension of rural service.

In January, 1926, the Railroad Commission of Wisconsin held the first public hearing on the proposed uniform rural schedule. The farmers present opposed its approval on the grounds that in many cases it increased their bills, and that they did not fully understand the new features. The company, therefore, moved an adjournment to give the farmers time to organize for a thorough study of the proposed plan, and offered to place at their disposal its books and all of the cost data upon which the figures of the schedule were based. After adjournment the farmers organized and selected 100 representative delegates. At their first meeting these delegates elected a working committee of five with power to act for the larger group.

The committee secured all available literature on rural ratemaking and took up the study of the costs of service. Their most serious problem was the satisfactory allocation of these costs between large and small users of the service. Toward the end of each day's discussion they called a company representative into conference and presented their objections and counter-proposals to certain features of the schedule. At each session some of the objections were overcome and some of the farmers' suggestions were accepted.

During the same period the farmers throughout the territory were holding local meetings to discuss the same problems and to hear the reports from the working committee. These meetings were not under the auspices of the company, but representatives of the company were often invited to speak. Through them the farmers came to understand the difficulties of rural service and the company learned to appreciate the farmers' attitude. When, by concession and compromise, an agreement was reached between the company and the committee, the revised schedule was presented to the original 100 delegates and was approved by them. It was then submitted to the Railroad Commission of Wisconsin and was formally approved on June 21, 1926.

The working committee, in reporting its final action to the farmers, made the following statements:

> After many meetings, covering a period of a number of months, in which your committee gathered data from Canada and every State in the Union that has rural users of electricity, we consider that we now have the best farmers' rate, taking into consideration the territory it covers, that is in existence today.
>
> Electricity is going to be a big help to the farmer for light, power and heat. We recommend this rate as deserving of a fair trial. Take advantage of this contract and use as much electricity as you possibly can, for the more you use the less it costs you per kilowatt. Demand good service from the company, and we believe the results will be satisfactory.

The authors of this letter were originally elected to the committee because of their strong and active opposition to the company's proposal. The frank recommendation quoted above is typical of the support and cooperation which the new uniform rural schedule has received throughout the entire territory.

The company believes this method of establishing a new rate affecting thousands of people over an extended area and resulting in increased bills for a large number of them is unique. Its value from a public relations standpoint can hardly be overestimated. It is a method that any company can employ. The only requirements are a genuine desire to give real service fitted to the customer's needs, and a readiness to take the customer completely into the company's confidence and cooperate with him at every point.

This past spring further meetings were held with the farmers' committee for the purpose of simplifying the contract. The resulting contract and the Rules Governing Rural Extensions are shown in Fig. 3, 4, 5, 6 and 7.

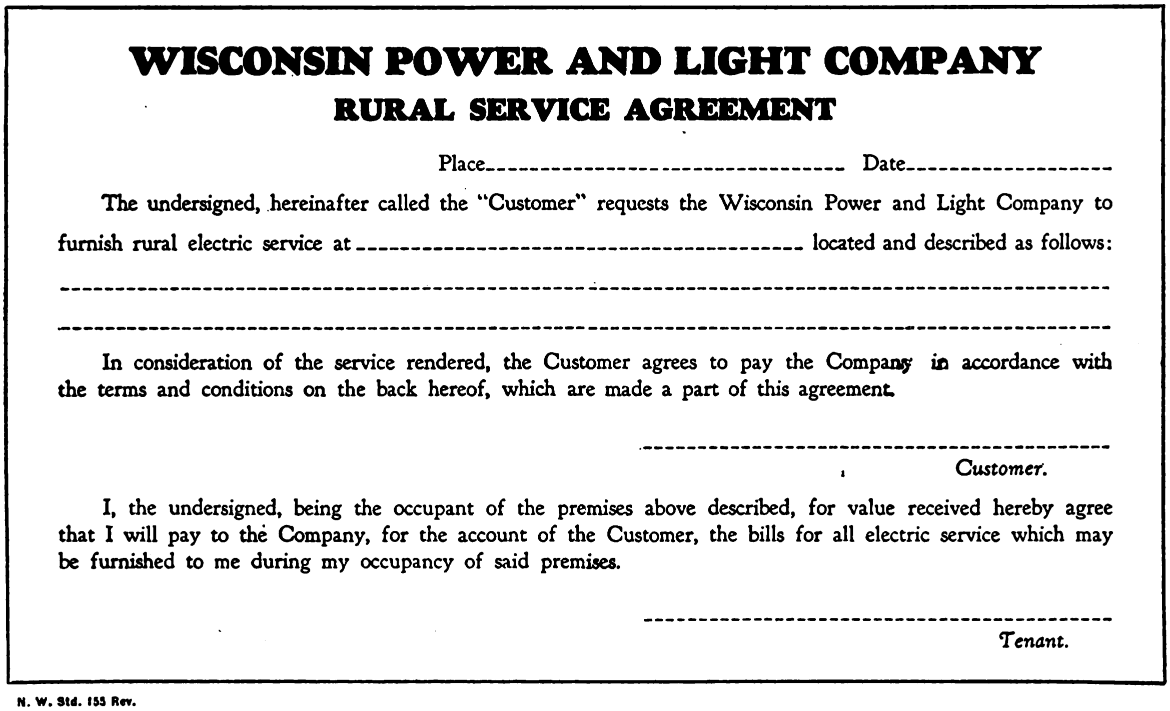
Rural Line Building

Rural lines are built by the regular local line crews, by special local line crews assigned to farm lines, or by construction department crews sent into a district for that purpose.

Whoever does the actual building, the staked-out project must be approved by a highway commission engineer. Efforts are made to apply for this approval far enough in advance so he can lay out a plan for his trips and inspect the greatest number of lines with the least inconvenience. Advance planning also allows the shifting of personnel where necessary.

The company owns three digging machines which are routed throughout the property for line building, including rural lines. Their efficient use demands a program of construction in which neighboring districts cooperate; also that the poles at least, and preferably the crossarms as well, be on the ground when the digger arrives.

The farmers have been employed to haul out the



WISCONSIN POWER AND LIGHT COMPANY

RURAL SERVICE AGREEMENT

Place................................ Date...................

The undersigned, hereinafter called the "Customer" requests the Wisconsin Power and Light Company to furnish rural electric service at .... located and described as follows:

....

....

In consideration of the service rendered, the Customer agrees to pay the Company in accordance with the terms and conditions on the back hereof, which are made a part of this agreement.

....

Customer.

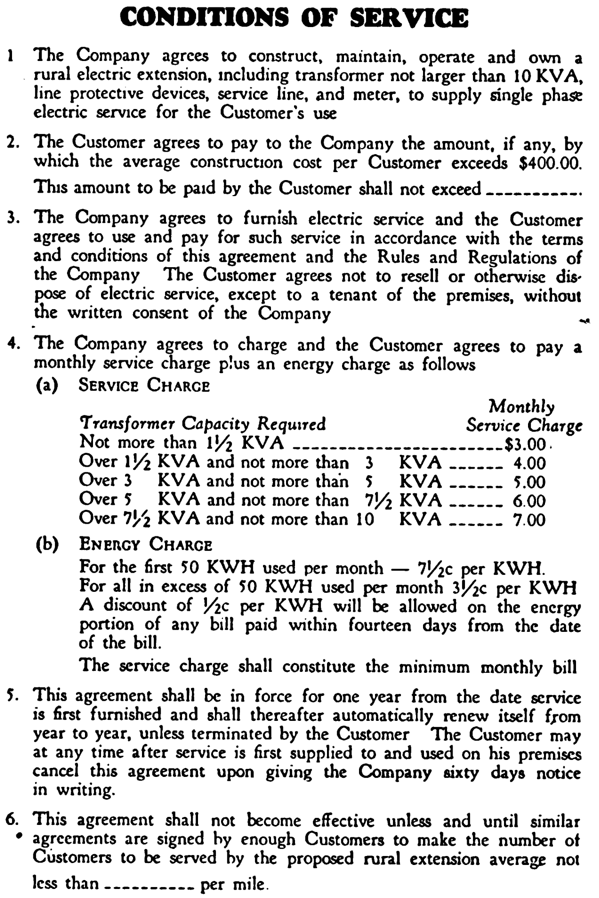
I, the undersigned, being the occupant of the premises above described, for value received hereby agree that I will pay to the Company, for the account of the Customer, the bills for all electric service which may be furnished to me during my occupancy of said premises.

....

Tenant.

N. W. Std. 153 Rev.

FIG. 3—RURAL SERVICE AGREEMENT, WISCONSIN POWER AND LIGHT COMPANY.



CONDITIONS OF SERVICE

1 The Company agrees to construct, maintain, operate and own a rural electric extension, including transformer not larger than 10 KVA, line protective devices, service line, and meter, to supply single phase electric service for the Customer's use

2. The Customer agrees to pay to the Company the amount, if any, by which the average construction cost per Customer exceeds $400.00.

This amount to be paid by the Customer shall not exceed ....

3. The Company agrees to furnish electric service and the Customer agrees to use and pay for such service in accordance with the terms and conditions of this agreement and the Rules and Regulations of the Company The Customer agrees not to resell or otherwise dispose of electric service, except to a tenant of the premises, without the written consent of the Company

4. The Company agrees to charge and the Customer agrees to pay a monthly service charge plus an energy charge as follows

(a) SERVICE CHARGE

Transformer Capacity Required	*Monthly Service Charge*
Not more than 1½ KVA	$3.00
Over 1½ KVA and not more than 3 KVA	4.00
Over 3 KVA and not more than 5 KVA	5.00
Over 5 KVA and not more than 7½ KVA	6.00
Over 7½ KVA and not more than 10 KVA	7.00

(b) ENERGY CHARGE

For the first 50 KWH used per month — 7½c per KWH.
For all in excess of 50 KWH used per month 3½c per KWH
A discount of ½c per KWH will be allowed on the energy portion of any bill paid within fourteen days from the date of the bill.

The service charge shall constitute the minimum monthly bill

5. This agreement shall be in force for one year from the date service is first furnished and shall thereafter automatically renew itself from year to year, unless terminated by the Customer The Customer may at any time after service is first supplied to and used on his premises cancel this agreement upon giving the Company sixty days notice in writing.

6. This agreement shall not become effective unless and until similar agreements are signed by enough Customers to make the number of Customers to be served by the proposed rural extension average not less than .... per mile.

FIG. 4—CONDITIONS OF SERVICE.

Rules Governing Rural Extensions

1. INTENT

These rules are intended to facilitate the securing of electric service in rural communities on such a basis as will stimulate the wide-spread use of electricity for heat, light, and power. In interpreting these rules, a rural extension should, so far as is practicable, be considered a community enterprise from which each individual customer will derive benefit through cooperation with all the other customers.

2. RURAL CUSTOMER DEFINED

For the purpose of these rules, a rural customer is defined as a purchaser of electric service (except customers of a class for which the Company has a suitable urban rate filed with the Railroad Commission) who can be adequately served from one transformer of not more than 10 Kva capacity; and who uses the service in the conduct of one enterprise, occupation, or institution, located outside the limits of a city or village or community with similar characteristics, at such distance that it cannot be adequately served from the secondary lines of the local distribution system.

3. RURAL EXTENSION DEFINED.

Rural extensions as herein used shall include all extensions to distribution systems built primarily to serve rural customers.

4. COST OF EXTENSION DEFINED

The construction cost shall include the costs of all materials, and the costs of all labor and other expense required for the distribution and installation of poles, wire, cross arms, insulators, line hardware, switching and protective devices, transformers, meters, appurtenances, right of way permits, etc.

An item not exceeding 10% of material costs shall be included to cover purchasing expense, freight, cartage to storeroom, and stores department expense.

An item not exceeding 15% of all above-mentioned costs shall be included to cover general overhead, engineering promotion, office supervision, clerical labor, contingencies, etc.

5. ANALYSIS OF EXTENSION

When one or more prospective rural customers make application for electric service the Company will investigate the extension, ascertain the number of customers who can be advantageously served, the number who will contract for service under the terms herein prescribed, and will estimate the construction cost as outlined in Rule 4, provided that, in the opinion of the Company, the extension is justified.

6. PAYMENTS BY CUSTOMERS

When the analysis of the proposed rural extension indicates that electric service is justified from both the Company's and the Customer's standpoint, the Company will execute with each prospective rural customer a contract setting forth the rates, terms, and conditions of service in substantially the form attached hereto.

If the number of contracts signed is such that the estimated cost of the extension will not exceed an average of $400.00 per customer, the Company will proceed to construct the extension at its own expense.

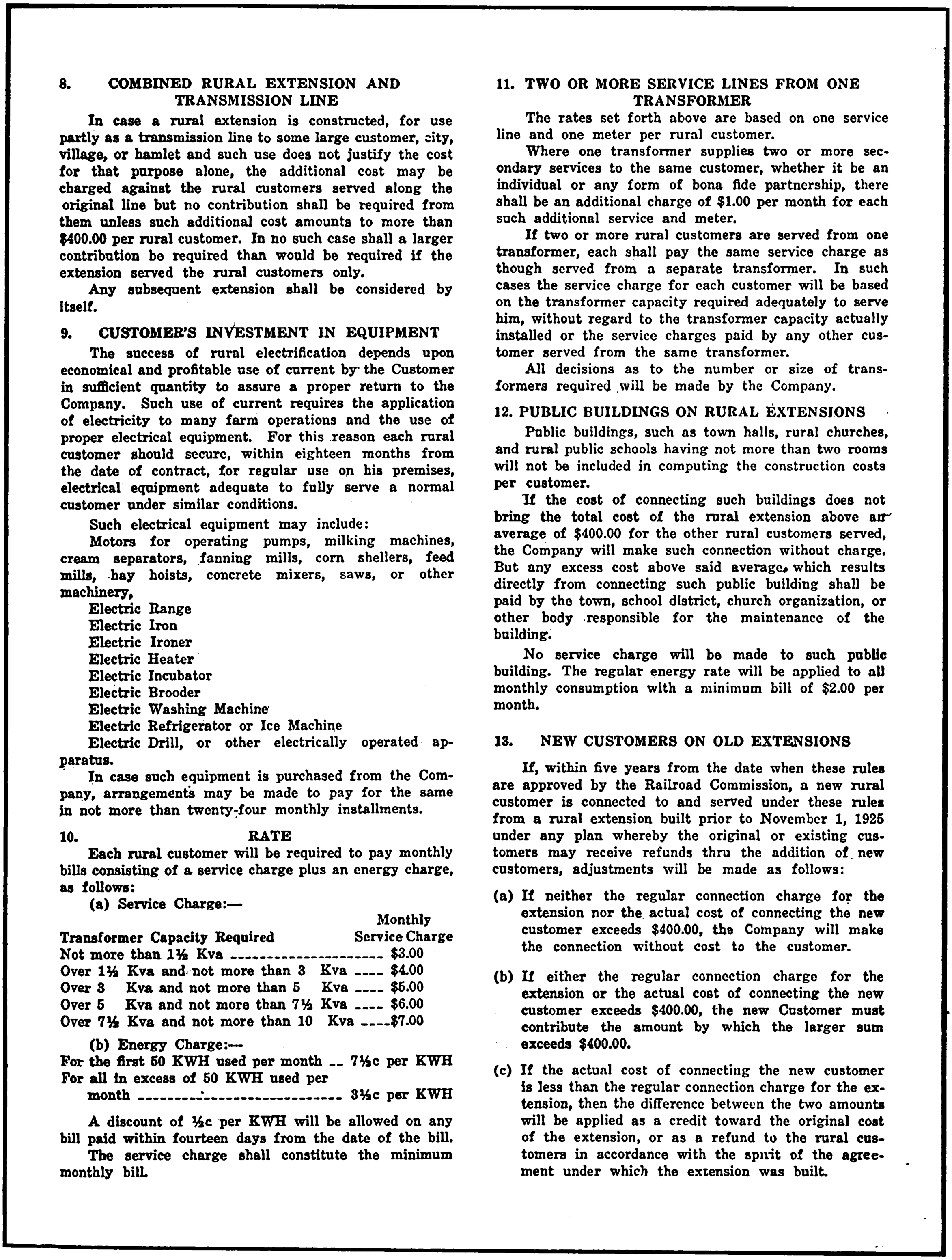
If the cost of the extension is estimated to be more than an average of $400.00 per customer, the amount by which said costs are estimated to exceed said average shall be contributed by the customers. One-half of such contribution shall be paid to the Company when the poles are set and the remainder shall be paid when service is available. The amount of the second payment shall be adjusted on the basis of the actual cost of construction above an average of $400.00 per customer.

7. ADDITIONAL CUSTOMERS

If, within five years from the date when service is first established on a rural extension, additional rural customers are connected to the extension, either directly, or by any branch from or addition to the extension, the cost of connecting them will be included in a new determination of the average cost per customer whenever such inclusion will lower the average cost per customer already served by the extension. In such cases the new customers shall pay to the Company and the Company shall refund to the customers already served such sums as will equalize all the customers' investment in the extension. No such redetermination shall be made as would tend to increase the contribution required from existing customers, but the additional customers shall contribute the amount by which the connection cost exceeds an average of $400.00 each.

If, within five years from the date when service is first established on a rural extension, an urban customer is connected to the extension at an actual connection cost less than the urban free limit as defined in the urban rules of the Company, then the difference between such actual cost of connection and the urban free limit shall be refunded to the rural customers served by the extension in proportion to the investment, if any, that each has in the extension.

FIG. 5—RULES GOVERNING RURAL EXTENSION—PAGE 1, WISCONSIN POWER AND LIGHT COMPANY.



8. COMBINED RURAL EXTENSION AND TRANSMISSION LINE

In case a rural extension is constructed, for use partly as a transmission line to some large customer, city, village, or hamlet and such use does not justify the cost for that purpose alone, the additional cost may be charged against the rural customers served along the original line but no contribution shall be required from them unless such additional cost amounts to more than $400.00 per rural customer. In no such case shall a larger contribution be required than would be required if the extension served the rural customers only.

Any subsequent extension shall be considered by itself.

9. CUSTOMER'S INVESTMENT IN EQUIPMENT

The success of rural electrification depends upon economical and profitable use of current by the Customer in sufficient quantity to assure a proper return to the Company. Such use of current requires the application of electricity to many farm operations and the use of proper electrical equipment. For this reason each rural customer should secure, within eighteen months from the date of contract, for regular use on his premises, electrical equipment adequate to fully serve a normal customer under similar conditions.

Such electrical equipment may include:

Motors for operating pumps, milking machines, cream separators, fanning mills, corn shellers, feed mills, hay hoists, concrete mixers, saws, or other machinery,
Electric Range
Electric Iron
Electric Ironer
Electric Heater
Electric Incubator
Electric Brooder
Electric Washing Machine
Electric Refrigerator or Ice Machine
Electric Drill, or other electrically operated apparatus.

In case such equipment is purchased from the Company, arrangements may be made to pay for the same in not more than twenty-four monthly installments.

10. RATE

Each rural customer will be required to pay monthly bills consisting of a service charge plus an energy charge, as follows:

(a) Service Charge:—

Transformer Capacity Required	Monthly Service Charge
Not more than 1½ Kva	$3.00
Over 1½ Kva and not more than 3 Kva	$4.00
Over 3 Kva and not more than 5 Kva	$5.00
Over 5 Kva and not more than 7½ Kva	$6.00
Over 7½ Kva and not more than 10 Kva	$7.00

(b) Energy Charge:—

For the first 50 KWH used per month	7½c per KWH
For all in excess of 50 KWH used per month	3½c per KWH

A discount of ½c per KWH will be allowed on any bill paid within fourteen days from the date of the bill.

The service charge shall constitute the minimum monthly bill.

11. TWO OR MORE SERVICE LINES FROM ONE TRANSFORMER

The rates set forth above are based on one service line and one meter per rural customer.

Where one transformer supplies two or more secondary services to the same customer, whether it be an individual or any form of bona fide partnership, there shall be an additional charge of $1.00 per month for each such additional service and meter.

If two or more rural customers are served from one transformer, each shall pay the same service charge as though served from a separate transformer. In such cases the service charge for each customer will be based on the transformer capacity required adequately to serve him, without regard to the transformer capacity actually installed or the service charges paid by any other customer served from the same transformer.

All decisions as to the number or size of transformers required will be made by the Company.

12. PUBLIC BUILDINGS ON RURAL EXTENSIONS

Public buildings, such as town halls, rural churches, and rural public schools having not more than two rooms will not be included in computing the construction costs per customer.

If the cost of connecting such buildings does not bring the total cost of the rural extension above an average of $400.00 for the other rural customers served, the Company will make such connection without charge. But any excess cost above said average, which results directly from connecting such public building shall be paid by the town, school district, church organization, or other body responsible for the maintenance of the building.

No service charge will be made to such public building. The regular energy rate will be applied to all monthly consumption with a minimum bill of $2.00 per month.

13. NEW CUSTOMERS ON OLD EXTENSIONS

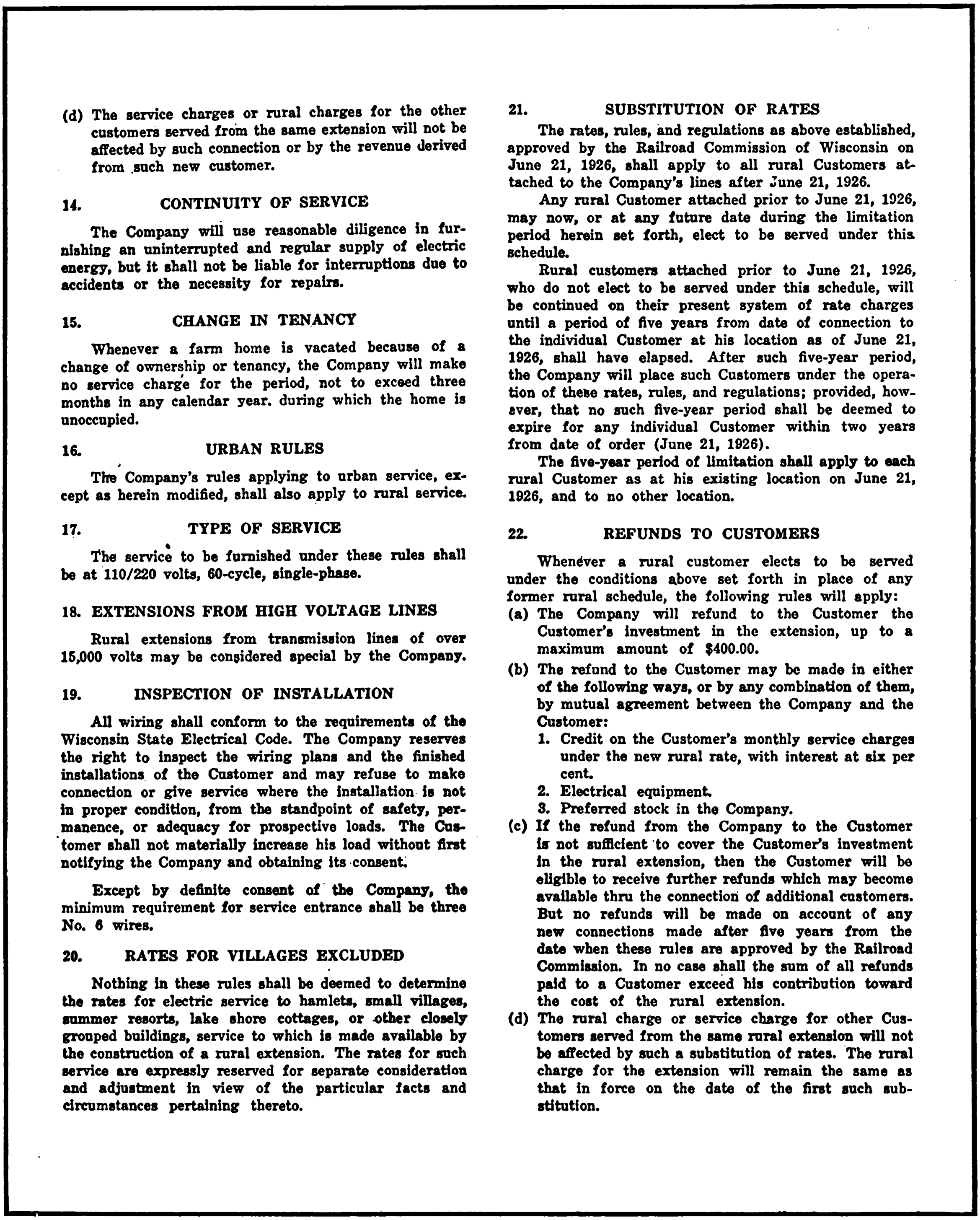
If, within five years from the date when these rules are approved by the Railroad Commission, a new rural customer is connected to and served under these rules from a rural extension built prior to November 1, 1925 under any plan whereby the original or existing customers may receive refunds thru the addition of new customers, adjustments will be made as follows:

(a) If neither the regular connection charge for the extension nor the actual cost of connecting the new customer exceeds $400.00, the Company will make the connection without cost to the customer.

(b) If either the regular connection charge for the extension or the actual cost of connecting the new customer exceeds $400.00, the new Customer must contribute the amount by which the larger sum exceeds $400.00.

(c) If the actual cost of connecting the new customer is less than the regular connection charge for the extension, then the difference between the two amounts will be applied as a credit toward the original cost of the extension, or as a refund to the rural customers in accordance with the spirit of the agreement under which the extension was built.

FIG. 6—RULES GOVERNING RURAL EXTENSION—PAGE 2, WISCONSIN POWER AND LIGHT COMPANY.



(d) The service charges or rural charges for the other customers served from the same extension will not be affected by such connection or by the revenue derived from such new customer.

14. CONTINUITY OF SERVICE

The Company will use reasonable diligence in furnishing an uninterrupted and regular supply of electric energy, but it shall not be liable for interruptions due to accidents or the necessity for repairs.

15. CHANGE IN TENANCY

Whenever a farm home is vacated because of a change of ownership or tenancy, the Company will make no service charge for the period, not to exceed three months in any calendar year, during which the home is unoccupied.

16. URBAN RULES

The Company's rules applying to urban service, except as herein modified, shall also apply to rural service.

17. TYPE OF SERVICE

The service to be furnished under these rules shall be at 110/220 volts, 60-cycle, single-phase.

18. EXTENSIONS FROM HIGH VOLTAGE LINES

Rural extensions from transmission lines of over 15,000 volts may be considered special by the Company.

19. INSPECTION OF INSTALLATION

All wiring shall conform to the requirements of the Wisconsin State Electrical Code. The Company reserves the right to inspect the wiring plans and the finished installations of the Customer and may refuse to make connection or give service where the installation is not in proper condition, from the standpoint of safety, permanence, or adequacy for prospective loads. The Customer shall not materially increase his load without first notifying the Company and obtaining its consent.

Except by definite consent of the Company, the minimum requirement for service entrance shall be three No. 6 wires.

20. RATES FOR VILLAGES EXCLUDED

Nothing in these rules shall be deemed to determine the rates for electric service to hamlets, small villages, summer resorts, lake shore cottages, or other closely grouped buildings, service to which is made available by the construction of a rural extension. The rates for such service are expressly reserved for separate consideration and adjustment in view of the particular facts and circumstances pertaining thereto.

21. SUBSTITUTION OF RATES

The rates, rules, and regulations as above established, approved by the Railroad Commission of Wisconsin on June 21, 1926, shall apply to all rural Customers attached to the Company's lines after June 21, 1926.

Any rural Customer attached prior to June 21, 1926, may now, or at any future date during the limitation period herein set forth, elect to be served under this schedule.

Rural customers attached prior to June 21, 1926, who do not elect to be served under this schedule, will be continued on their present system of rate charges until a period of five years from date of connection to the individual Customer at his location as of June 21, 1926, shall have elapsed. After such five-year period, the Company will place such Customers under the operation of these rates, rules, and regulations; provided, however, that no such five-year period shall be deemed to expire for any individual Customer within two years from date of order (June 21, 1926).

The five-year period of limitation shall apply to each rural Customer as at his existing location on June 21, 1926, and to no other location.

22. REFUNDS TO CUSTOMERS

Whenever a rural customer elects to be served under the conditions above set forth in place of any former rural schedule, the following rules will apply:

(a) The Company will refund to the Customer the Customer's investment in the extension, up to a maximum amount of $400.00.

(b) The refund to the Customer may be made in either of the following ways, or by any combination of them, by mutual agreement between the Company and the Customer:

1. Credit on the Customer's monthly service charges under the new rural rate, with interest at six per cent.
2. Electrical equipment.
3. Preferred stock in the Company.

(c) If the refund from the Company to the Customer is not sufficient to cover the Customer's investment in the rural extension, then the Customer will be eligible to receive further refunds which may become available thru the connection of additional customers. But no refunds will be made on account of any new connections made after five years from the date when these rules are approved by the Railroad Commission. In no case shall the sum of all refunds paid to a Customer exceed his contribution toward the cost of the rural extension.

(d) The rural charge or service charge for other Customers served from the same rural extension will not be affected by such a substitution of rates. The rural charge for the extension will remain the same as that in force on the date of the first such substitution.

FIG. 7—RULES GOVERNING RURAL EXTENSION—PAGE 3, WISCONSIN POWER AND LIGHT COMPANY.

poles, particularly in winter, and in a few cases where a contribution was required of them they have made it in labor. But in general the use of farm labor for line building is not considered very efficient.

The work in all districts and by all types of labor is performed according to very detailed and definite rural line specifications. These call for a line of rather high quality, looking toward the greatest efficiency and economy over a period of many years.

The lines now being built are 6600-volt, single-phase; 6600-volt, 3-phase, or 11,400-volt, 4-wire, in any case giving the rural customer single-phase service.

Service to Farm Customers

Shortly after the Rural Service Department was organized, one traveling repairman and counselor was employed to assist farmers in making the most economical and beneficial use of electric service. This man reported to the head of the department. He received no commission and he sold no merchandise except lamps, which he carried for the accommodation of the customers.

He fixed all equipment and apparatus that could be adjusted or repaired in a few minutes on the premises, charging only for the replacement parts —nothing for time or labor. In more serious difficulties, such as rewinding motors or re-slotting commutators, he advised the most economical remedy. He was able to forestall the failure of hundreds of pieces of equipment before they gave serious trouble, to put back in service at little or no cost to the owner idle appliances amounting to about 250 watts per day, and daily sold an equal wattage of lamps.

While this form of activity was successful in many ways, it soon became evident that this type of service should be under the immediate control and direction of the district office, and such a change was made.

Meter Reading

To provide another opportunity for contact with the rural customer, the practice of actually reading rural meters every month has been adopted. In some districts this is still done by a meter department employee. But it offers such a good opportunity for combination with the service work mentioned above that it is becoming a part of the rural man's duties.

In fact, this tendency is just another step in the experiment now being tried of having one man make all personal contact with the farmer and his family.

Developing an Appreciation of Electric Service on the Farm

If rural electric service is to be made successful, there are two distinct fields, viz.: in the company organization and among farmers, for the development of an appreciation of the possibilities.

In the Company

It is important that the entire management of a utility organization should believe in farm electrification if much headway is to be made in this development. The farmers who deal with such an organization will soon recognize the sincerity of its aims from the attitude of the individuals who represent it. As a result there is developed between the farmers in the territory and the people of the utility company a feeling of confidence which is valuable and necessary to satisfactory farm electrification. It is, therefore, one of the jobs of the principal executives of a company to see to it that the entire organization of the company fully understands the objectives of the company as regards rural electric service and to give sufficient information to convince them that farm electrification is worth developing and will pay its own way.

At the time the Wisconsin Power & Light Co. began intensive work on farm electrification, the division and district managers and department heads of the company were called in to a meeting and the entire plan of procedure as regards farm electrification was explained in detail. A full discussion of all points was encouraged, with the result that at the end of two days everyone in attendance at the meeting was convinced that farm electrification could be made profitable to both the farmers and the company, and that it was advisable from every viewpoint to bring about general farm electrification as rapidly as possible.

As the farm electrification program developed it was found that from time to time there were new problems arising which called for consideration, and in order to keep in close touch with these new problems and to get the benefit of the ideas of the men in the field there was created in the Wisconsin Power & Light Co. a rural service committee, made up of district managers, one division manager and members of the rural service department. This committee meets at least four times a year, oftener if necessary, and discusses the new problems which have arisen in this development, and recommends such changes as it thinks desirable in the plan of procedure. These recommendations are presented to the department head and district and division managers' meetings, which are held quarterly, and here the recommendations are discussed and finally voted on by this organization. They then need, of coure, the approval of the chief executives of the company before any changes are made. This form of procedure, however, makes the entire management familiar with and holds their interest in farm electric development.

Among the Farmers

In a previous chapter the story has been told of how one uniform farm rate was substituted for a multiplicity of farm rates which had prevailed in the territory served by the Wisconsin Power & Light Co.; of how the farmers held mass meetings, organized, appointed a committee, negotiated with the company, and how a mutually harmonious conclusion was arrived at approved by the State regulatory commission.

This attainment of a uniform rural rate mutually satisfactory to company and customers was by no means the only achievement brought about by these negotiations, mass meetings, and the work of the farmers' committee. The entire experience proved of inestimable educational value to everyone who participated, and imparted to everyone a working knowledge, not only of rates but of the modern-day idea of the application of electricity to agriculture.

Since the establishment of this rate the company has continued its educational activities in an orderly way, as follows:

Talks on "What Electric Service Is Doing for Wisconsin Farmers," given in rural homes, schoolhouses and halls at meetings of Parent-Teachers Associations, Farm Bureau, Co-operative Marketing Groups, Church Societies and unorganized meetings called for that purpose.

Advertisements in the State agricultural papers on the general advantages of electric service.

During the past year a uniform series of 2-column by 8-in. advertisements, each one dealing with a single important use of electricity were run in 53 local weekly papers in the territory. Twelve different advertisements were run in each paper.

Feature stories on actual farm experiences, the results of tests, how to install or operate electrical equipment and other helpful information are submitted to farm papers having the widest circulation and the strongest influence in the territory. Because these stories are of interest and genuine benefit to farm readers, because every statement contained can be verified, and because the stories are scrupulously free from company or appliance advertising, the most conservative agricultural editors seem glad to publish them.

Last year a 3-pole tent, 20 ft. by 40 ft., was purchased to shelter an agricultural exhibit at a series of county fairs. The exhibit represented a dairy and a kitchen interior and an outdoor scene, and the appropriate equipment was in actual operation. This year at 10 or 12 fairs the emphasis will be on shallow and deep well water systems, feed grinding and silo filling with 5 h.p.

A copy of C. R. E. A. Bulletin, Volume IV, Number 1, was given to each farm customer by a company representative. Each month the publication, "Electricity on the Farm," is distributed to farm customers. Literature published by manufacturers is also distributed.

There is being developed a number of demonstration farms in the different divisions of the territory. With the increasing use of electricity on the farm these demonstration farms do not promise to be as important as was originally anticipated.

Demonstrations of cooking, feed grinding, silo filling and water pumping have been made on farms. Other operations will be demonstrated as conditions warrant.

A demonstration truck, on which important uses in operation will be featured, is being built.

Selling Equipment

Selling merchandise is one of the important activities of the company, and the value of the rural market is beginning to be appreciated. All selling is in charge of the merchandise department. For selling to farmers special salesmen who really understand modern farming are being selected and developed. In some districts these salesmen themselves are the rural representatives and, therefore, do other rural promotion work. This is in line with the policy of combining rural duties in one man.

The rural department cooperates with the merchandise department as follows:

1. First of all, in selecting good merchandise for resale. That is, equipment that will stand the gaff of farm service.
2. In furnishing to the salesmen data on capacity, electric consumption, recommended operating conditions and advantages of farm equipment for sales talk.
3. In reporting prospects.
4. By making specific recommendation for a particular machine and especially for its installation and operation to fit an individual farmer's conditions.

To farmers the generally accepted line of household appliances are sold, plus outdoor equipment of which the electric feature is an integral part, such as water systems, brooders, etc. The company also features the introduction of machines newly adapted to the electric drive. Hammer mills and hay hoists are good examples. It does not sell other farm machinery that is already well established through implement dealers. For instance, the electric drive of milking machines is very common, but the company does not sell them. The company also feels that the implement trade should handle the silo filler, though it cooperates in showing its adaptation to electric drive.

The selling is done through the following-up of leads and the investigation of prospects reported, rather than by straight house-to-house canvassing.

A cooperative arrangement with plumbers and electrical dealers is carried out by special agreements. Salesmen from the manufacturers of water systems, pump jacks, hammer mills and motors often go with the company's salesmen to finally close sales.

Pumping with various forms of outfits is perhaps the most popular farm use. In the farm house probably more irons are sold than any other item. Range sales are also increasing. Motors ranging from ½ h.p. to 5 h.p. are sold in considerable numbers; they are used for a wide variety of purposes.

The Ideal Arrangement

The ideal arrangement for dealing with rural customers is to have as few men as possible who come in contact with them. That is, to let the same man handle all matters pertaining to rural service in a certain area. This practice decreases the expense of reaching the rural customers for meter reading, service calls, trouble calls, merchandise sales, stock sales, complaints, information on new equipment or advice and help on new installation. It avoids useless irritation with so-called "canvassers" or "peddlers."

It creates customers' confidence in the rural man and allows him to get better acquainted with their problems. It avoids having to refer questions and problems from man to man, which looks to the customer like "passing the buck."

For these reasons the company is working toward this arrangement. The shifting of service work from the general office to the districts was such a step.

Cooperation with Other Agencies

1. Definite cooperation with other agencies in the State and national C. R. E. A. work.
2. Cooperation with Wisconsin Utilities Association, Rural Lines Committee and its activities outside C. R. E. A.
3. Direct cooperation with the College of Agriculture in:
    - (a) Rural electrification short course designed mainly for utility employees.
    - (b) Farmers' and home-makers' week.
    - (c) Farmers' institutes.
    - (d) Supplying statistics and other data and receiving suggestions and advice on special problems.
4. Cooperation with the manufacturers of machinery in demonstrating their product. Silo fillers are the most important example.
5. Cooperation with customers and prospects in the sale of their individual light plants.
6. Continued cooperation with the farmers' committee elected to represent the customers when the uniform rate was established. They are consulted on proposed innovations, such as a direct-mail advertising campaign.

Results

The company has a farm policy.

The company has an organization to further develop and execute this policy. As far as the company is concerned, the "farm problem" has entirely changed. Instead of "What to do with it," the main problem now is "How to Build the Load."

The idea that electric service is possible and practical for the farmer is established with the company personnel and with a majority of the farmers in the company's territory.

The company has a good start on a plan for merchandising equipment to farmers.

Sixty-nine different rates for farm service have been superseded by one rate for farm service applicable throughout the company's territory, and this rate was agreed to by a committee representing the farm customers of the company.

The development of the farm business has become regular routine in just the same manner as the development of any other line of new business.

The officers of the company are convinced that a farm rate and a farm organization within the company are essential to success.

The farmers have respect for and confidence in the recommendations of the men in the rural service department.

The number of farm customers is increasing.

The average energy consumption per farm is increasing.

Farms served from company lines, Jan. 1, 1926	1,624
Farms served from company lines, Jan. 1, 1927	3,146
Farms served from company lines, Jan. 1, 1928	4,308
Farms served from company lines, July 1, 1928	5,142
Farms served through wholesale connections, July 1, 1928	2,150
Total farms served July 1, 1928	7,292
Per cent of farms in territory served July 1, 1928	14.6
Increase in number of farms served, Jan. 1, 1926, to Jan. 1, 1928	165%

Use of energy by rural customers	Kw-hr. per month per customer
1925	36
1927	52

Average increase in energy consumption over two-year period	44.4%

During 1926 and 1927 the number of customers increased by 165 per cent of the number at the beginning of that period. Not only a large number but a very large proportion of the customers, included in making up the average consumption figures, are, therefore, new customers. Only one, two or three months' meter readings have been recorded for some of them. The expense of wiring the premises had doubtless absorbed much of the ready cash in many cases, so that they had purchased little electrical equipment. Consumption records show that it normally takes many months for the average farm customer to "hit his stride" in using the service. The increased use of energy by the relatively small group of older customers is not apparent in the figures because of the large percentage of beginners.

For customers who have been served at the uniform rural rate (which encourages use) for a year and a half or more, connected prior to Jan. 1, 1927, the average use per month is estimated to be nearly 100 kw-hr.

Rural Electric Service in Alabama

By Thomas W. Martin, *President*
Alabama Power Company

ALABAMA POWER COMPANY, within the past few years, has invested more than $2,000,000.00 to enable it to furnish rural electric energy and is now serving more than 6000 Alabama farmers. This statement is made with considerable pride for back of it are plans, purposes and efforts that have been an integral part of the Company's life and growth.

Our trade slogan—"Serving Farm, Factory and Fireside"—puts the farm in a leading place in the Company's ideal of service. In working to this ideal, the necessities of sound financing and healthy growth, governing our Company as they do all succcessful utilities, required that the service be first extended to cities and thickly populated industrial centers. As these objectives were attained, it was possible to widen the circle and reach farther and farther into the rural sections. This was most opportune for farm life needed a revivifying touch if a balanced ratio between agricultural and industrial pursuits, urban and rural life, was to be maintained.

Electrified farm operation was the contribution the Company began to make and is making towards the relief of this situation. A happy and prosperous, contented and progressive farm home radiates a beneficent and inspiring influence that is reflected in the life of the entire State as well as in the local community. Abundant electric energy at reasonable rates, by removing household drudgery, making profits possible and by affording leisure for the enjoyment of the cultural agencies it brings, gives the farmer the opportunity to have such a home.

The use of household appliances on the 256 lines now in operation is quite general. The application of electric power in farm operations is constantly increasing in scope, as evidenced by the installations being made.

While our rural power revenue is not as yet making a satisfactory return on the investment, we are quite hopeful that the business will be built up to self-sustaining proportions within a reasonable time. Viewing this work from both the economic and social standpoint, we feel fully justified in continuing it as an integral part of our program of service, confident that it is contributing to the prosperity of Alabama.

DEVELOPING ELECTRIC SERVICE FOR THE FARM

AS EXEMPLIFIED BY THE ORGANIZATION AND METHODS OF ALABAMA POWER COMPANY

In order to make available practical information on how electric light and power companies may organize to develop electric service on the farm, the Rural Electric Service Committee has undertaken issuance of a series of reports which reflect in detail how this class of business is being handled by a number of companies.

This is the second of the series. It portrays in detail the rural electric service department of the Alabama Power Company, Birmingham, Ala.; how it was organized; how it fits in with the rest of the organization, how it operates, and the results achieved. In the near future similar reports regarding rural electric service departments in other companies will be issued.

It should be understood that the Rural Electric Service Committee of the National Electric Light Association in presenting these reports does not pretend to recommend the plan of organization and operation of any one company. It merely presents the methods of these companies for what they may be worth to others undertaking the organization and operation of such departments.

THE AGRICULTURE OF ALABAMA

Alabama is divided into seven agricultural divisions, based on general soil characteristics, as shown in Fig. 1. While certain of these divisions lend themselves particularly well to specialized agricultural pursuits—winter and spring vegetables in the southern part of the Lower Coastal Plain, and dairying and other livestock in the Black Belt that is well adapted to good, low-cost permanent pasture—the long growing season and the versatility of the soil adapts practically the entire State to a diversified farming program.

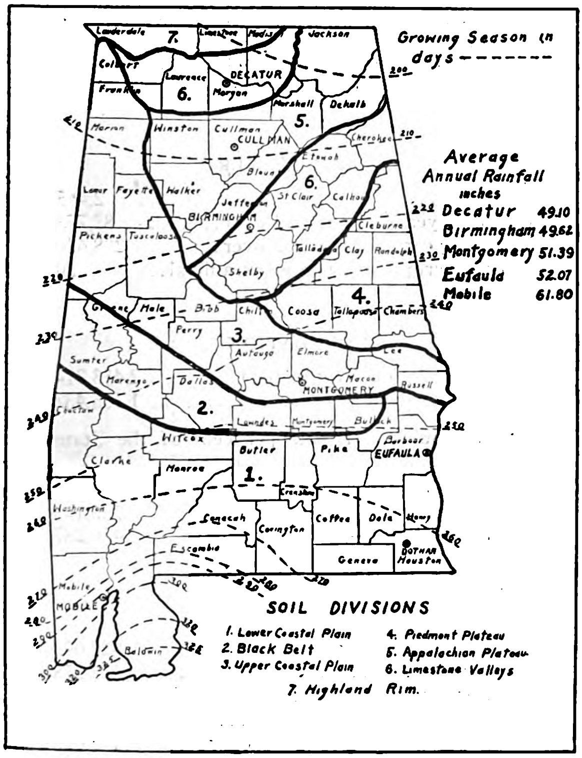

Growing Season in days
Average Annual Rainfall inches
Decatur 49.10
Birmingham 49.62
Montgomery 51.39
Eufaula 52.07
Mobile 61.80
SOIL DIVISIONS
1. Lower Coastal Plain
2. Black Belt
3. Upper Coastal Plain
4. Piedmont Plateau
5. Appalachian Plateau
6. Limestone Valleys
7. Highland Rim.
200
210
220
230
240
250
260
270
280
290
300
320
DECATUR
CULLMAN
BIRMINGHAM
MONTGOMERY
EUFAULA
DOTHAN
MOBILE
Lauderdale
Limestone
Madison
Jackson
Colbert
Lawrence
Morgan
Franklin
Marshall
Dekalb
Marion
Winston
Cullman
Cherokee
Etowah
Blount
Lamar
Fayette
Walker
Jefferson
St Clair
Calhoun
Cleburne
Pickens
Tuscaloosa
Talladega
Clay
Randolph
Shelby
Greene
Hale
Bibb
Chilton
Coosa
Tallapoosa
Chambers
Perry
Autauga
Elmore
Lee
Sumter
Marengo
Dallas
Macon
Russell
Choctaw
Lowndes
Montgomery
Bullock
Wilcox
Barbour
Clarke
Monroe
Butler
Pike
Crenshaw
Washington
Conecuh
Covington
Coffee
Dale
Henry
Escambia
Geneva
Houston
Mobile
Baldwin

FIG. 1—STATE OF ALABAMA, SHOWING SOIL DIVISIONS, RANGE IN GROWING DAYS, AND AVERAGE RAINFALL.

Cotton is generally adapted to the entire State and is the chief money crop. Experimental studies and experience have developed economical methods of cotton production under boll-weevil conditions. Therefore, cotton will continue to be the major money crop, but there is a trend already under rapid development to supplement the cotton crop with more farm products, both for local consumption and for out of State markets. The production of dairy products, poultry products, beef cattle, hogs, fruits, vegetables, pecans and other crops, both on specialized farms and as supplementary to cotton and corn production, is advancing rapidly.

The State Agricultural Experiment Station, Auburn, Ala., has, through the development of specific information, laid the foundation for vast improvements in soil fertilization, crop varieties, rotation and methods of cultivation. This is resulting in increased production per acre and per man, and a reduced cost of production per unit. The experimental work is being made more comprehensive and effective through the establishment of branch experimental stations and fields in the different agricultural sections of the State.

Through the work of the Agricultural Extension Service, which directs the efforts of the County Agricultural and Home Demonstration agents, recently developed information relating to better agricultural practices is disseminated to the farmers throughout the State.

The State Department of Agriculture cooperates in the dissemination of information to the farmers, and through its inspection, standardization and other regulatory activities is having a profound influence upon the production and marketing of the State's agricultural products.

The Farm Bureau is, through its cooperative marketing and purchasing associations, rendering agriculture a great aid, not only in the handling of products, but also in establishing the cooperative idea among farmers.

Publication No. 289.61, Serial Report, Rural Electric Service Committee.

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Industries of the State have become more familiar with the agricultural problems and are cooperating with the farmers very effectively, especially in the distribution of agricultural products for local consumption.

These activities, together with the increased industrialization of the State, are creating a trend toward improved farming methods and a more prosperous agriculture.

Statistical Picture of Alabama Agriculture

Based Largely on Data Collected by U. S. Bureau of Census—1925

Land area of State	32,818,560 acres
Land area in farms	16,739,139 acres
Per cent of land area in farms	51.0

CLASSIFICATION OF FARM LAND

	Acres	Per Cent of Farm Land
Crop land	7,691,713	45.9
Pasture land	3,544,351	21.2
Woodland—not pasture	3,855,958	23.1
All other land in farms	1,647,114	9.8

FARMS BY SIZE

	Farms by Size	Per cent of Total
Under 3 acres	102	0.04
3 to 9 acres	9,807	4.10
10 to 19 acres	26,262	11.05
20 to 49 acres	104,030	43.75
50 to 99 acres	53,667	22.60
100 to 174 acres	27,885	11.76
175 to 259 acres	8,255	3.50
260 to 499 acres	5,356	2.25
500 to 999 acres	1,616	0.68
1000 to 4999 acres	632	0.26
5000 acres and over	19	0.01
Total farms in State	237,631	
Average size farm	70.4 acres	

FARMERS—COLOR AND TENURE

		Per cent of Total
White farm operators	152,310	64.2
Colored farm operators	85,321	35.8
Farm owners—white	78,614	33.1
Farm owners—colored	14,782	6.2
Tenants—white	73,696	31.0
Tenants—colored	70,539	29.7

Percentage of farm owners, 39.3.

FARM VALUES

Land	$308,663,620
Buildings	106,195,027
Implements and machinery	23,850,657
Livestock	62,031,018
All farm property	500,740,322
Average value per farm	2,107
Average value per acre	30

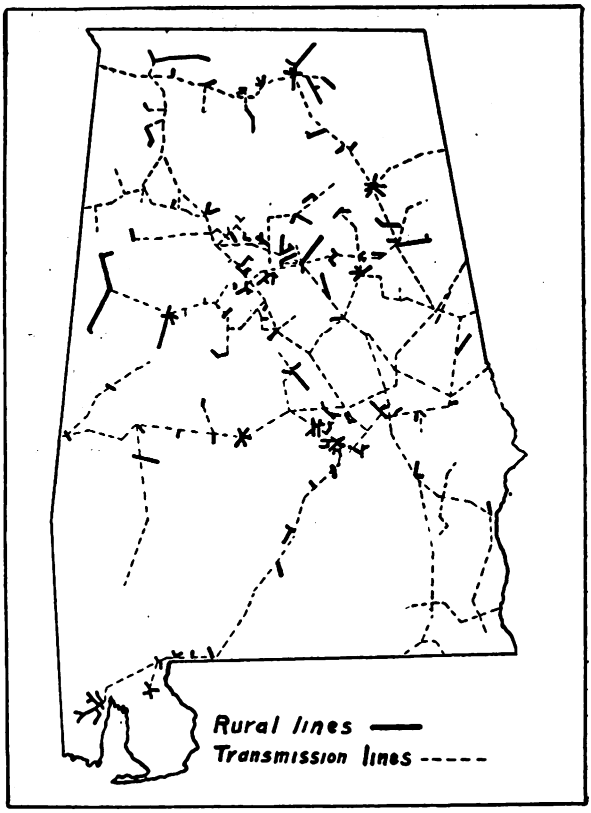


FIG. 2—DISTRIBUTION OF RURAL LINES AND THE TRANSMISSION SYSTEM OF ALABAMA POWER COMPANY. THE COMPANY HAS RURAL LINES IN 44 OF THE 67 COUNTIES OF THE STATE.

FARM POWER

Tractors	2,465
Horses 2 years of age and over	82,778
Mules 2 years of age and over	298,636
Average crop acres per work animal	20

POPULATION

State population (estimated)	2,453,214
Farm population	1,166,432

The farm population is 47.5 per cent of the State population.

Average population per farm	4.9
Farm population—white	730,145
Farm population—colored	436,287

LIVESTOCK

Cattle—total number	822,093
Milk cows	325,578
Milk production	95,364,944 gal.
Average production per cow	293 gal.
Beef cows—2 years old and over	165,065
Sheep	55,554
Goats	72,469
Swine	826,833
Chickens	6,284,460
Egg production	19,466,770 doz.
Chickens raised	9,527,321

Crops

	Acres	Average Yield per Acre
Corn	2,788,733	12.0 bushels
Wheat	6,070	10.0 bushels
Oats	84,853	15.0 bushels
Sorghum	23,867	....
Peanuts	253,827	19.5 bushels
Velvet beans	310,872	....
Navy beans	2,109	....
Hay	508,949	.73 tons
Cotton	2,948,072	.333 bales
Sugar cane and sorghum for syrup	35,020	....
Potatoes, white	16,695	98.0 bushels
Sweet potatoes and yams	48,443	77.0 bushels
Strawberries	3,125	....
Watermelons	20,608	....
Vegetables	8,198	....

Trees

Apple trees of bearing age	798,070	12.50 bush. per tree
Apple trees not of bearing age	426,342	
Peach trees	1,849,990	
Orange trees—bearing age	262,689	
Orange trees—not bearing age	359,126	
Pecan trees—bearing age	303,399	
Pecan trees—not bearing age	406,271	
Other fruit trees	317,034	

Vines

Grape vines	239,221

Value of all farm crops, $181,026,321.

Community Enterprises

Gins	1,525
Creameries and cheese plants	76
Canneries (1927)	18

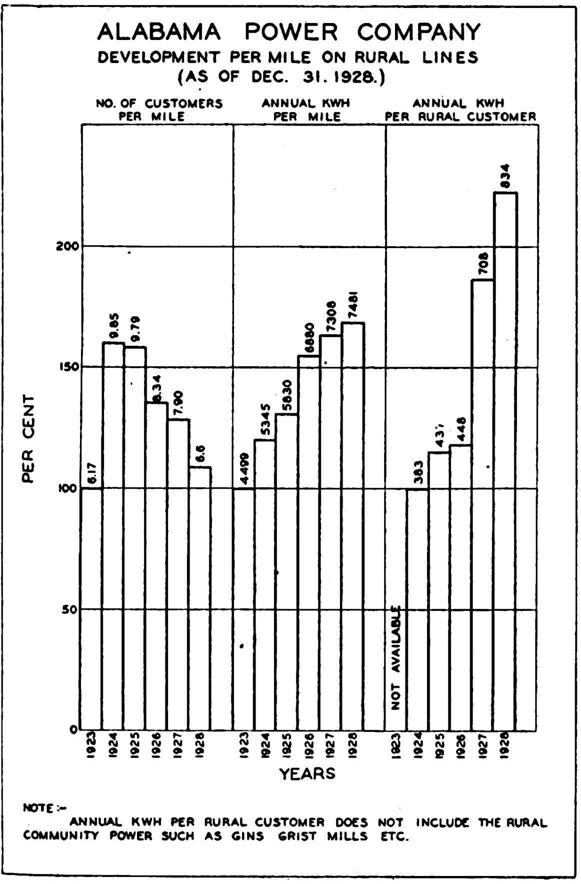
State Highways

The state highway system, which is under the supervision of the State Highway Department, comprises approximately 5600 miles of road. This is less than 10 per cent of the total road mileage of the State, and is classified as follows:

	Miles of Road
Paved	700
Gravel	1,705
Sand-clay	844
Improved dirt	768
Unimproved dirt	1,576

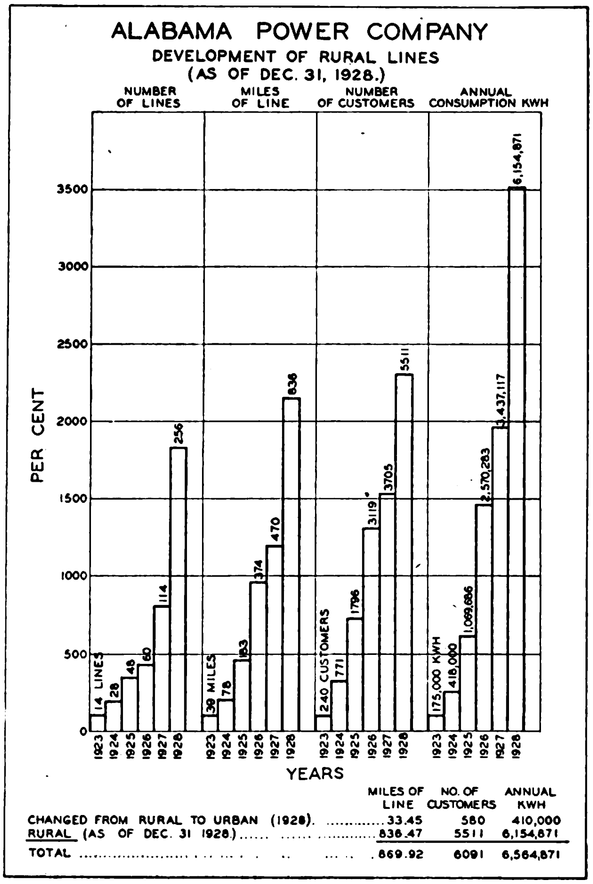
RURAL ELECTRIC DEVELOPMENT IN ALABAMA

The rural electric development by Alabama Power Company includes the expansion of electric service outside the corporate limits of towns and cities, serving less than twenty customers per mile of distribution line, and does not refer to purely farm service. On Jan. 1, 1929, the company was serving 5511 rural customers from 836.5 miles of lines, an average density of 6.8 customers per mile



NOTE:—
ANNUAL KWH PER RURAL CUSTOMER DOES NOT INCLUDE THE RURAL COMMUNITY POWER SUCH AS GINS GRIST MILLS ETC.

FIG. 3—Development per Mile on Rural Lines—Alabama Power Company.



	MILES OF LINE	NO. OF CUSTOMERS	ANNUAL KWH
CHANGED FROM RURAL TO URBAN (1928)	33.45	580	410,000
RURAL (AS OF DEC. 31 1928)	836.47	5511	6,154,871
TOTAL	869.92	6091	6,564,871

FIG. 4—Development of Rural Lines—Alabama Power Company.

of line. Approximately 70 per cent of the rural customers served at the date were farmers, and the company was serving 2000 farmers from distribution lines that are not classed as rural.

ORGANIZATION AND WORK OF RURAL SERVICE SECTION

The rural electrification work of the Alabama Power Company is organized as a section of the Rural and Towns Division of the Sales Department. At present the personnel of this section consists of a chief agricultural engineer, an assistant agricultural engineer and four agricultural engineers assigned to operating division offices. It is planned to expand this personnel to include one agricultural engineer for each division office, and ultimately when the number of rural customers increases sufficiently, it is expected that agricultural engineers will be assigned to district offices.

The work of the Rural Section consists primarily of developing the electrical consciousness in rural communities, which have requested electric service, to the point that there is available a sufficient load to justify the extension of new rural lines and assisting farmers and others already served in reaching the ultimate economic limit for uses of electricity. In this work there is a special effort made to recommend only such uses of electricity that will be a benefit to the customer. This necessitates that the men in this work be thoroughly familiar with practices, new developments and trends in agriculture in their territories, and speak a language which the farmer can understand. They must keep accurately informed as to applications of electricity and equipment best suited to the existing conditions and be able to assist the farmers in making changes in their methods of operation that will prove more profitable and make electricity more valuable to them.

Following are the main activities of the Rural Section:

(a) In answer to requests for electric service, community meetings and personal contact work is conducted to familiarize the prospective customers with the different uses of electricity applicable to the conditions, and with the company's rural rate.

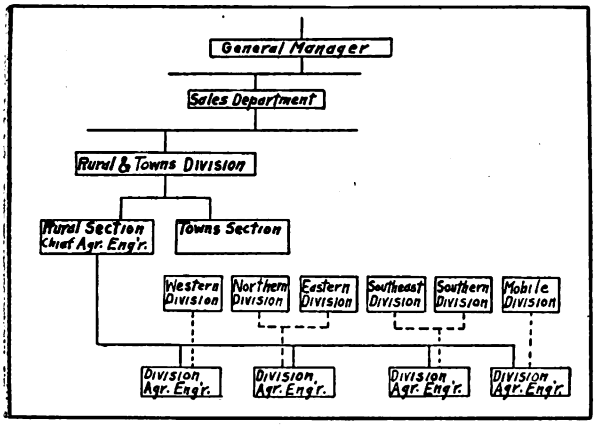


FIG. 5—ORGANIZATION OF ALABAMA POWER COMPANY FOR RURAL ELECTRIC DEVELOPMENT.

(b) If the results of this preliminary work indicate that electric service is feasible to the community requesting service, a complete commercial survey is made including map of proposed line with prospective customers and loads indicated.

(c) If the preliminary work indicates that the proposed line is not feasible at that time, the educational efforts are continued periodically at the request of the people until sufficient load is developed. In many instances this activity continues as long as two years or more before the project is developed to the point of signing customers.

(d) Where the farm operations are of considerable volume the rural service men make a detailed analysis and prepare a written report including time, labor and costs with and without electric service for each operation to assist the farmer in his problems. This is done for both prospective and existing customers.

(e) After the preliminary work is completed and surveys indicate that the extension will be feasible both to the company and the proposed customers, an effort is made to sign the customers for service, at which time the explanations are continued at considerable length with each prospective customer. Rural customers are signed by both the rural service men and by a crew of men in the Towns Section, who devote their entire efforts to making surveys and signing customers in new towns and on rural lines.

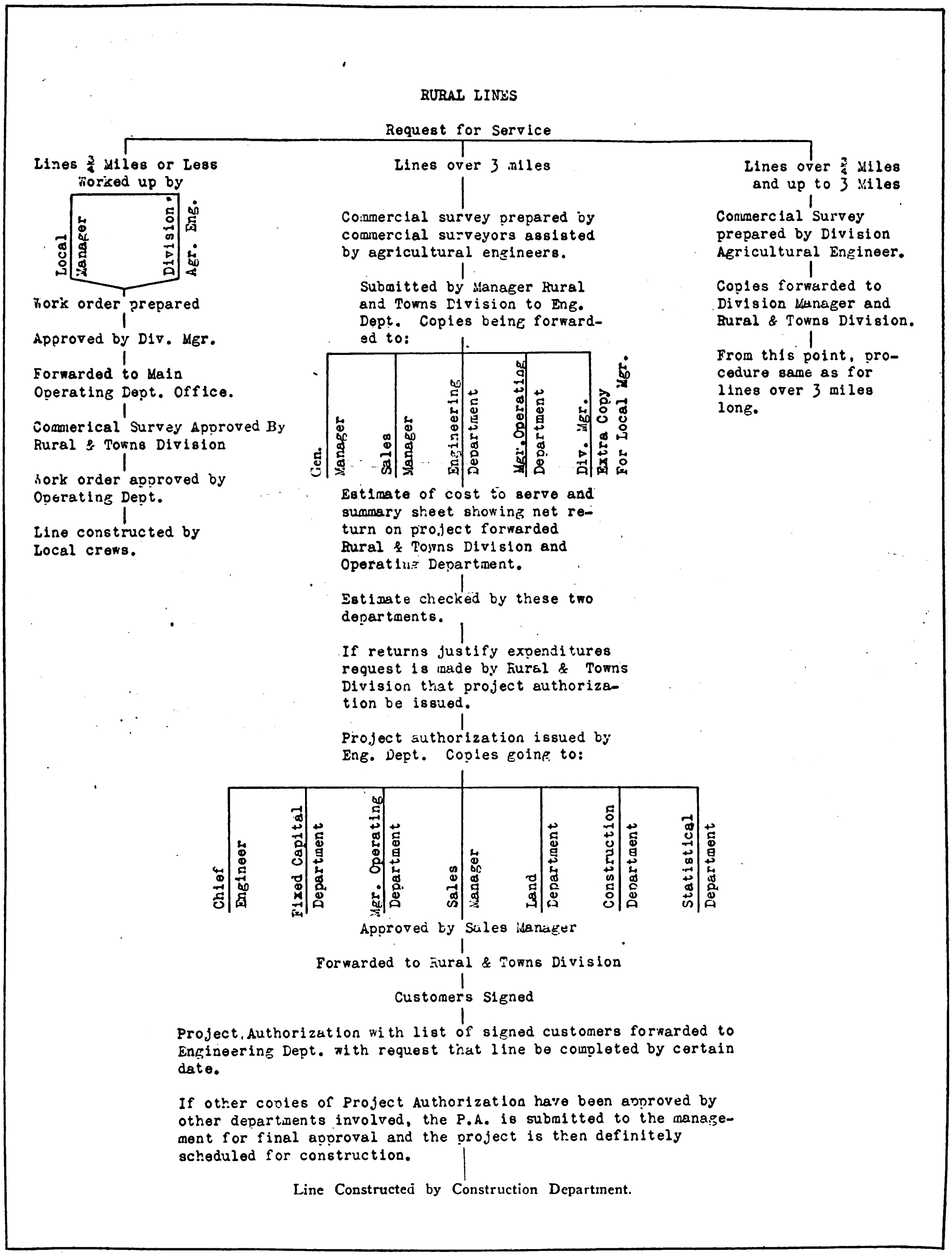
(f) As rural customers are signed, each customer indicates what equipment he intends to use. Then, when the customer signing is completed, a list of signed customers and equipment to be used by each is made and copies mailed to the Merchandise Sales Supervisor of the local territory in which the line is to be built. Salesmen, either alone or with the rural service man, follow through and make the sales of equipment that is handled by the company, and local dealers are advised of live prospects for equipment not sold by the company. Representatives of the Rural Section do not actually sell equipment, but cooperate with both the company's salesmen and local dealers in completing sales.

(g) After rural lines have been in operation for a year or more, the rural service men conduct periodical community meetings at which electrical equipment for the home and farm is discussed and demonstrated. These meetings are held in cooperation with the State Agricultural Extension Service and equipment manufacturers, and are usually confined to a limited list of equipment at any one meeting.

(h) The Rural Service Section is continuously analyzing reports pertaining to uses of electricity on the farm, and information that is considered applicable to local conditions is summarized and distributed through the rural service section.

(i) The rural service men make periodical calls on the customers to discuss with them their problems and to call to their attention new ideas pertaining to the use of electricity.

(j) The Rural Service Section aggressively presents to manufacturing companies equipment needs that are not at present met, and cooperates with the


RURAL LINES
Request for Service
Local Manager
Division Agr. Eng.
Gen. Manager
Sales Manager
Engineering Department
Mgr. Operating Department
Div. Mgr.
Extra Copy For Local Mgr.
Chief Engineer
Fixed Capital Department
Mgr. Operating Department
Sales Manager
Land Department
Construction Department
Statistical Department

Lines ¾ Miles or Less Worked up by

Work order prepared

Approved by Div. Mgr.

Forwarded to Main Operating Dept. Office.

Commerical Survey Approved By Rural & Towns Division

Work order approved by Operating Dept.

Line constructed by Local crews.

Lines over 3 miles

Commercial survey prepared by commercial surveyors assisted by agricultural engineers.

Submitted by Manager Rural and Towns Division to Eng. Dept. Copies being forwarded to:

Estimate of cost to serve and summary sheet showing net return on project forwarded Rural & Towns Division and Operating Department.

Estimate checked by these two departments.

If returns justify expenditures request is made by Rural & Towns Division that project authorization be issued.

Project authorization issued by Eng. Dept. Copies going to:

Approved by Sales Manager

Forwarded to Rural & Towns Division

Customers Signed

Project Authorization with list of signed customers forwarded to Engineering Dept. with request that line be completed by certain date.

If other copies of Project Authorization have been approved by other departments involved, the P.A. is submitted to the management for final approval and the project is then definitely scheduled for construction.

Line Constructed by Construction Department.

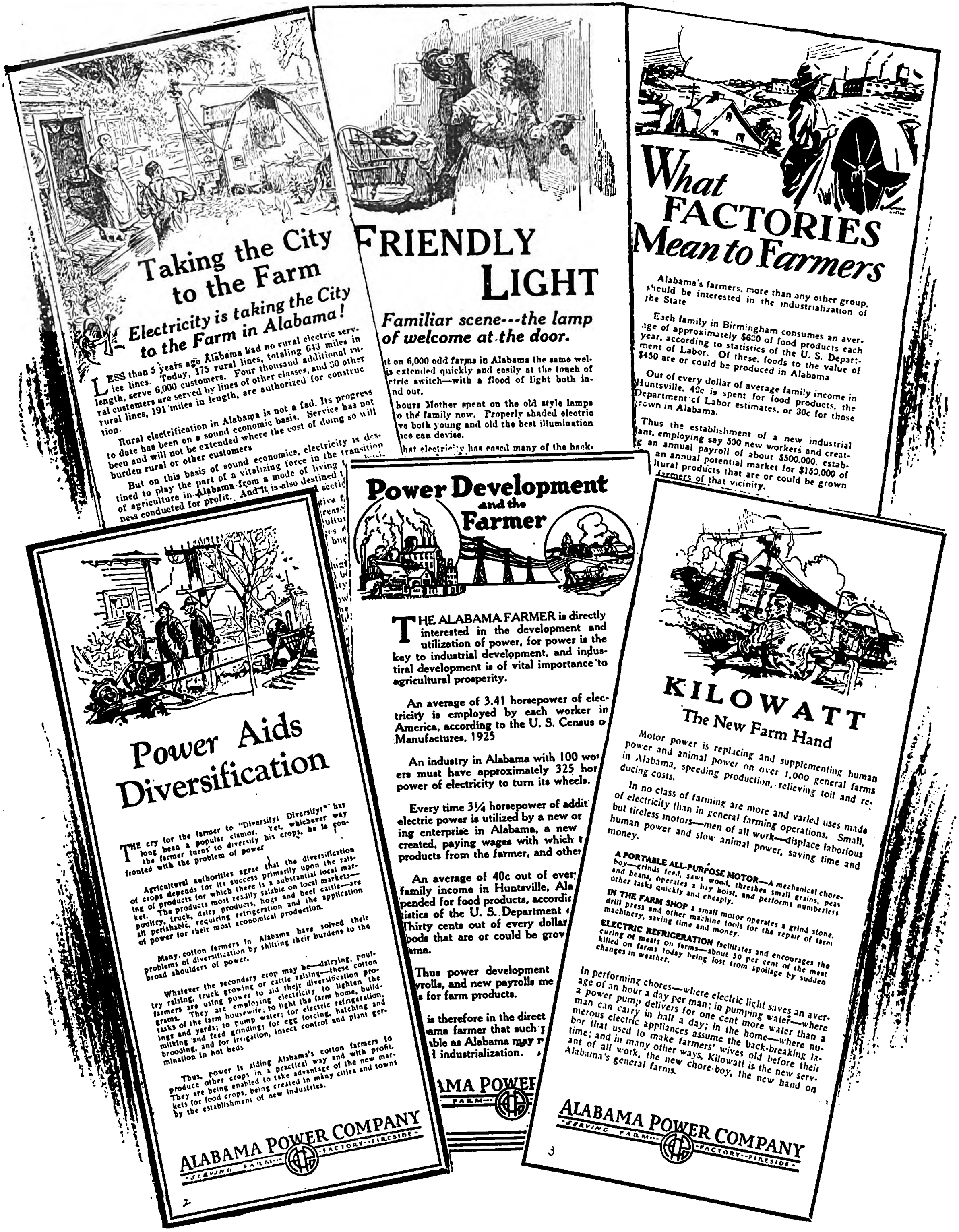
Lines over ¾ Miles and up to 3 Miles

Commercial Survey prepared by Division Agricultural Engineer.

Copies forwarded to Division Manager and Rural & Towns Division.

From this point, procedure same as for lines over 3 miles long.

FIG. 6—OUTLINE OF THE METHODS OF PROCEDURE WITHIN ALABAMA POWER COMPANY INCIDENT TO THE ESTABLISHING OF ELECTRIC SERVICE IN A RURAL COMMUNITY.



Taking the City to the Farm

Electricity is taking the City to the Farm in Alabama!

LESS than 5 years ago Alabama had no rural electric service lines. Today, 175 rural lines, totaling 643 miles in length, serve 6,000 customers. Four thousand additional rural customers are served by lines of other classes, and 30 other rural lines, 191 miles in length, are authorized for construction.

Rural electrification in Alabama is not a fad. Its progress to date has been on a sound economic basis. Service has not been and will not be extended where the cost of doing so will burden rural or other customers

But on this basis of sound economics, electricity is destined to play the part of a vitalizing force in the transition
of agriculture in Alabama from a mode of living t
ness conducted for profit. And it is also destined t

FRIENDLY LIGHT

Familiar scene---the lamp of welcome at the door.

it on 6,000 odd farms in Alabama the same wel-
is extended quickly and easily at the touch of
etric switch—with a flood of light both in-
nd out.

hours Mother spent on the old style lamps
o the family now. Properly shaded electric
ve both young and old the best illumination
nce can devise.

hat electricity has eased many of the back-

What FACTORIES Mean to Farmers

Alabama's farmers, more than any other group, should be interested in the industrialization of the State

Each family in Birmingham consumes an average of approximately $600 of food products each year, according to statistics of the U. S. Department of Labor. Of these, foods to the value of $450 are or could be produced in Alabama

Out of every dollar of average family income in Huntsville, 40c is spent for food products, the Department of Labor estimates, or 30c for those grown in Alabama.

Thus the establishment of a new industrial
lant, employing say 500 new workers and creat-
g an annual payroll of about $500,000, estab-
an annual potential market for $150,000 of
ltural products that are or could be grown
farmers of that vicinity.

Power Aids Diversification

THE cry for the farmer to "Diversify! Diversify!" has long been a popular clamor. Yet, whichever way the farmer turns to diversify his crops, he is confronted with the problem of power

Agricultural authorities agree that the diversification of crops depends for its success primarily upon the raising of products for which there is a substantial local market. The products most readily salable on local markets—poultry, truck, dairy products, hogs and beef cattle—are all perishable, requiring refrigeration and the application of power for their most economical production.

Many cotton farmers in Alabama have solved their problems of diversification by shifting their burdens to the broad shoulders of power.

Whatever the secondary crop may be—dairying, poultry raising, truck growing or cattle raising—these cotton farmers are using power to aid their diversification programs. They are employing electricity to lighten the tasks of the farm housewife; to light the farm home, buildings and yards; to pump water; for electric refrigeration, milking and feed grinding; for egg forcing, hatching and brooding, and for irrigation, insect control and plant germination in hot beds

Thus, power is aiding Alabama's cotton farmers to produce other crops in a practical way and with profit. They are being enabled to take advantage of the new markets for food crops, being created in many cities and towns by the establishment of new industries.

ALABAMA POWER COMPANY
SERVING FARM--FACTORY--FIRESIDE

2

Power Development and the Farmer

THE ALABAMA FARMER is directly interested in the development and utilization of power, for power is the key to industrial development, and industiral development is of vital importance to agricultural prosperity.

An average of 3.41 horsepower of electricity is employed by each worker in
America, according to the U. S. Census o
Manufactures, 1925

An industry in Alabama with 100 wo
ers must have approximately 325 ho
power of electricity to turn its wheels.

Every time 3¼ horsepower of addit
electric power is utilized by a new or
ing enterprise in Alabama, a new
created, paying wages with which t
products from the farmer, and othe

An average of 40c out of ever
family income in Huntsville, Ala
pended for food products, accordi
tistics of the U. S. Department
Thirty cents out of every dolla
oods that are or could be grov
ama.

Thus power development
yrolls, and new payrolls me
s for farm products.

is therefore in the direct
ama farmer that such
able as Alabama may
l industrialization.

AMA POWE
FARM--

KILOWATT

The New Farm Hand

Motor power is replacing and supplementing human power and animal power on over 1,000 general farms in Alabama, speeding production, relieving toil and reducing costs.

In no class of farming are more and varied uses made of electricity than in general farming operations. Small, but tireless motors—men of all work—displace laborious human power and slow animal power, saving time and money.

A PORTABLE ALL-PURPOSE MOTOR—A mechanical chore-boy—grinds feed, saws wood, threshes small grains, peas and beans, operates a hay hoist, and performs numberless other tasks quickly and cheaply.

IN THE FARM SHOP a small motor operates a grind stone, drill press and other machine tools for the repair of farm machinery, saving time and money.

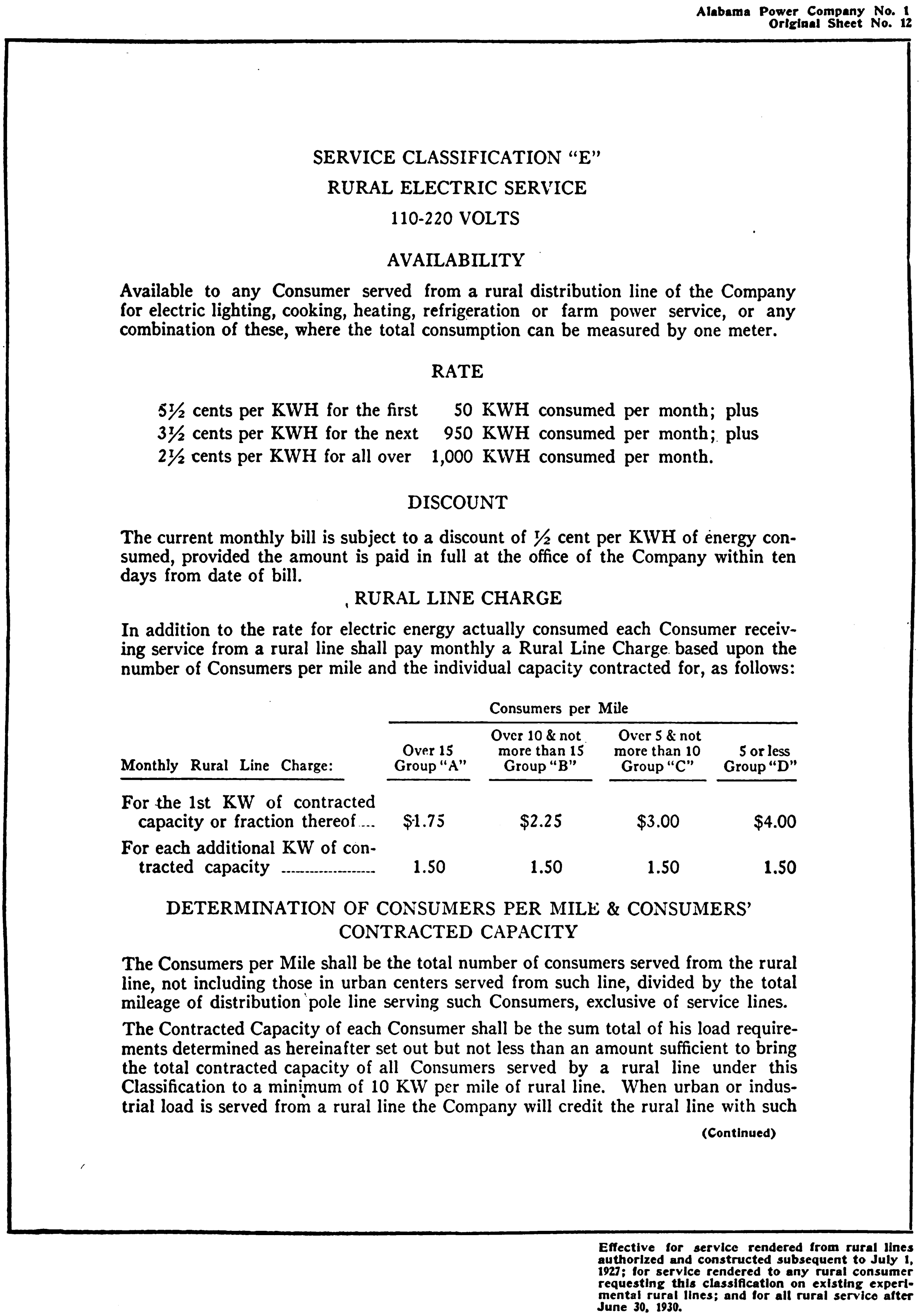
ELECTRIC REFRIGERATION facilitates and encourages the curing of meats on farms—about 50 per cent of the meat killed on farms today being lost from spoilage by sudden changes in weather.

In performing chores—where electric light saves an average of an hour a day per man; in pumping water—where a power pump delivers for one cent more water than a man can carry in half a day; in the home—where numerous electric appliances assume the back-breaking labor that used to make farmers' wives old before their time; and in many other ways, Kilowatt is the new servant of all work, the new chore-boy, the new hand on Alabama's general farms.

ALABAMA POWER COMPANY
SERVING FARM--FACTORY--FIRESIDE

3

FIG. 7—THE COMPANY USES NEWSPAPER ADVERTISING TO ACQUAINT FARMERS WITH THE POSSIBILITIES OF ELECTRICITY IN AGRICULTURE, AND ALSO TO EMPHASIZE THAT INDUSTRIAL DEVELOPMENT IN THE STATE CREATES ADDITIONAL MARKETS FOR AGRICULTURAL PRODUCTS.



Alabama Power Company No. 1
Original Sheet No. 12

SERVICE CLASSIFICATION "E"

RURAL ELECTRIC SERVICE

110-220 VOLTS

AVAILABILITY

Available to any Consumer served from a rural distribution line of the Company for electric lighting, cooking, heating, refrigeration or farm power service, or any combination of these, where the total consumption can be measured by one meter.

RATE

5½ cents per KWH for the first 50 KWH consumed per month; plus
3½ cents per KWH for the next 950 KWH consumed per month; plus
2½ cents per KWH for all over 1,000 KWH consumed per month.

DISCOUNT

The current monthly bill is subject to a discount of ½ cent per KWH of energy consumed, provided the amount is paid in full at the office of the Company within ten days from date of bill.

RURAL LINE CHARGE

In addition to the rate for electric energy actually consumed each Consumer receiving service from a rural line shall pay monthly a Rural Line Charge based upon the number of Consumers per mile and the individual capacity contracted for, as follows:

	Consumers per Mile			
Monthly Rural Line Charge:	Over 15 Group "A"	Over 10 & not more than 15 Group "B"	Over 5 & not more than 10 Group "C"	5 or less Group "D"
For the 1st KW of contracted capacity or fraction thereof....	$1.75	$2.25	$3.00	$4.00
For each additional KW of contracted capacity	1.50	1.50	1.50	1.50

DETERMINATION OF CONSUMERS PER MILE & CONSUMERS' CONTRACTED CAPACITY

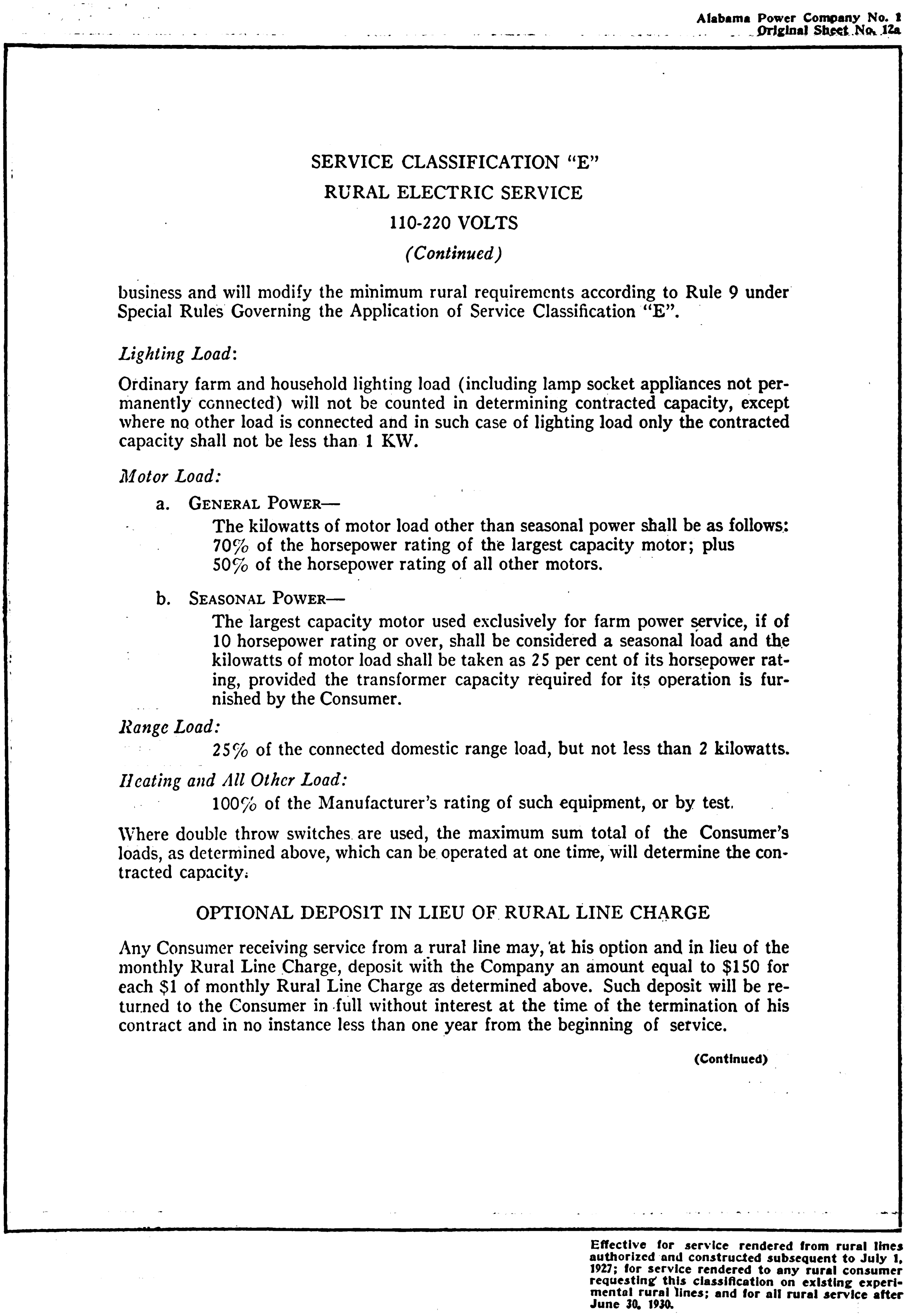
The Consumers per Mile shall be the total number of consumers served from the rural line, not including those in urban centers served from such line, divided by the total mileage of distribution pole line serving such Consumers, exclusive of service lines.

The Contracted Capacity of each Consumer shall be the sum total of his load requirements determined as hereinafter set out but not less than an amount sufficient to bring the total contracted capacity of all Consumers served by a rural line under this Classification to a minimum of 10 KW per mile of rural line. When urban or industrial load is served from a rural line the Company will credit the rural line with such

(Continued)

Effective for service rendered from rural lines authorized and constructed subsequent to July 1, 1927; for service rendered to any rural consumer requesting this classification on existing experimental rural lines; and for all rural service after June 30, 1930.

FIG. 8—SERVICE CLASSIFICATION "E," RURAL ELECTRIC SERVICE—PAGE 1, ALABAMA POWER COMPANY.



Alabama Power Company No. 1
Original Sheet No. 12a

SERVICE CLASSIFICATION "E"
RURAL ELECTRIC SERVICE
110-220 VOLTS
(Continued)

business and will modify the minimum rural requirements according to Rule 9 under Special Rules Governing the Application of Service Classification "E".

Lighting Load:

Ordinary farm and household lighting load (including lamp socket appliances not permanently connected) will not be counted in determining contracted capacity, except where no other load is connected and in such case of lighting load only the contracted capacity shall not be less than 1 KW.

Motor Load:

a. GENERAL POWER—
The kilowatts of motor load other than seasonal power shall be as follows:
70% of the horsepower rating of the largest capacity motor; plus
50% of the horsepower rating of all other motors.

b. SEASONAL POWER—
The largest capacity motor used exclusively for farm power service, if of 10 horsepower rating or over, shall be considered a seasonal load and the kilowatts of motor load shall be taken as 25 per cent of its horsepower rating, provided the transformer capacity required for its operation is furnished by the Consumer.

Range Load:
25% of the connected domestic range load, but not less than 2 kilowatts.

Heating and All Other Load:
100% of the Manufacturer's rating of such equipment, or by test.

Where double throw switches are used, the maximum sum total of the Consumer's loads, as determined above, which can be operated at one time, will determine the contracted capacity.

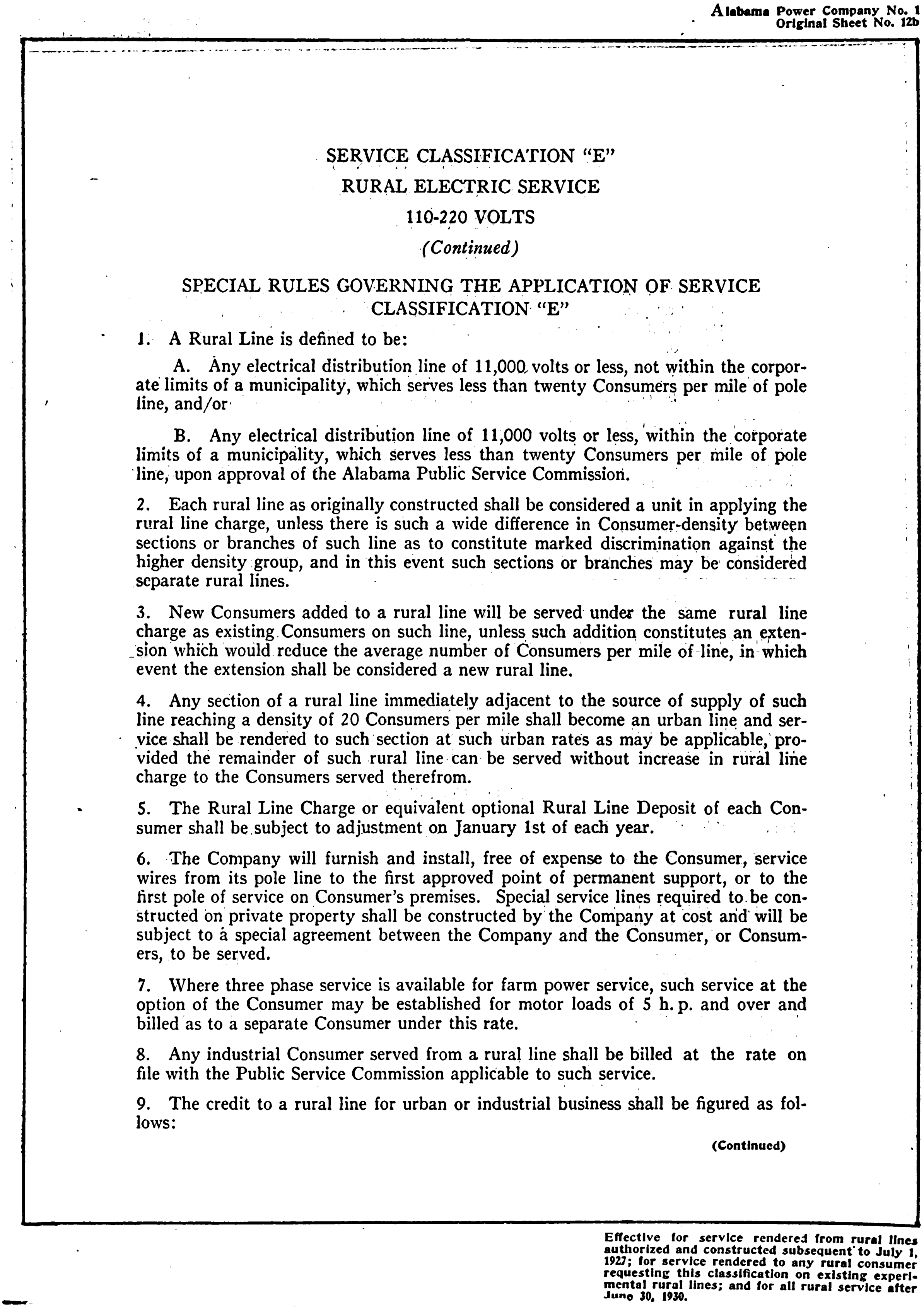
OPTIONAL DEPOSIT IN LIEU OF RURAL LINE CHARGE

Any Consumer receiving service from a rural line may, at his option and in lieu of the monthly Rural Line Charge, deposit with the Company an amount equal to $150 for each $1 of monthly Rural Line Charge as determined above. Such deposit will be returned to the Consumer in full without interest at the time of the termination of his contract and in no instance less than one year from the beginning of service.

(Continued)

Effective for service rendered from rural lines authorized and constructed subsequent to July 1, 1927; for service rendered to any rural consumer requesting this classification on existing experimental rural lines; and for all rural service after June 30, 1930.

FIG. 9—SERVICE CLASSIFICATION "E," RURAL ELECTRIC SERVICE—PAGE 2, ALABAMA POWER COMPANY.



Alabama Power Company No. 1
Original Sheet No. 12b

SERVICE CLASSIFICATION "E"
RURAL ELECTRIC SERVICE
110-220 VOLTS
(Continued)

SPECIAL RULES GOVERNING THE APPLICATION OF SERVICE CLASSIFICATION "E"

1. A Rural Line is defined to be:

A. Any electrical distribution line of 11,000 volts or less, not within the corporate limits of a municipality, which serves less than twenty Consumers per mile of pole line, and/or

B. Any electrical distribution line of 11,000 volts or less, within the corporate limits of a municipality, which serves less than twenty Consumers per mile of pole line, upon approval of the Alabama Public Service Commission.

2. Each rural line as originally constructed shall be considered a unit in applying the rural line charge, unless there is such a wide difference in Consumer-density between sections or branches of such line as to constitute marked discrimination against the higher density group, and in this event such sections or branches may be considered separate rural lines.

3. New Consumers added to a rural line will be served under the same rural line charge as existing Consumers on such line, unless such addition constitutes an extension which would reduce the average number of Consumers per mile of line, in which event the extension shall be considered a new rural line.

4. Any section of a rural line immediately adjacent to the source of supply of such line reaching a density of 20 Consumers per mile shall become an urban line and service shall be rendered to such section at such urban rates as may be applicable, provided the remainder of such rural line can be served without increase in rural line charge to the Consumers served therefrom.

5. The Rural Line Charge or equivalent optional Rural Line Deposit of each Consumer shall be subject to adjustment on January 1st of each year.

6. The Company will furnish and install, free of expense to the Consumer, service wires from its pole line to the first approved point of permanent support, or to the first pole of service on Consumer's premises. Special service lines required to be constructed on private property shall be constructed by the Company at cost and will be subject to a special agreement between the Company and the Consumer, or Consumers, to be served.

7. Where three phase service is available for farm power service, such service at the option of the Consumer may be established for motor loads of 5 h. p. and over and billed as to a separate Consumer under this rate.

8. Any industrial Consumer served from a rural line shall be billed at the rate on file with the Public Service Commission applicable to such service.

9. The credit to a rural line for urban or industrial business shall be figured as follows:

(Continued)

Effective for service rendered from rural lines authorized and constructed subsequent to July 1, 1927; for service rendered to any rural consumer requesting this classification on existing experimental rural lines; and for all rural service after June 30, 1930.

FIG. 10—Service Classification "E," Rural Electric Service Page 3, Alabama Power Company.

SERVICE CLASSIFICATION "E"

RURAL ELECTRIC SERVICE

110-220 VOLTS

(Continued)

a. *Equivalent Rural Consumers:* To be found by taking four times the estimated first year's revenue to be received from the urban or industrial load less the initial cost to connect such additional load and dividing the remainder by 200.

b. *Contracted Capacity*: Each equivalent Rural Consumer as determined above shall be considered as having one (1) kilowatt of contracted capacity.

NOTE: Rule 9 is based on the Company being willing to spend four times the initial annual revenue to obtain urban or industrial business served from a rural line and upon an average revenue per rural Consumer of $50.00 per year. Reduced to a formula Rule 9-a becomes:

Equivalent Rural Consumers equals

$$\frac{\text{Estimated First Year's Revenue}}{\$50} \text{ less } \frac{\text{Estimated Initial Cost to Connect}}{\text{4 times } \$50}\text{, or}$$

$$\frac{\text{(4 times Estimated First Year's Revenue) minus (Initial Cost to Connect).}}{200}$$

MINIMUM

In consideration of the readiness of the Company to furnish such service, a monthly minimum charge equal to the Rural Line Charge will be made.

TERM OF CONTRACT

Service under this Classification shall be for a period of not less than:

(1) Five years on rural lines having an average of not over five (5) Consumers per mile of line,

(2) Three years on rural lines having an average of not less than five (5) and not over ten (10) Consumers per mile of line,

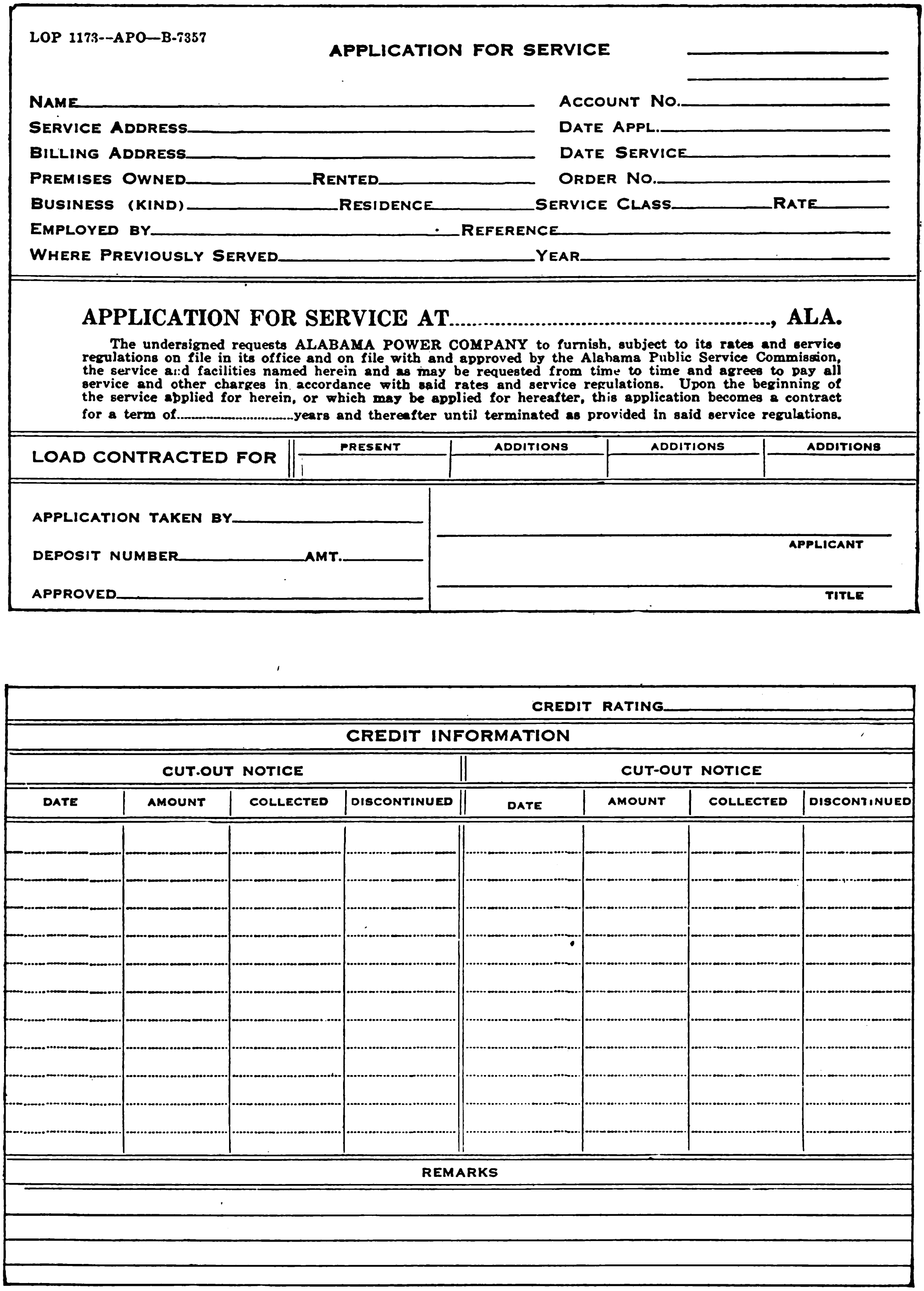
(3) One year on rural lines having an average of more than ten (10) Consumers per mile of line,

and thereafter from year to year, unless terminated by thirty (30) days written notice.

Service under this Classification is subject to
Rules and Regulations approved or prescribed
by the Alabama Public Service Commission.

Effective for service rendered from rural lines authorized and constructed subsequent to July 1, 1927; for service rendered to any rural consumer requesting this classification on existing experimental rural lines; and for all rural service after June 30, 1930.

FIG. 11—SERVICE CLASSIFICATION "E," RURAL ELECTRIC SERVICE—PAGE 4, ALABAMA POWER COMPANY.



LOP 1173--APO—B-7357

APPLICATION FOR SERVICE

Name
Service Address
Billing Address
Premises Owned Rented
Business (Kind) Residence
Employed by
Where Previously Served

Account No.
Date Appl.
Date Service
Order No.
Service Class Rate
Reference
Year

APPLICATION FOR SERVICE AT ……………, ALA.

The undersigned requests ALABAMA POWER COMPANY to furnish, subject to its rates and service regulations on file in its office and on file with and approved by the Alabama Public Service Commission, the service and facilities named herein and as may be requested from time to time and agrees to pay all service and other charges in accordance with said rates and service regulations. Upon the beginning of the service applied for herein, or which may be applied for hereafter, this application becomes a contract for a term of …………… years and thereafter until terminated as provided in said service regulations.

	PRESENT	ADDITIONS	ADDITIONS	ADDITIONS
LOAD CONTRACTED FOR				

Application taken by
Deposit Number Amt.
Approved

Applicant

Title

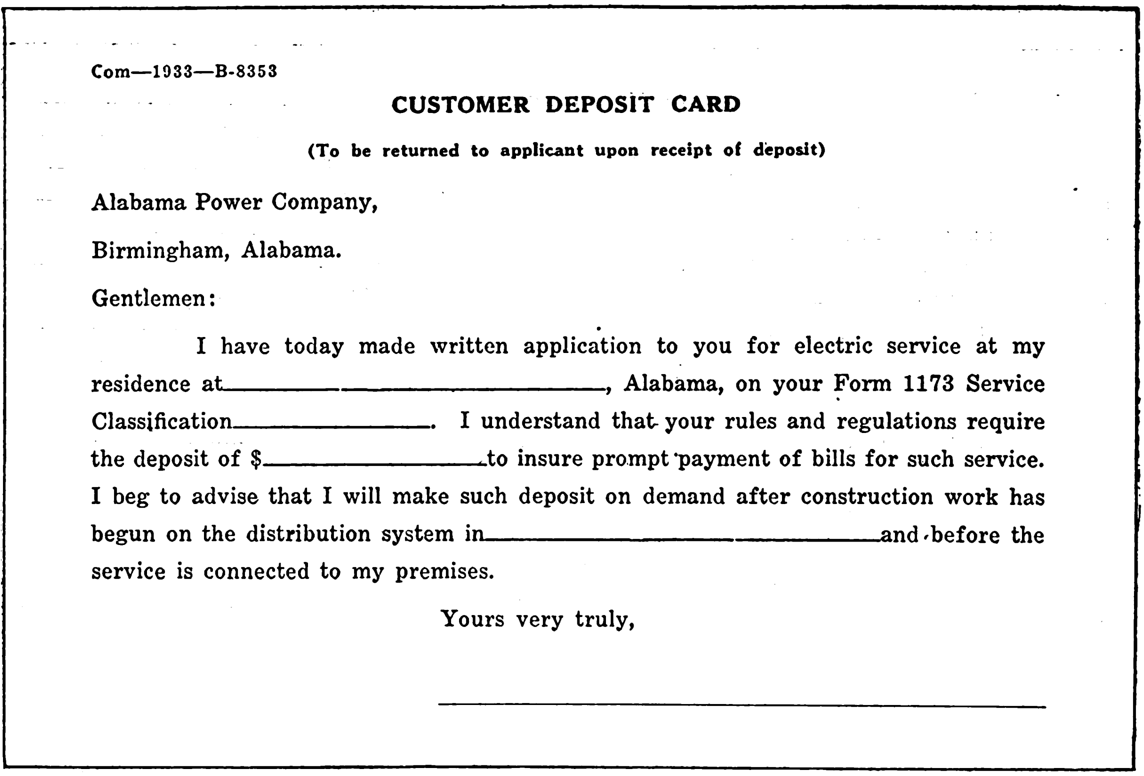
Credit Rating

CREDIT INFORMATION

CUT-OUT NOTICE				CUT-OUT NOTICE			
DATE	AMOUNT	COLLECTED	DISCONTINUED	DATE	AMOUNT	COLLECTED	DISCONTINUED

REMARKS

FIG. 12—Application for Service Form, Alabama Power Company.



Com—1933—B-8353

CUSTOMER DEPOSIT CARD

(To be returned to applicant upon receipt of deposit)

Alabama Power Company,

Birmingham, Alabama.

Gentlemen:

I have today made written application to you for electric service at my residence at____________________, Alabama, on your Form 1173 Service Classification_______________. I understand that your rules and regulations require the deposit of $_______________to insure prompt payment of bills for such service. I beg to advise that I will make such deposit on demand after construction work has begun on the distribution system in____________________and before the service is connected to my premises.

Yours very truly,

____

FIG. 13—CUSTOMER DEPOSIT CARD, ALABAMA POWER COMPANY.

manufacturers in the development of equipment needed for local conditions.

(k) When a farmer requests information for special installations, the Rural Service Section furnishes all available information and refers the prospect to such manufacturing companies that have shown ability and willingness to insure proper installations.

(l) Through the Manager of the Rural and Towns Division, the Engineering and Operating Departments are informed as to the nature of rural load affecting the construction and operation of rural lines. A consistent effort is made to prevent the lagging of rural line construction too far behind the signing of customers.

(m) In cooperation with the company's Publicity Department, the Rural Service Section prepared a thirty-two page booklet entitled "Electricity Serves the Farm." Ten thousand copies of this booklet were published and distributed, mainly to farmers of the State.

(n) The Rural Service Section cooperates with the Publicity Department in the preparation of advertising and news items for newspapers and magazines. The company's slogan is "Serving Farm, Factory and Fireside."

(o) Copies of "Electricity on the Farm" are distributed regularly to a selected list of 300 farm customers.

(p) The Rural Service Section cooperates with other agricultural agencies of the State in problems pertaining to the use of electricity in agriculture. An annual report of the Progress of Rural Electrification is made to the Director of Agricultural Extension Service. Information as to the development of rural electric service is furnished the Agricultural Editor of the Extension Service.

(q) Close cooperation is maintained with the National Committee on the Relation of Electricity to Agriculture and the Rural Electric Service Committee of the National Electric Light Association, in the effort to make available more general and specific information as to rural electrification.

(r) The Rural Service Section keeps records of individual customers, rural lines and different equipment, necessary to keep an accurate check of the development's progress. A monthly report is made to the management, including the number of customers, number of lines and miles of lines added during the month, the total on the first of each month, the projects authorized and under construction and those under consideration.

A detailed annual report is made to the management, including customers, miles of lines and annual kilowatt-hour sales, with the progress made during the year in the different parts of the activity, as load building and increased energy consumption per rural customer, and per mile of rural line.

Selling Equipment to Rural Customers

Equipment handled by the company is sold to rural customers by representatives of the Merchandise Division. In case a rural customer desires equipment not sold by the company, arrangements are made to have his needs taken care of either by a local dealer or by the manufacturing company.

The company handles the usual line of electrical equipment, including ranges, water heaters, household refrigerators, washing machines and small appliances for the home. In addition, the company sells a line of water pumps especially for small town and rural customers.

Other equipment demanded by farmers, including dairy refrigerators, feed grinders, overhead irrigation systems, milking machines, incubators, brooders and motors, is sold by local dealers or factory representatives. The general sales plan is through the "live prospect" approach. These prospects are turned in by the rural service men. Prospects are found by the rural service men at the time of signing customers, or by the customers writing to the Rural Service Section for information pertaining to the use of some piece of equipment.

For equipment sold by the company the same term payments are offered to rural customers as to other classes of customers. These terms vary with different pieces of equipment.

The most important items sold to rural customers from a satisfactory load building standpoint are ranges, dairy refrigerators, household refrigerators and water systems. It is probable that farm refrigeration in its different ramifications will become the base load for rural electrification in this State. Sales efforts are turning in this direction.

Meter Reading and Billing Rural Customers

Meter reading and billing rural customers is handled just as the other classes of customers served by the company. Meters are read each month by the regular meter readers, and bills are rendered monthly by the Accounting Department.

Developing Appreciation of Rural Electric Service

Within the Company

Realizing that the success of rural electric development is dependent upon making it a part of the company's general program, rather than purely the activity of a separate division, those directly connected with this work have continuously attempted to sell the other departments of the company as to the progress and results obtained. This effort is through direct contact with employees of the different departments and through the preparation of monthly and annual progress reports. However, with the method of procedure followed by this company practically every department has an active part in the development just as with other classes of service. The surveys for new proposed lines are made by the Towns Division, the engineering is handled by the Engineering Department, the lines are built by the construction company, household equipment is sold to rural customers by the Merchandise Division, the lines are operated and service maintained by the Operating and Service Departments, and the rural customer billing and collecting is taken care of by the Accounting Department. Therefore, each department is somewhat familiar with the progress of the development.

Among Rural People

Interest in rural electric service was created in Alabama through exhibits at state and county fairs for two seasons, illustrating some of the uses and advantages of electricity, and through the progress of the experimental work conducted by the company and the Agricultural Experiment Station for a period of three years. This interest in and the appreciation of the value of electric service is maintained and developed among rural customers through education work conducted through direct contact with proposed and existing customers, and through cooperation with other agricultural agencies of the State. For example: In 1927 the company, in cooperation with the Dairy Department of the Agricultural Extension Service and the International Harvester Company, held a series of meetings throughout the State at which dairy equipment was discussed and demonstrated. In 1928 a series of meetings were held throughout the State in cooperation with the Home Demonstration Agents, and the Edison Electric Appliance Co. At these meetings the uses of electrical household appliances for the farm home were discussed and demonstrated. The agricultural engineers of the company devote the major part of their time in an effort to educate proposed and existing rural customers as to profitable applications of electricity. In 1928, as a part of its load-building program, the company published a farm booklet, discussing and illustrating some of the uses of electricity on Alabama farms. These booklets have been distributed among the existing and proposed rural customers.

Results and Effects

Number of rural lines Jan. 1, 1924	14
Number of rural lines Jan. 1, 1929	256
Miles of rural lines, Jan. 1, 1924	39
Miles of rural lines, Jan. 1, 1929	836.5
Number of rural customers Jan. 1, 1924	240
Number of rural customers Jan. 1, 1929	5,511

ANNUAL KW-HR. CONSUMPTION PER RURAL CUSTOMER

Lines Built	Dec. 31, 1927	Dec. 31, 1928
1928	...	670
1927	...	728
1926	445	512
1925	629	671
1924 (or earlier)	900	1260
Total	708	834

The 256 lines are not only serving the present rural customers, but are also sources of electric service for additional extensions in the future development.

The company has an organization for conducting rural electric service work, actively engaged in an effort to build additional rural lines and to increase the load on existing rural lines.

The company had designed a rate for rural electric service, which has established rural electrification as a definite part of the company's development on a business basis.

The farmer's interest in the uses of electric service has been created and developed very rapidly.

The farmers of the State understand that the power company is perfectly willing and anxious to attempt in every way economically possible to extend service to them. They also appreciate the fact that if rural electric service is to be successful it must be satisfactory to the customers and the company.

The company realizes that it is possible to develop a satisfactory rural load.

The average energy consumption by rural customers has increased from 383 kw-hr. in 1924 to 834 kw-hr. in 1928.

Rural electric service is:

1. Resulting in more comfortable and attractive living conditions on the farm.
2. Creating new interest in farming as a life occupation.
3. Reducing farm operating costs and making practical a better balanced farming program.
4. Making available a source of convenient power for the operation of rural community enterprises.
5. Establishing a better mutual understanding between the farmers and the company.

RURAL LINES AND SYSTEMS

I. Types of Systems

(a) 2300 and 4000-volt systems.
(b) 6900-volt systems.
(c) 11,500-volt systems.

The 2300 and 4000-volt systems are merely short extensions of existing urban distribution systems which are extended into rural territory. The 6900-volt, 3 ø lines were first constructed when it developed that the 2300 and 4000-volt lines did not have capacity to supply the loads as found in the rural territory in Alabama. The majority of these lines have been reconnected as four-wire systems for 11,000-volt operation. Practically all of the rural lines now being constructed by the company are 11,000-volt systems.

These lines are supplied either from step-up banks located at the end of an urban feeder or from separate rural distribution substations. These are usually 44,000 to 6900-volt Y substations, equipped with automatic reclosing circuit breaker and ground relay protection which opens the circuit in case the conductor falls to the ground.

II. Line Construction

Lines are constructed according to the following general specifications:

(a) Right of way:

Lines are constructed along the margin of the public road, permission being obtained from state or county authorities. Tree trimming and anchor rights are obtained from individual property owners.

(b) Poles:

35 ft. 6 in. top creosoted pine.

(c) Cross arms:

Standard N. E. L. A. 6-pin arms with standard braces and hardware.

(d) Conductors:

Conductors are either hard-drawn copper or aluminum cable steel reinforced.

(e) Pins:

Standard wood pins are used on straight line construction. A clamp-on steel pin for small angles and dead end with strain insulators on angles 30 deg. and over.

(f) Insulators:

Insulators are standard 17 kv. porcelain pin type.

NOTE: Even though lines are built to operate at 2300 or 6900 volts, they usually are insulated for 11,000-volt operation, in view of changing over to this voltage as load conditions may require.

(g) Pole Spacing:

Pole spacing is approximately 275 ft. with copper conductors, and 325 to 350 ft. with aluminum. Highway conditions often make it impossible to obtain a 325-ft. span, in which case the company has found it more economical to use copper conductors.

(h) Anchoring:

Angles of 7 deg. and less usually are held by raking the pole without anchoring. Angles of over 7 deg. are supported with one or two patented anchors as required.

Pole setting and wire stringing is done in accordance with the National Electric Safety Code.

III. Secondary Service

Secondary service usually is furnished at 110-220 1 ø or 220 3 ø. Transformers are standard distribution transformers protected with open type of fuses and standard lightning arresters.

On the majority of systems of the Alabama Power Company it is found economical to string secondary systems and connect several customers from the same transformer bank.

BUILDING THE LOAD ON THE FARM

FOREWORD

There has been serious question in the minds of many people as to whether an acceptable load for electric light and power companies can be developed on the 6,371,640 farms in the United States. This serial report is being published by the Rural Electric Service Committee as some evidence, at least, that such a load exists and that it can be developed by intelligent effort.

This term "acceptable load" calls for some explanation. To one unfamiliar with the problem of extending electric light and power company service to the farm, this talk of building a bigger and bigger consumption on the farm might be suggestive of greed on the part of the companies. No such conclusion is warranted by the facts. Those familiar with the problem know that if scattered farm customers are to be small and conservative users of electric energy it is well nigh impossible to extend that service to them at a price acceptable to the company and at the same time not prohibitive to the farmers.

An Acceptable Load

It follows, therefore, that the only way to reach the American farm with power company service is to make the farmer a relatively large consumer. This is vital, but the industry must not lose sight of the fact that in increasing the farm customer consumption it must show the farmer how to use this additional amount of electric current to his own advantage.

This naturally brings up the question of what constitutes a small and conservative user and what constitutes an acceptable load. Of course, the figures offered in answer to both these questions vary according to conditions. As rural service is largely a problem of distribution costs, it must be obvious that where there are ten to fifteen farm customers to a mile of line there is less necessity for load building than in rural districts where there are from one to three customers to the mile.

Those Scattered Farms

Under average conditions throughout the United States there are fewer than three potential farm customers to a mile and it is on this average condition that the answer to these two questions will be made. Farmers using 300 kw-hr. a year under these conditions clearly and certainly fall into the class of small and conservative users, which is to say that if the company is to earn a fair return on such service it must maintain a rate well-nigh prohibitive to the farmer; at least a rate which necessitates the farmer counting electric service as something of a luxury.

It is more difficult to answer the second question as to how much current a farmer must use under these average conditions to make electric service really feasible to him and at the same time acceptable to the company. There is no definite figure which can be offered as an answer, but those who speak with more or less authority are generally agreed that when the farmer uses 1200 kw-hr. a year, it is perfectly feasible for the company to establish a rate acceptable to both the company and the farmer.

This figure of 1200 kw-hr. a year, when compared with conditions existing a few years ago when the electric industry first went into partnership with other agencies in seeking a solution of this problem, sounds rather high. It represents about four times the old average per farmer per year. This comparatively small average consumption of several years ago pertained generally throughout the nation, excepting in arid agricultural districts where electricity was in demand for water pumping. Outside of the areas where electricity was in demand for pumping of water for irrigation purposes, 300 kw-hr. a year represented average farm consumption.

Multiplying Consumption

Naturally an existing average consumption of 300 kw-hr. a year some five or six years ago and the necessity for quadrupling this consumption to make the farm service feasible, gave rise to doubts in the minds of many as to whether it ever could be done. Much, however, can be learned in five years, and at the meeting of the Rural Electric Service Committee of the National Electric Light Association held in Chicago in September, 1928, it was determined to obtain some idea of what kind of a load actually has been built on farms since we began developing real facts. In going about this job it was determined to gather data from every part of the United States so that no one could say: "Oh, probably a load can be built with the type of agriculture they have in other parts of the country, but in our state it is different."

A communication was sent by the Rural Electric Service Committee to every state in the union asking for from three to five examples of actual farmers using in excess, not of 1200 kw-hr. a year but of 3000 kw-hr. a year. It was specified that the National Committee did not wish the names of city men operating farms as playthings, but of real farmers wresting a living from the soil. In a few instances this admonition was not heeded, but in the vast majority of cases it was strictly adhered to.

Returns have been received and will be found in this report from almost every state in the union. Some states sent only the minimum of three examples asked for, some sent five and some sent many times the number requested, and many offered to send numerous others on request.

Ten Times Old Average

Listed in this report, as visual evidence that an acceptable load can be built on the farm, are the

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Publication No. 289-65. Serial Report, Rural Electric Service Committee.

names of these farmers, their addresses and current consumption, and a brief summary of the purposes for which the electricity is employed. It will be noted in going over this list that the modern farmer does not stop at 3000 kw-hr. a year, but that he uses 4000, 5000, 10,000 and 20,000 kw-hr. a year and does not stop even there.

When it is taken into consideration that this building of a load on the farm still is in its infancy there is much cause for gratification in the fact that at this early period almost every one of our forty-eight states offers examples of farms using in excess of ten times the old average. It is probable that the few states missing from the list have similar examples, though the companies in those states failed to answer the questionnaire.

Some of those who study this list may suggest that dairy and poultry farming predominate. This is true, and quite naturally so. When the study of applying electricity to agriculture first was taken up seriously, the investigators started in on the jobs nearest at hand—on the use which appeared most obvious. It was found on dairy farms that there were so many things that were just "crying out loud" for electricity that the investigators took them on first. To a large extent this also was true of poultry farming. Hence the predominance in this list of dairy and poultry farms.

A close study will reveal, however, that many of the services rendered by electricity on dairy and poultry farms can be equally well employed on any farm and it will be further revealed that uses for electricity are being developed on other types of farms.

Every Type of Farm Has Possibilities

Electricity operated water systems and refrigerators occur frequently in the description of the various uses to which electricity is being put on dairy and poultry farms. Both these improvements are equally essential on every farm. It will be found that in the Pacific Northwest electricity is playing its part in operating prune driers, operating hop ranches and driving spray pumps on fruit ranches. There is one mention of an electrical honey extractor and there are several mentions of electric motors employed in farm shops to drive lathes, drills and other tools. It has been contended in the South that cotton farming did not lend itself readily to the application of electricity, but at a rural conference held last November in Dallas, Texas, an interesting paper was read on the employment of electrically operated pumps to irrigate cotton lands. The figures showed that the experiment in cotton irrigation was very much of a success.

For household purposes electricity is just as important on the cotton plantation, or on one of the big wheat farms in the central West or Northwest, as it is on any other kind of a farm, and as the investigators proceed they likely will find in this virgin field plenty of advantageous uses for electric energy in all types of farming.

In the more distant future there is the idea of employing electric power in field work. Little is known about this as yet, but a number of individuals are working on this problem and if a successful solution can be found it will open up a bigger field for electric power in agriculture than anything that has so far been explored.

The National Experimental Project located in the State of Maryland will be utilized for a considerable exploration along this line.

How Load Has Been Built

Those most intimately in touch with this work feel that so far only the surface has been scratched and that beyond lies a most inviting field bidding the ingenuity of man to try to conquer it.

Leaving this for the time being for the investigators to explore, there are two questions which naturally are prompted by a study of the list of farm customers contained in this report. The first is—how the load was built on these farms, and the second is—whether these farmers using this considerable amount of service really find it to their advantage.

The history of the building of this load covers a comparatively brief period. It started really with the experimental rural electric lines. The first thing these lines developed was that nobody knew very much about putting electricity to work on the farm: that it was a new field; that everything was different from things in the cities, and that it represented a virgin class of service all by itself. The investigators put electricity to work at every conceivable task which came to their attention. They devised and invented and changed things around, tried it out a new way, and finally began developing definite facts which could be utilized on other farms. As these facts began to materialize, there came into existence rural electric service departments, which have been inaugurated by most of the progressive light and power companies in the United States.

Not all of these departments are separate and independent from any other part of the organization. In fact, in many cases, they are part of the sales department or some other department, but the main idea is that in each instance the individual in charge is made responsible for keeping up to date on the application of electricity to agriculture and maintains himself and his department in a position to show any farmer in the territory served by his company how electricity best can be employed on his farm.

Those Rural Service Departments

Before these experiments were inaugurated and before the rural electric service departments were formed, very few power companies had anything practical to say to a farmer inquiring about service. For the most part the companies had no rate especially devised for farm service and had no one who was in a position to advise the farmer as to the use of electricity on his farm. Usually the only course left open to the company was to get rid of the farmer as diplomatically as possible.

Today all that is changed. The farm applicant is referred to the rural electric service department and there he meets a man who not only knows electricity but knows how to put it to work on the farm. This National Committee is engaged now in issuing serial reports descriptive of the organization and operation of rural electric service departments in companies which have met with outstanding success in this field. The first of these reports[1] dealt with the Wisconsin Power & Light Co. of Madison, Wis. Others will follow.

It is these rural specialists who have, for the most part, built this farm load which bids fair to be only a forerunner of what is to come. They have taken the facts as developed by the experimental lines and put them to work on thousands of other farms. They are in a pioneer field and are doing great work both for the industry and for agriculture.

Can Electricity Pay Its Way?

The second question pertains to whether the farmer finds liberal use of electric energy to his own advantage. There is already much general evidence, and as time goes on more and more specific evidence regarding this point. It is common knowledge among the electric light and power men engaged in rural electrification that the best satisfied farm customers are the ones who are making the greatest use of electric energy and that as a rule those who do complain are the ones who are making very limited use of it.

There is a good reason for this. It has been cited before that a 300-kw-hr.-a-year customer, if he is paying a rate sufficient to protect the company's investment, must count his service as something of a luxury. On the other hand, if the farmer is to be a liberal consumer, the company is in a position to extend to him a much lower unit rate. It therefore is obvious that the small consumer may be paying a relatively high price for a limited amount of service and that for two or three times the cost, he may obtain ten to fifteen times the amount of current. It is quite natural, then, that the small consumer is likely to be the one to complain, while the large consumer is more inclined to the true opinion that he is getting a very liberal service for a comparatively small cost.

It is equally obvious that the liberal consumer is not content merely because his liberal consumption earns him a low unit cost. In addition thereto he knows that electricity is performing numerous tasks for him at a lower cost than is obtainable by any other means of operation.

The number of liberal farm consumers is steadily on the increase and the number of small consumers steadily on the decrease, which is further general evidence that farmers are finding liberal use of electric energy a profitable investment.

Definite Figures from Red Wing

There is also specific evidence that electricity intelligently employed may be a profitable investment. The report of E. A. Stewart, former professor at the University of Minnesota and project director on the Red Wing, Minn., experimental line, shows that on five farms from which continuous records over a period of more than four years are obtainable, the gross earnings the fourth year exceeded the first year by 42.9 per cent, that the operating expenses increased only 1 per cent and that the net earnings increased 81 per cent.

In this case, the operating expenses include the bills paid the power company for current consumed, but not the overhead on the investment in equipment operated by electricity. This equipment for the five farms, if bought at retail prices, would have totaled $16,667. Figuring the interest and depreciation at 12½ per cent, this would have called for a charge the fourth year of $2,083, but even when that is added to the operating expenses and subtracted from the net earnings, there is still left an increase of 50.9 per cent in the net.

This certainly is specific evidence that electricity has proved a profitable investment on these farms. More and more of this specific evidence is becoming available. At each of the rural service conferences being held in the Geographic Divisions in cooperation with the Rural Electric Service Committee of the National Electric Light Association, farmers have stood up and told plainly and emphatically how and why electricity is more than earning its way on their farms. It is not probable that these farmers are fooling themselves. Those who have offered this testimony are farmers who keep books, who know what things cost and who offer detailed figures in support of their assertions.

The whole evidence to date, both general and specific, is strongly indicative that electricity both intelligently and liberally employed is a good investment for the farmer. Hence, as an indication that there is an acceptable load for electric light and power companies on the farm, and that that load can and is being developed, the Rural Electric Service Committee of the National Electric Light Association offers for the consideration of all interested persons the following list of farmers, scattered all over the United States, who are today using in excess of 3000 kw-hr. a year—ten times the average on farms served a few years ago:

NAMES AND ADDRESSES OF FARMERS USING 3,000 KW-HR. OR MORE PER YEAR

Alabama

A. F. Alsobrook, Five Points.—3,620 kw-hr. Lights, range, refrigerator, water pump for house and livestock.

L. C. Young, Montgomery.—15,328 kw-hr. Lights for home and dairy, refrigerator for home and one for dairy, water pump for home and dairy, milking machine.

Mrs. Kate McLean Stewart, Hope Hull.—14,040 kw-hr. Lights, both house and barn, range, refrigerator for dairy.

Aaron Fleming, Huntsville, Route No. 4.—3,777 kw-hr.

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[1] Pub. No. 289-12. Developing Electric Service for the Farm.

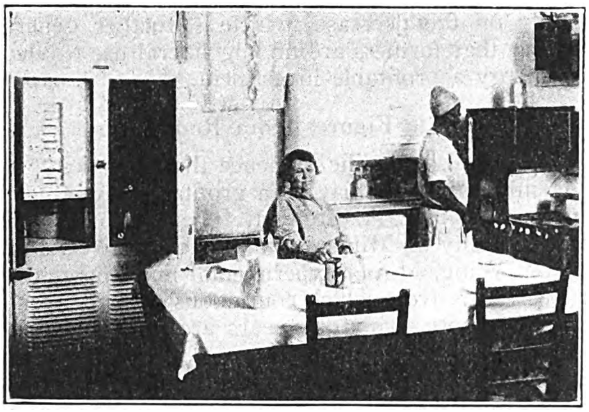

FIG. 1—COOL COOKING AND COOLING FOOD IN A FARMHOUSE IN SUNNY ALABAMA.

Range, refrigerator, water pump, motors in blacksmith shop, fanning mill for lespedeza seed, lights for home and barns.

Clarendon Davis, Huntsville, Route No. 2.—3,950 kw-hr. Lights for home and barns, range, refrigerator, water pump, water heater.

Arizona

S. K. Phillips, Phoenix, Route No. 7, Box 195.—4,218 kw-hr. Motor, range, refrigerator, iron, vacuum cleaner, waffle iron, percolator, 3 fans, sewing machine, lights.

M. B. Brooks, Phoenix, Route No. 4.—4,758 kw-hr. Milking machine, motor on water pump, washing machine, fan, sweeper, iron, range, lights.

LeRoy Butler, Phoenix, Route No. 3.—5,738 kw-hr. Motor, range, iron, washer, heater, refrigerator, lights.

J. W. Pendergast, Tolleson, Maricopa County, Route No. 1. 3,860 kw-hr. Milking machine, pump, washer, refrigerator, iron, fan, toaster, waffle iron, heater, lights.

Joseph Roer, Phoenix, Route No. 6.—3,326 kw-hr. Range, motors, washer, refrigerator, iron, fan, lights.

Arkansas

Chas. Lemaire Dairy Farm, Little Rock, Route No. 3.—3,761 kw-hr. Water system, milking machine, cream separator, small appliances.

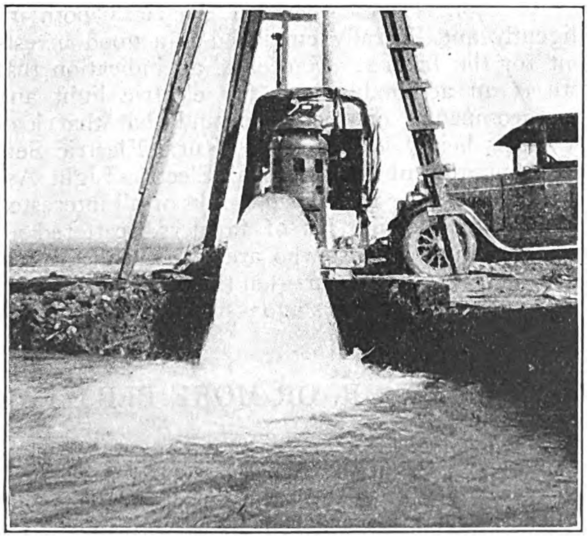

FIG. 2—160-ACRE ALFALFA IRRIGATION IN CALIFORNIA.

Ensminger Dairy, McGehee.—5,454 kw-hr. Refrigerator, range, separator, churn, water system, water heater, iron, percolator, radio.

Pickens Plantation, Walnut Lake.—30,131 kw-hr. Gin, grist mill, water pump, blacksmith shop, grinder, 2 water heaters, 2 ranges.

Gus Cash, Camden.—3,011 kw-hr. Pump, refrigerator, 3 fans, milking machine, cream separator, bottle washer.

H. C. Williamson, Earle.—14,285 kw-hr. Gin motor, water system, milk machine, refrigerator.

C. S. Douglass, Mablevale.—3,116 kw-hr. Milking machine, pump, bottle washer, household appliances.

R. A. Nelson, Mablevale.—3,809 kw-hr. Refrigerator, range, small appliances.

C. N. Alexander, North Little Rock, Route No. 4.—3,100 kw-hr. Refrigerator, pump, lights, household appliances.

A. L. Alexander, Scotts.—3,599 kw-hr. Refrigerator, pump, household appliances.

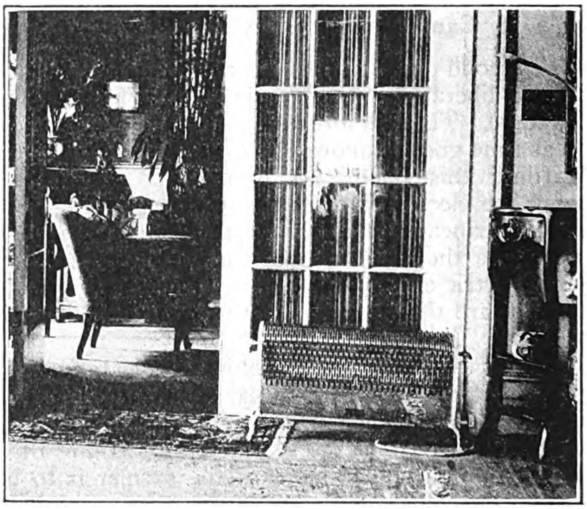

FIG. 3—EVEN A CALIFORNIA FARMHOUSE REQUIRES A LITTLE ELECTRIC HEAT.

California

LeRoy Anderson, WS SARA. Rd. 100' S. Doyle Rd., Santa Clara County, San Jose.—5,422 kw-hr. Range, air heater, pump, motor.

Andrew Christensen, ES San Antonio Rd. off Portola Ave., Santa Clara County.—14,420 kw-hr. Motor, irrigation pump, range, water heater, 3 air heaters.

H. Schwab, H.Str. Rd., Sacramento County.—9,130 kw-hr. Range, water heater, refrigerator, vacuum cleaner, toaster, iron, percolator.

Frank Dagostino, Folsom Rd., Sacramento County.—5,063 kw-hr. Motor, refrigerator, washing machine, range, water heater, iron.

C. W. Keele, District No. 10, Yuba County.—5,933 kw-hr. Motor, water heater, range, water pressure and irrigating yard, lights.

Ray Chandler, Yuba City, Sutter County.—8,699 kw-hr. Motor, range, water heater, refrigerator, lights.

D. A. Alexander, Linda District, Yuba County.—7,410 kw-hr. Irrigating, pressure system, grindstone, range, water heater, electric heating, lights.

Henry Clausen, Gonzales, Monterey County.—12,693 kw-hr. Irrigating, water heater, range, dairy sterilizer, lights.

Vierra Bros., Salinas-Chualar River Rd., 7 miles south of Salinas, Cal., Monterey County.—60,375 kw-hr. Irrigating only.

H. A. Sellers, Firebaugh, Fresno County.—12,921 kw-hr. Irrigating, water heater, range, heater, refrigerator.

A. R. McGuire, Mendota, Fresno County.—15,042 kw-hr. Irrigating, range, water heater, 2 air heaters.

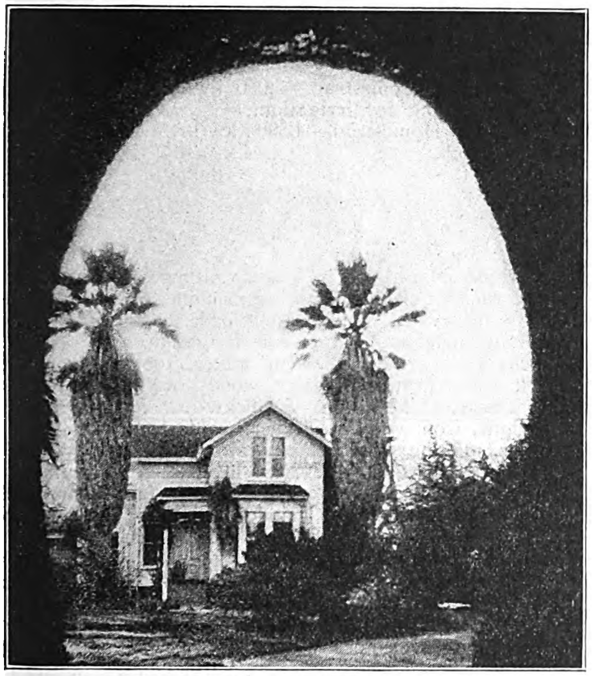

FIG. 4—A CALIFORNIA ELECTRIFIED FARMHOUSE.

M. S. Meeker, Fresno County, Kerman.—4,293 kw-hr. Irrigating, range, water heater, air heater.

Sanborn Young, Fresno County.—15,892 kw-hr. Irrigating, water heater, cooler, milker, sterilizer, range, water system.

Frank Andrews, Fresno County.—13,265 kw-hr. Range, 3 motors, water heater.

M. R. Knauft, Walnut.—8,174 kw-hr. Irrigating, walnut dehydrator, range, water heater, refrigerator, fan, piano, radio, drink mixer, air heater.

P. C. Huddleston, Magnolia Rd., North of Katella, Orange County—3,567 kw-hr. Irrigating, range, water heater, refrigerator, ironer, water pump, 2 heaters, washing machine, plate, battery charger and eliminator, percolator, toaster, vacuum cleaner, iron.

J. A. Ragle, Box 275, Woodlake.—3,368 kw-hr. Irrigating, range, water heater, motor, percolator, iron, washing machine.

Herrold Gist, Tulare County, Tulare.—Owner meter 7,414 kw-hr.; tenant meter, 4,696 kw-hr. 3 motors for irrigation pumping, (owner) range, water heater, servel, air heater, single phase motor, DeLaval separator, fan, washing machine, iron, percolator, vacuum cleaner, toaster, grill, waffle iron. (Tenant) range, washing machine, hedlite heater, percolator, iron, waffle iron, refrigerator, pad, fan.

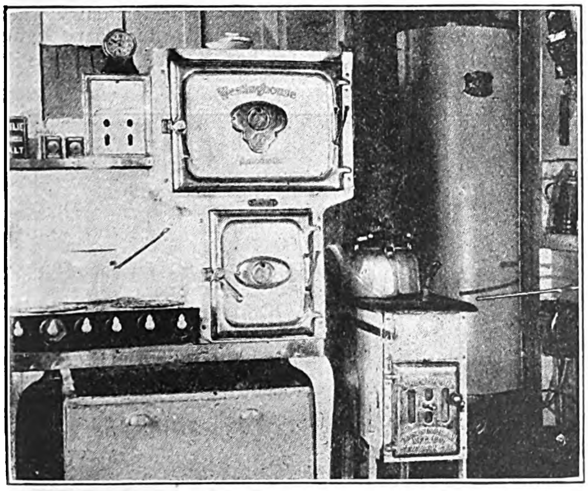

FIG. 5—ELECTRICITY WORKS IN THE KITCHEN OF A CALIFORNIA FARMHOUSE.

Colorado

Lloyd Fahrney, Olathe.—4,067 kw-hr. Incubator, sells day old chicks. Kw-hr. used through lighting meter includes several lamps used for heating incubators, lights 5 room house and hatchery room, fans.

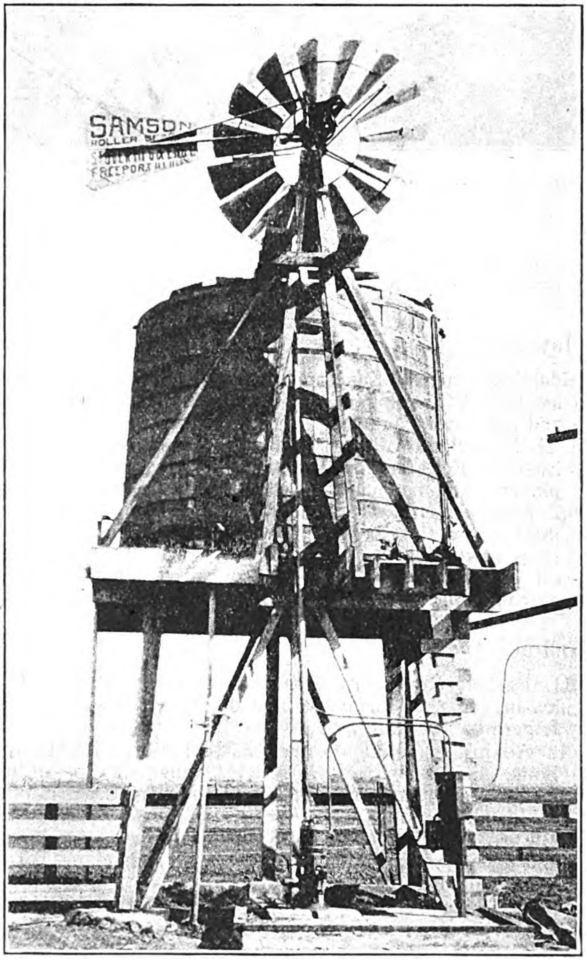

FIG. 6—THIS 3-HP. TURBINE PUMP ON A CALIFORNIA FARM DOES THE HALF-DAY WORK OF A WINDMILL IN TWENTY MINUTES.

Connecticut

R. C. Wetherell, Suffield Rd., Suffield, Conn.—5,852 kw-hr. Washer, iron, ironer, toaster, percolator, 2 refrigerators, milking machine.

A. H. Grant, Melrose, Broad Brook.—6,389 kw-hr. Toaster, iron, percolator, grill, washer, milking machine, refrigerator, water pump.

Geo. M. Hendee, Mapleton Ave., Suffield.—19,445 kw-hr. Milking machine, 2 refrigerators, hay hoist, clippers, separators, range.

A. B. Thompson, Main St., Melrose.—4,203 kw-hr. Range, refrigerator, oil burner, all table appliances, cleaner, washer, sump pump, water pump.

H. C. Welles, Scantic.—4,119 kw-hr. Range, refrigerator,

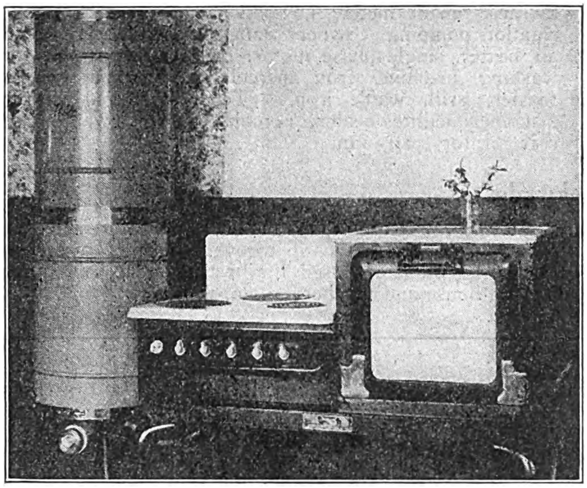

FIG. 7—MANY CALIFORNIA FARMHOUSES USE ELECTRICITY FOR WATER HEATING AND COOKING.

iron, toaster, percolator, chafing dish, heating pad, pump, milking machine, another refrigerator in dairy.

Delaware

Breidablick Farms, Lancaster Pike, Wilmington.—21,849 kw-hr. Water pump, ice machine, circulating pump, and separator, 2 milking machines, lights.

Col. H. F. duPont, Winterthur Farms, Winterthur.—216,188 kw-hr. Feed mixer, ammonia compressor, saw and planer, 2 pumps, 3 hay hoists, fan exhaust, elevator, 2 fan exhausts, water pump, milk conveyor, washing machine, pasturizer, churn, extractor, wringer, repair shop motors, brine pump, laundry machine, separator, oil burners, refrigerator, ice cream freezer, chipping machine, lights.

Florida

J. H. Barber, Route No. 3, Box 411, Ferry Pass.—7,080 kw-hr. Lights for house and dairy, water system, refrigerator for dairy.

T. L. Adkinson, Myrtle Grove.—3,384 kw-hr. Lights for home and dairy, water system, range, 1 hp. utility motor, 3 hp. feed grinder, 1½ hp. dairy refrigerator to be installed soon.

H. P. Caro, Myrtle Grove.—8,352 kw-hr. Lights for house and dairy, water system, range, washing machine, bottle washer, churn, cooling system.

Fairglades Dairy, Donato Bufano, Prop., Kendall.—50,846 kw-hr. Lights, range, water pumping, dairy power, ice crusher, bottling machine, compressor, brine pump, line shaft.

Dr. J. Peterson, Homestead.—3,000 kw-hr. Lights, range, water pumping for irrigation.

C. S. Allen, Homestead.—4,500 kw-hr. Lights, range, water pump.

Georgia

Idaho

J. F. Bruins, Boise.—5,296 kw-hr. Range, water heater, iron, vacuum cleaner, washing machine, sewing machine, air heater, radio, fan, heating pad, toaster, percolator, milking machine, pump for irrigation and watering stock, feed grinder, cement mixer, tool grinder, hay fork, water heater for dairy, wood saw.

Harold Davidson, Meridian.—5,420 kw-hr. Range, washing machine, iron, vacuum cleaner, waffle iron, fan, 1½ hp. motor, milking machine, separator and pump.

R. M. White, Meridian.—3,312 kw-hr. Range, washing machine, iron, water heater, air heater, fan, 3 brooders, 3 incubators, 2 hp. feed grinder and 1 hp. pump.

G. A. Koger, Meridian—8,940 kw-hr. Range, washing machine, iron, battery charger, ½ hp. motor on pump, ¼ hp. separator, 1 hp. honey extractor, 500-watt heater in poultry house and 3 brooders.

Fay Davis, Parma.—14,090 kw-hr. Iron, washing machine, range, water heater, water system, vacuum cleaner, curling iron, lighting of barn, yard, poultry house, incubator and brooder, pump.

H. Solterbeck, Payette.—14,794 kw-hr. Range, iron, washing machine, 2 water heaters, fan, percolator, water system, milking machine, separator, bottle washer, outside lighting.

Archie Larson, Weiser.—18,572 kw-hr. Range, water heater, sweeper, iron, toaster, radio, cozy glow heater, water system, sewing machine, feed grinder, hay cutter, separator, lights in barn, henhouse and yard.

H. W. Hume, Wilder.—6,382 kw-hr. Iron, washing machine, range, toaster, waffle iron, table appliances, vacuum cleaner, fan, water system, refrigerator, sewing machine, incubator, brooder, separator, milking machine, shop grinder, shop motor, utility motor, lights in barn, yard, and poultry house.

O. E. Peret, Wilder.—4,110 kw-hr. Iron, washing machine, range, water heater, toaster, waffle iron, percolator, vacuum cleaner, fan, refrigerator, water system, barn, yard and poultry house lighting, utility motor.

Walter Little, Boise.—7,715 kw-hr. Water heater, range, iron, ironer, washer, percolator, vacuum cleaner, toaster, waffle iron, commercial pump, lights.

Mye & Buchanan, Jerome.—7,101 kw-hr. Range, urn, vacuum cleaner, washer, iron, water heater, dairy water heater, separator, water system, house and barn lights.

W. F. Thode, Boise.—5,319 kw-hr. Lights, iron, washer,

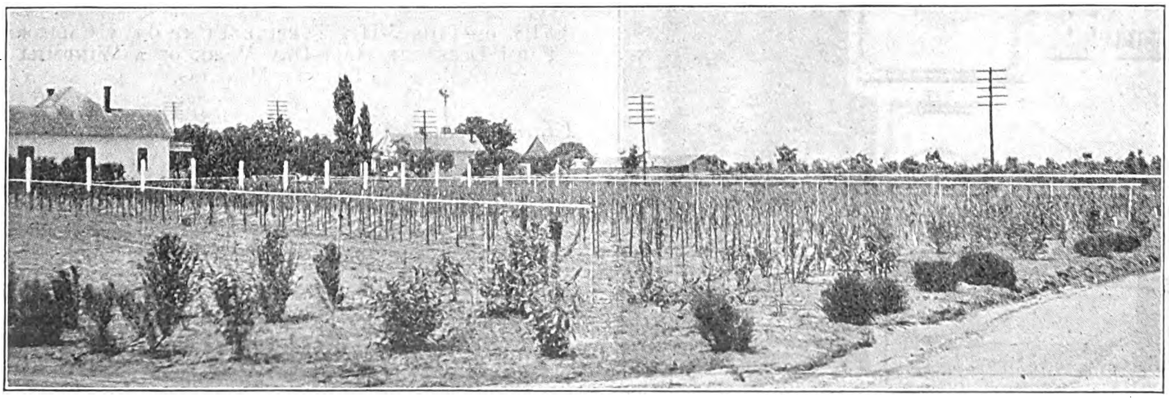

FIG. 8—WHEN BULBS ARE THIRSTY, ELECTRICITY MAKES IT RAIN IN GEORGIA.

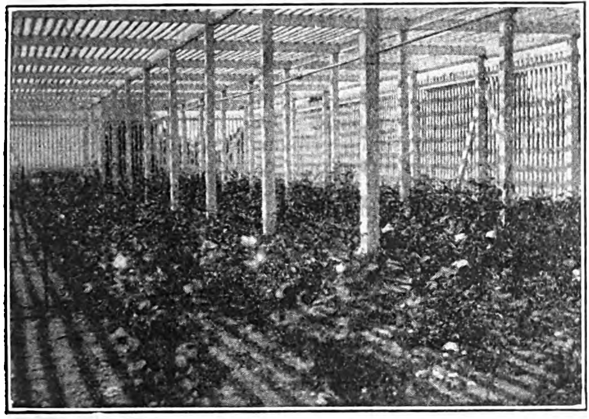

FIG. 9—ELECTRICITY PROVIDES OVERHEAD IRRIGATION TO MAKE ROSES BLOOM IN GEORGIA.

range, water heater, air heater, waffle iron, vacuum cleaner, sterilizer, bottle washer, utility motor.

Henry Hege, Aberdeen.—6,004 kw-hr. Range, washer, milking machine, iron, water system, vacuum cleaner, curler, toaster, vibrator, lights, water heater, warming pad, feed grinder, utility motor.

Mike Barclay, Blackfoot.—12,491 kw-hr. Iron, washer, range, water heater, air heater, toaster, waffle iron, percolator, vacuum cleaner, refrigerator, water system, sewing machine, ironer, curling iron, radio, lights in house, barn, poultry house and yard.

W. E. Cleveland, Twin Falls.—3,669 kw-hr. Range, milker, washer, separator, iron, toaster, percolator, water system, house and yard lights.

Eli Simmons, Ucon.—3,521 kw-hr. Lights and range.

Herman Erickson, Route No. 1, Thornton.—3,296 kw-hr. Lights, range, pumping.

Rudolph Nelson, Route No. 1, Firth.—3,034 kw-hr. Lights, range, refrigerator, motor for pumping water.

Dan Bucklund, Idaho Falls, Route No. 4.—4,262 kw-hr. Lights, range, motor for pumping water.

Fred Anderson, care of Elmer Anderson, Idaho Falls, Idaho Route No. 4.—3,750 kw-hr. Lights, range, motor for pumping water.

Illinois

A. F. Randolph, Canton.—4,316 kw-hr. Iron, cleaner, washer, milker, 2 pumps, toaster, range, separator.

Jeptha Randolph, Canton.—3,780 kw-hr. Iron, range, washer, pump, milker, separator, sewing machine.

Marion Lawson, Norris.—5,914 kw-hr. Battery charger, iron, range, cleaner, washer, water system.

Charles Rock, Norris.—3,000 kw-hr. Iron, cleaner, range.

Clyde Eshelman, Norris.—4,200 kw-hr. Iron, range, cleaner, washer, water system, 2 pumps.

Howard Smith, Bardolph.—3,000 kw-hr. Range, iron, washer.

Indiana

M. J. Schlarb, Goshen.—5,727 kw-hr. Pump, iron, milking machine, bottle washer and miscellaneous power, refrigerator.

Daniel Bechtel, Goshen.—3,290 kw-hr. Milking machine, pump, washing, ironing, cook range, sweeper, incubator, automatic clock on chicken house.

C. M. Enders, Goshen.—3,596 kw-hr. Pump, washer, iron, refrigerator, cream separator, general power, milking machine.

Mervin Eby, Goshen.—5,758 kw-hr. Pump, washer, iron, refrigerator, separator, general power, milking machine, feed grinder, range, silo filler.

Cedric Adams, Goshen.—3,410 kw-hr. Cooking, lights in henhouses, pumps, water.

Alderman Farm, Goshen.—4,049 kw-hr. Pump, 2 ranges, hot water heater, grinder, general utility motor, lights, brooders, special heaters for fruit storage.

J. B. E. LaPlant, Vincennes.—8,000 kw-hr. General farming.

H. D. Simpson, Vincennes.—7,000 kw-hr. 120 acres, orchard and nursery.

Geo. Armstrong, Vincennes.—3,000 kw-hr. General farming.

Wm. R. Lapsley, Vincennes.—4,000 kw-hr. Truck and poultry farm, completely electrified.

Phillip Ramsey, Vincinnese.—3,000 kw-hr. 160 acres, general farming.

Eugene Reibel, Vincennes.—3,000 kw-hr. 120 acres, general farm.

Frank Tellman, Columbus.—4,800 kw-hr. 346 acres, general farming.

Paul Jones, Columbus.—4,800 kw-hr. General farming.

W. H. Graffis, Monticello.—4,195 kw-hr. 320 acres, general farming.

Capper Stock Farm, Monticello.—5,480 kw-hr. Large stock farm.

Stephens Hatchery, Monticello.—3,000 kw-hr. Hatchery and poultry farm.

Iowa

Paul Kilburn, Route No. 3, Mt. Vernon.—4,300 kw-hr. Refrigerator, water pump, water heater, such small power as you would find around average farm.

Mike Sproles, Garner.—3,857 kw-hr. Refrigerator, water pump, water heater, small power uses.

W. C. Tyell, Bellemont.—3,745 kw-hr. Refrigerator, water pump, water heater, small power uses.

Mike Scalario, Route No. 4, Cedar Rapids.—3,355 kw-hr. Refrigerator, water pump, water heater, small power uses.

Henry Grunewalt, Blairstown.—3,102 kw-hr. Refrigerator, water pump, water heater, small power uses.

Clarence Lawhorn, Garner.—3,054 kw-hr. Refrigerator, water pump, water heater, small power uses.

Kansas

J. Fred Miller & Sons, Larned.—4,097 kw-hr. Milking machine, bottle washer, cream separator, running water, lights, elevating, grinding and mixing equipment, water pumping, washing machine, ironer, vacuum cleaner, hot plate, fan, lights.

A. L. Stockwell, Larned.—3,091 kw-hr. Feeding operations, irrigation pumps, lights in house and barns, water system, grain and forage mill equipped with elevating attachment, silo filling and pumping water, range, refrigerator, ironer, vacuum cleaner, space heater, fan,

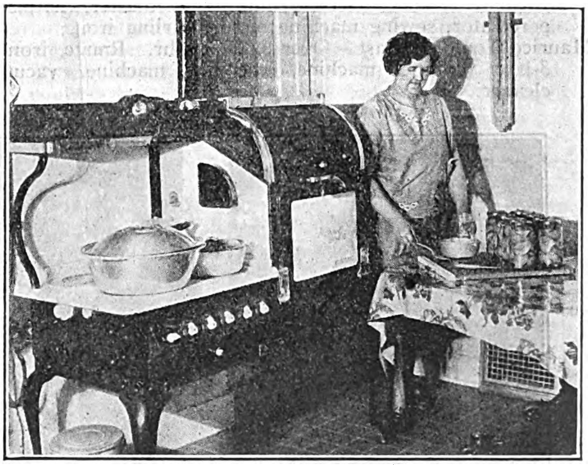

FIG. 10—WITH ELECTRICITY AVAILABLE THE FRUIT CANNING SEASON IS A PLEASANT ONE FOR THIS IDAHO FARM HOMEMAKER.

table stove, radio, washing machine, cream separator, emery wheel.

J. M. Lewis, Larned.—3,722 kw-hr. Light, range, water heater, refrigerator, water system, washer, ironer, iron, vacuum cleaner, fan, radio, cream separator, lights for house and barns, motor for shop equipment, pumping water, grinding and elevating grain, silo filling, irrigation pumping.

Roy A. Robinson, Larned.—3,078 kw-hr. Lights, washing machine, water system, range, toaster, waffle iron, refrigerator, fan, vacuum cleaner, battery charger, washing machine in 2 houses, cream separator, motor on air compressor, emery wheel, drill, motor for grinding, cleaning and elevating grain, pumping water.

L. L. Lupfer, Larned.—3,450 kw-hr. Lights, range, toaster, waffle iron, washer, iron, vacuum cleaner, water system, space heater, incubator, motor driven churn, ice-cream freezer, cellar-sump pump, radio charger, cream separator, elevating and grinding feed, water heater, refrigerator, ironer, floor waxer, motor for lineshaft driving drill, grindstone, air compressor and circular saw, portable electric drill, portable milking machine.

Fred B. Reed, Larned.—3,961 kw-hr. Lights, milking machine, cream separator, water pump all operated by individual motors; range, vacuum cleaner, washing machine, iron, fan, sewing motor, water system.

Kentucky

C. M. Camden, Varsailles, on Frankfort Pike.—33,620 kw-hr. Pumping, lights, water heating, cutting and grinding (has in excess of 50 h.p. in motors).

Louisiana

W. J. Perkins, Mansfield Road, Shreveport.—3,143 kw-hr. Pump, refrigerator, milker, small appliances.

Roemer Farm, Taylortown Road, Shreveport.—3,693 kw-hr. Pump, refrigerator, milker, cream separator.

W. E. Hamilton, Taylortown Road, Shreveport.—6,250 kw-hr. Pump, refrigerator, milker, cream separator.

A. L. Alexander, Greenwood Road, Shreveport.—7,907 kw-hr. Pump, refrigerator, milker, cream separator.

Maine

W. H. Burgess, Sanbornville.—Over 3,000 kw-hr. Range, water heater, 1-h.p. motor for milking, water pumping, cutting bone, turning grindstone, etc., washing machine, iron, sewing machine motor.

Fred J. Wood, Topsham.—Over 3,000 kw-hr. Water heater, ½-h.p. water pump, iron, small household appliances.

R. A. Rackley, Topsham.—Over 3,000 kw-hr. Range, washing machine, 5-h.p. utility motor, iron, water heater, refrigerator, milking machine, water pump, milk cooler, vacuum cleaner, electric fan, iron, toaster, hotplate, percolator, sewing machine motor, curling iron.

Maurice Toule, Belfast.—Over 3,000 kw-hr. Range, ironer, 3-h.p. milking machine, washing machine, vacuum cleaner.

Frank H. Richardson, Lewiston.—Over 3,000 kw-hr. Range, water heater, refrigerator, deep well pump, milk separator, cooler, milking machine.

R. G. Lowell, Greene.—Over 3,000 kw-hr. Milking machine, water pump, small household appliances.

E. C. Buzzell, Fryeburg.—Over 3,000 kw-hr. 7½-h.p. motor for threshing, grinding, wood sawing, silo filling and general utility work, electric pump, washing machine, iron, small household appliances, range and refrigerator being installed.

Maryland

Geo. W. White, S. S. Sweathouse Road, 1 E. Harford Road, Mt. Vista, Harford County.—10,911 kw-hr. Range, milking machine, 20-h.p. motor, 2-h.p. for water pumping.

Janon Fisher, W. S. Park Heights Ave., 1 N. Caves Road. Eccleston.—9,748 kw-hr. Milking machine, water pump, range.

J. Edwin Griffith, W. S. Pimlico Road, 5 N. Smith Ave., Mt. Washington.—6,181 kw-hr. Stock farm, lights.

Samuel H. Shoemaker, N. S. Valley Road, 1 W. Park Heights Ave., Eccleston.—33,213 kw-hr. Dairy farm completely electrified.

Wallace W. Lanahan, E. S. Pitts Road, 3 N. Cinder Road, Timonium.—42,406 kw-hr. Range, refrigerator, water pump, small motors for general use.

Geo. Zaiser, W. S. Maiden Choice Lane, 1 S. McTavish Ave., Catonsville.—18,697 kw-hr. Range, 2 motors on milking machine, ice machine, 10-h.p. utility motor, small motors on bottle washers and bottling machines, water pumps.

Geo. Knapp, W. S. Rolling Road, 1 S. Bloomsbury Road, Catonsville.—22,276 kw-hr. Refrigerator, bottle washer bottle machine, water pump.

Massachusetts

Manuel S. Leal, Jr., Raymond Road, Burlington.—5,477 kw-hr. Incubator, range, refrigerator, water pump, portable saw, 6 brooders, lights for poultry house.

Edyth W. MacIntosh, Richards Street, Sharon.—7,000 kw-hr. Incubator, 6 brooders, lights.

Donald Macomber, Bedford Road, Lincoln.—8,914 kw-hr. Range, refrigerator, incubator, lights, mangle.

C. B. Tillson, E. Plain St., Jct. E. Pond St., Cochituate.—3,685 kw-hr. Incubator, small appliances, lights.

Geo. W. Sarano, Lincoln St. cor. State Road, Lexington.—4,022 kw-hr. Refrigerator, small appliances, incubator, lights.

Charles H. Miller, Lincoln St., near School, Lexington.—7,430 kw-hr. Range, refrigerator, small appliances, mangle, lights, incubator.

Michigan

E. J. Bidigard, Route No. 4, Monroe.—3,265 kw-hr. Iron, washer, water system, range, sweeper, pump.

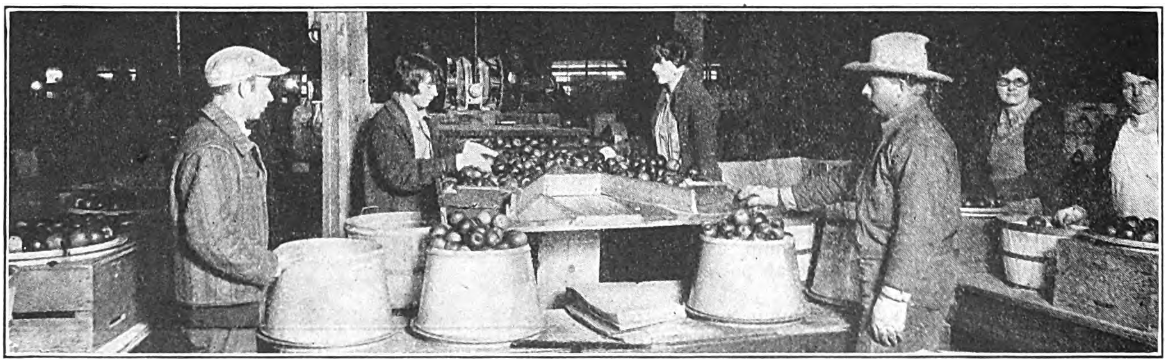

FIG. 11—AN ELECTRICALLY OPERATED MACHINE WHICH SORTS, WASHES AND PACKS APPLES ON AN IDAHO RANCH.

John Leppel, Route No. 1, Monroe.—3,241 kw-hr. Iron, range, sweeper, washer, water system, cider mill, pump.

G. H. Wood, Route No. 2, Monroe.—7,265 kw-hr. Large dairy, sells bottled milk. Iron, range, refrigerator, sweeper, washer, 2 water systems, cream separator, bottle washer, bottler, ice machine, grinder, water pump.

Fred C. Blume, S. Custer Road, Monroe.—3,040 kw-hr. Iron, range, sweeper, washer, water system.

Ernest Wright, Route No. 2, Monroe.—3,024 kw-hr. Iron, milker, range, sweeper, washer, water pump, water system.

Albert W. Miller, S. Custer Road, Monroe.—5,418 kw-hr. Iron, refrigerator, range, sweeper, washer, 2 water systems, brooder, drill, feed grinder, incubator, milk cooler, paint spray, pump jack, tool ginder, 2 motors.

Marshall Buckberry, Romulus—3,283 kw-hr. Iron, range, ice refrigerator, sweeper, washer, 2 water systems.

E. W. Christner, Saline.—4,007 kwhr. Iron, range, refrigerator, sweeper, washer, 2 water systems.

L. E. Wiard, Route No. 2, Ypsilanti.—5,006 kw-hr. Refrigerator, iron, range, sweeper, washer, 2 water systems.

Roy Wilkie, Route No. 2, Ypsilanti.—4,193 kw-hr. Refrigerator, iron, range, sweeper, washer, water system, milker, motor for general use, 2 water pumps.

G. W. Slaughter, Route No. 1, Ypsilanti.—4,304 kw-hr. Refrigerator, iron, range, sweeper, washer, water system, blower, 2 oat crushers, water pump.

F. Palma, Route No. 1, Ypsilanti.—38,008 kw-hr. Refrigerator, iron, range, sweeper, washer, water system, bottle washer, bottler, feed grinder, ice machine.

J. S. Lathers, Route No. 2, Ypsilanti.—6,806 kw-hr. Iron, range, sweeper, washer, water system, milker.

Fred J. Korte, Route No. 4, Ypsilanti.—3,333 kw-hr. Iron, range, sweeper, washer, 2 water systems, milker, utility motor.

Knudt Jorgensen, Route No. 3, Ypsilanti.—6,044 kw-hr. Refrigerator, iron, range, sweeper, 2 water systems, milker.

Wm. Honck, Route No. 3, Ypsilanti.—4,112 kw-hr. Iron, sweeper, washer, 2 water systems.

Edw. D. Foster, Route No. 3, Ypsilanti.—4,001 kw-hr. Refrigerator, iron, range, sweeper, 2 water systems, washer.

L. F. Field, Route No. 3, Ypsilanti.—4,325 kw-hr. Iron, sweeper, washer, water system, 2 incubators, water pump.

John Bagley, Route No. 5, Ypsilanti.—5,755 kw-hr. Refrigerator, iron, milker, range, sweeper, washer, 2 water systems.

F. M. Robbins, Saline.—3,151 kw-hr. Refrigerator, iron, range, sweeper, washer, water pump, water system.

Bolgos Bros., Route No. 5, Ann Arbor.—6,845 kw-hr. Refrigerator, iron, sweeper, washer, water system, bottler, milker, separator, water pump.

W. W. Davis, Route No. 1, Ann Arbor.—4,001 kw-hr. Iron, range, sweeper, washer, water system, water pump, motor on pumps.

H. George Field, Route No. 5, Ann Arbor.—6,347 kw-hr. Refrigerator, iron, range, sweeper, washer, 2 water systems, water heater, 2-h.p. on pumps at barn.

Geo. Aprill, Route No. 4, Ann Arbor.—3,561 kw-hr. 2 ice refrigerators, iron, range, sweeper, washer, 2 water systems, churn, cider mill, feed grinder, separator.

V. C. McNitt, Route No. 4, Ann Arbor.—4,563 kw-hr. Refrigerator, iron, range, sweeper, 2 water systems.

A. Haener, Route No. 5, Ypsilanti.—3,329 kw-hr. Iron, range, sweeper, water pump, water system.

M. C. Britz, Route No. 5, New Boston.—3,719 kw-hr. Refrigerator, iron, range, sweeper, washer, water system.

Charles Joh, Hall Road, Mt. Clemens.—8,040 kw-hr. Iron, range, refrigerator, sweeper, toaster, washer, water pump.

Fred W. Knack, Armada Ridge Road, Armada.—3,991 kw-hr. Iron, lights, range, sump pump, water pump.

Sidney N. Lagatree, Armada Ridge Road, Armada.—3,230 kw-hr. Iron, lights, range, washer, water pump.

Alex. Campbell, 12 Mile Road, Centerline.—4,543 kw-hr. Iron, percolator, range, refrigerator, sweeper, toaster, tool grinder, washer, water pump.

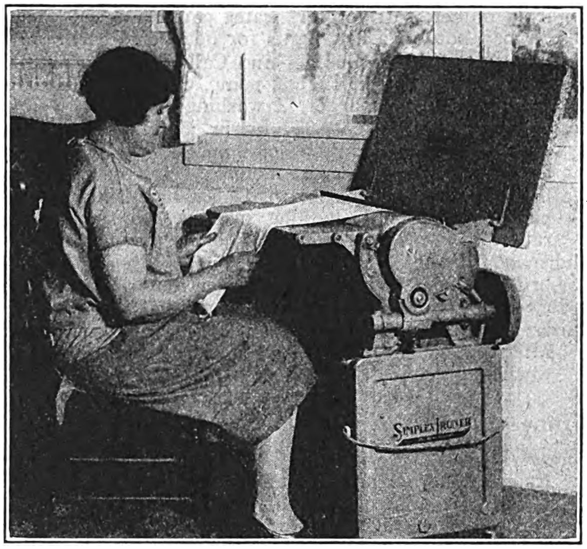

FIG. 12—HOUSEWORK IS DONE ELECTRICALLY IN THIS IDAHO RANCH HOUSE.

Paul Filo, 14 Mile Road, Centerline.—3,985 kw-hr. Iron, range, sweeper, washer, 2 water pumps.

John C. Busch, Ryan Road, Centerline.—3,612 kw-hr. Iron, range, sweeper, toaster, tool grinder, washer, water pump.

Erie Hallin, S. Gratiot Ave., Roseville.—3.799 kw-hr. Range, iron, refrigerator, sign at road, sweeper, waffle iron, water pump.

A. Gabler, Quick Road, New Baltimore.—5,224 kw-hr. Brooder, iron, incubator, toaster, washer, water pump.

Thomas D. Murphy, E. S., Auburn Road, Utica.—4.413 kw-hr. 3 brooders, incubator, iron, 6 poultry water heaters, lights, washer, water pump.

W. J. Boehmer, 15 Mile Road, Utica.—3,239 kw-hr. Iron, range, percolator, sweeper, toaster, washer, 2 water pumps.

Carl Schoonover, E. S., Ryan Road, Utica.—5,017 kw-hr. Cooker, iron, milking machine, range, toaster, washer, water pump.

Norbert Schwartz, Townline Road, Utica.—3,764 kw-hr. Iron, range, sweeper, washer, 2 water pumps.

Charles W. Stevenson, Griswold Road, Pt. Huron.—4,195 kw-hr. Iron, milking machine, range, refrigerator.

D. C. Griggs, W. St. Clair St., Romeo.—4,765 kw-hr. Grader, hotplate, ironer, range, refrigerator, sweeper, washer, water heater, 2 water pumps.

W. A. Downs, Romeo.—11,533 kw-hr. Air heater, fans, iron, 8 poultry water heaters, range, refrigerator, sweeper, toaster, washer, water heater, water pump.

J. B. Deneen, Imlay City.—7,894 kw-hr. 6 brooders, hotplate, incubator, poultry house lights, toaster, water circulator, water pump.

Ira Wilson, Fowlerville.—24,336 kw-hr. Brine pump, compressor, milker, range, water system.

M. J. McPherson, Howell.—5,100 kw-hr. Bottle washer, water system.

B. B. Soults, Milford.—3,288 kw-hr. Heaters, lights for fox pen.

Frank Nichols, Orchard Lake Road, Farmington.—4,860 kw-hr. Refrigerator, iron, range, sprinkler system, sweeper, washer, water system.

Charles Halstead, Halstead Road, Farmington.—3,072 kw-hr. Refrigerator, iron, range, sweeper, washer, water system.

J. McMullen, Hemlock.—7,150 kw-hr. Chicken hatchery.

J. W. Fordney, Hemlock.—25,383 kw-hr. Dairy, 240 acres.

Balmoral Farms, Ithaca.—11,561 kw-hr. Dairy, 200 acres.

L. J. Bradley, Route No. 2, Augusta.—5,017 kw-hr. Range.

iron, milker, refrigerator, water pump, washer, vacuum cleaner, bottle washer, lights for house and barn.

D. D. Aitkin, Cor. of Beecher and Calkins Rd. (Flint District).—8,600 kw-hr. Lights, pump, clippers, milk cooler, washer, battery charger, 2 washing machines, 2 irons.

Benj. Hachett, Jenison.—9,350 kw-hr. 3 milking machines, clippers, pump, cornsheller, pumps, radio, washer, toaster, 2 irons, sweeper, motor.

Wallinwood Farms, Jenison.—6,814 kw-hr. Bottle washer, pump, refrigerator, milking machine, emersion heater, range, iron, sweeper, separator, brine pump.

Thornwood Farms, Ada.—5,752 kw-hr. 2 bottle washers, brush, separator, oil burner, cooler motor, water pump, ice machine, milking machine, iron.

Burroughs Farm, Sheridan Road, Saginaw.—3,244 kw-hr. Milking machne, water pump, 2 vacuum cleaners, 2 washers.

Minnesota

Christ Theisen, Watkins.—3,339 kw-hr. 80 acre farm. Range, pump, cream separator, washing machine, lights.

Epple Bros., Montrose.—3,140 kw-hr. 275 acre farm. Operate feed mill, milking machine, pump, washing machine, iron, lights.

Hubert Hengle, St. Michael.—Over 3,000 kw-hr. Range, water heater, cream separator, milking machine, washing machine, iron, lights.

Moose Valley Farm, Duluth.—Over 3,000 kw-hr. (Theo. Holister, owner.) Lights, water pump, cream separator, feed grinder, washing machine, vacuum cleaner, iron, miscellaneous household appliances.

Lester River Dairy, Andrew Anderson, owner, Duluth.—3,791 kw-hr. Lights, milking machine, bottle washer, cream separator, pressure water system, washing machine, vacuum cleaner, miscellaneous household appliances.

Marshall Farm, Seth Marshall, owner, Duluth. — 11,909 kw-hr. Milking machine, bottle washer, cream separator, cow clipper, refrigerator dairy cooler, iron, water system, shop motor, range, washing machine, vacuum cleaner, miscellaneous household appliances.

Kenneth W. Thompson, Long Lake.—3,000 kw-hr. Range, pump, iron, washing machine.

Sandeen Bros., Maple Plain.—5,000 kw-hr. Lighting resort, pumping.

Northland Milk & Ice Cream Co., Anoka., Farm No. 1.—3,100 kw-hr. Milking machine, pump, lights, iron, washing machine.

Northland Milk & Ice Cream Co., Anoka, Farm No. 2.—4,300 kw-hr. Milking machine, pump, bottle washer, lights, iron, washer.

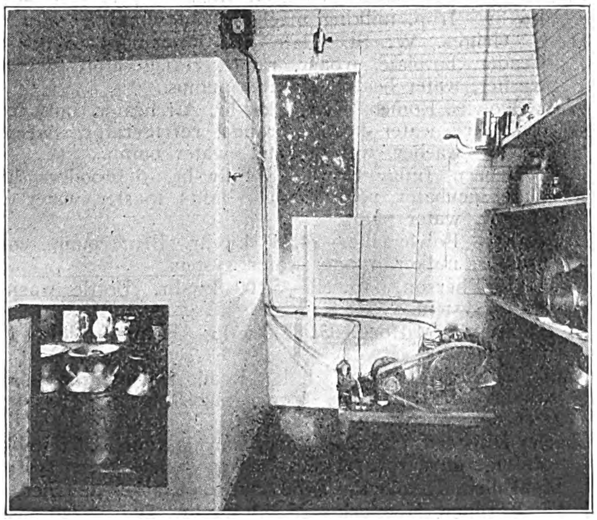

FIG. 13—ELECTRIC MILK COOLING ON A MINNESOTA FARM.

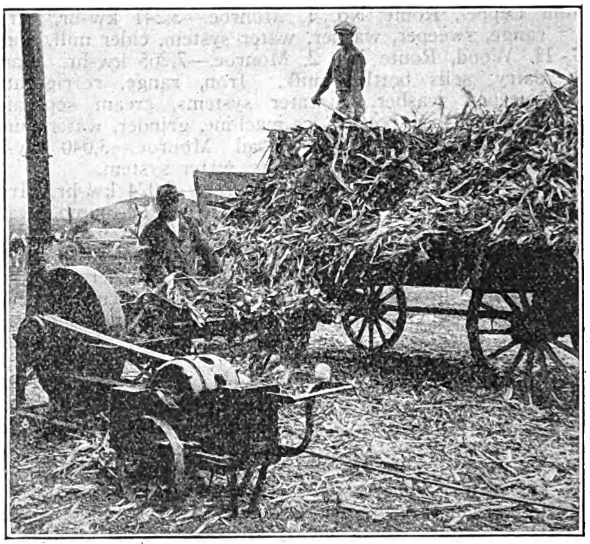

FIG. 14—7½-H.P. ELECTRIC MOTOR HANDLES SILO JOB ON A FARM IN MINNESOTA.

S. C. Campbell, Hopkins.—3,500 kw-hr. Water pump, lights, range, 7½-h.p. motor for filling 2 silos.

W. A. Johnston, Robbinsdale.—3,100 kw-hr. Pump, milking machine, lights in barn and in men's living quarters (no residence uses).

Wm. Moscrip, Lake Elmo.—13,700 kw-hr. Pump, milking machine, washing machine, iron, range.

Chas. E. Walker, Biscay.—6,000 kw-hr. Milking machine, battery, brooder, pump, lights, washing machine, iron.

D. G. Schwyzer, Bloomington.—12,000 kw-hr. Silo filling, feed and roughage grinding, range, dairy milk cooler, pump, water heater in house, iron, washing machine, lights.

Westwood Stock Farm, Farmington.—3,373 kw-hr. Milking machine, 2 pumps, 2-h.p. moors, 1¼-h.p. motor, lights, small appliances.

B. F. Bjornstad, Farmington.—7,014 kw-hr. Range, refrigerator, pump, milking machine, small appliances, lights.

Alice U. Nelson, Farmington.—3,553 kw-hr. Range, water system, washing machine, iron, lights.

Whitney Springhurst Farm, Farmington.—7,068 kw-hr. Milking machine, 7½-h.p. motor, feed mill, water system, washing machine, iron, lights.

Fred Cram, Waterville.—3,212 kw-hr. Range, water system, refrigerator, small appliances, lights.

J. J. Miller, Morristown.—4,493 kw-hr. Range, refrigerator, water system, lights, small appliances.

Henry Franzmier, Rich Valley.—7,063 kw-hr. Milking machine, silo filling and feed grinding, milk cooler, range, pump, lights, small appliances.

E. H. Knodt, Rich Valley.—3,048 kw-hr. Milking machine, silo filling and feed grinding, pumping, lights, small appliances.

Wm. Shuelke, Rosemount.—3,200 kw-hr. Range, refrigerator, lights.

Fred Yennie, West Concord.—3,206 kw-hr. Water system, water heater, range, lights, small appliances.

Wright A. Parkin, Mantorville.—3,145 kw-hr. Milking machine, water system, silo filling and feed grinding, range, small appliances, lights.

Mrs. Kate Fahlstrand, Herman.—3,616 kw-hr. Sewing machine, washing machine, iron, cleaner, cream separator, 2 milking machines, water pump, range, 5-h.p. motor.

Martin Melsness, Sacred Heart.—3,388 kw-hr. Water system, milker, fanning mill and grinder, cream separator, soft water system, range, iron, washer, vacuum cleaner, waffle ron, percolator, toaster.

W. A. Benham, Montevideo.—3,972 kw-hr. Feed grinder, milking machine, bottle washer, washer, iron, toaster and miscellaneous household appliances.

Ed. H. Ulrich, Biscay.—Over 3,000 kw-hr. Milking machine, 1-h.p. on Bulldozer pump, separator, soft water pump for house, washer, refrigerator, range, ironer, iron, vacuum cleaner, toaster, percolator, radio and sewing machine. Energy is also used for warming drinking water for chickens and forced laying of hens.

Werring & Johnson, Morgan.—Over 3,000 kw-hr. Milking machine, water pumping, separating, electric range, washer, iron, percolator, vacuum cleaner, toaster, fan.

Mississippi

A. P. Carney, Meridian.—11,144 kw-hr. Lights, refrigerator, water pump, milking machine.

J. H. Hardy, Crawford.—16,762 kw-hr. Lights for house and barns, water pump, feed mill, farm gin.

Geo. W. Ruff, Tupelo.—6,216 kw-hr. Lights, range, water heater, refrigerator, water pump.

Drumm Chicken Farm, Richburg Hill, Hattiesburg.—21,552 kw-hr. Lights, water pump, electric brooders.

James Evans, Muldon.—12,288 kw-hr. Lights, water pump, 20-h.p. motor for feed mill, silage cutter and hay press.

Missouri

Aubrey Fellows, Salisbury.—5,000 kw-hr. Poultry raising, range, refrigerator, washing machine, iron, percolator, water pump, vacuum cleaner.

R. E. Brown, Moscow Mills.—11,000 kw-hr. Milking machine, feed grinding, range, iron, washing machine.

H. S. LeCompte, Springfield.—3,205 kw-hr. Range, refrigerator, percolator, washing machine, vacuum cleaner, separator, water pump, radio.

F. W. French, Springfield.—6,354 kw-hr. Milking machine, water system, hot plate.

M. F. Duvall, Clarksville.—4,790 kw-hr. Storage box for milk, motor driven churn and pasturizer, water system, milking machine, grinding outfit, refrigerator, washing machine, iron, toaster, range.

Montana

Nebraska

E. H. Sprague, Waterloo.—8,350 kw-hr. Lights, in home, employees' house, barn, hog house, chicken coop, range, refrigerator, water system, with troughs in cowbarn, cream separator, motor on feed grinder, household appliances.

Carlton B. Noyes, Waterloo.—18,000 kw-hr. Lights, household appliances, water system, milking machine, bottle washer and cleaner, fans, ironing machine, milk cooler, refrigerator, expect to install range.

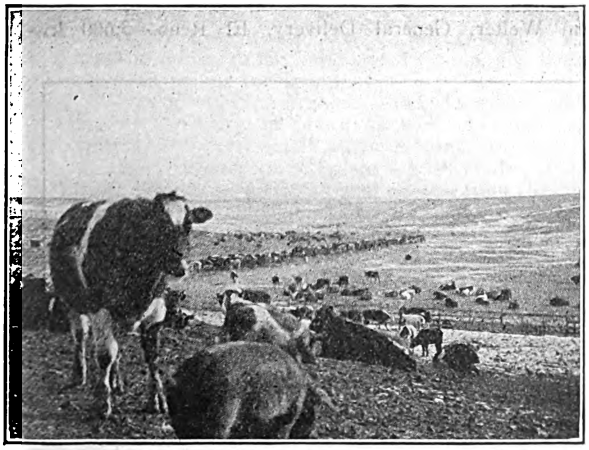

FIG. 15—A DAIRY FARM IN NEBRASKA WHICH USED 11,769 KW-HR. IN 1928.

Rapp Bros., Waterloo.—3,750 kw-hr. Motor, lights, household appliances, water pump, brooder, ironer.

Fritz Ackerlund, Route No. 1, Valley.—5,000 kw-hr. Elevator, water pumps, refrigerator, lights, household appliances.

J. P. Jensen, Route No. 6, Omaha.—10,000 kw-hr. Range, water heater, household appliances, lights in house and outbuildings, water system, refrigeration for milk cooling.

R. E. Krebb, Route No. 4, South Omaha.—3,020 kw-hr. Lights, household appliances, washing machine, vacuum cleaner, heater, toaster, iron, lamps, refrigerator, water pump, motor for grinder, line shaft and grain elevator.

Ralph Hickey, Gretna.—3,400 kw-hr. Lights, household appliances, refrigerator, range, motor on water pump.

H. W. Cockerill, Richfield.—25,500 kw-hr. Refrigerator, range, motors on two wells, grinder, motor on elevator.

Howard J. Luther, Nickerson.—8,000 kw-hr. Lights, appliances, stove, refrigerator, pump, 10-h.p. motor on grinder.

Geo. Cockerill, South of Gretna.—7,000 kw-hr. Lights, household appliances, refrigerator, cream separator, oil burner, ironing machine, water system, motor on pump.

Nevada

Dangberg Land & Livestock Co., Minden, Douglas County. —6,137 kw-hr. Range, water heater.

John Dangberg, Minden.—8,204 kw-hr. Range, water heater.

H. R. Jepsen, Minden.—3,995 kw-hr. Range, water heater.

Valley Farm, Minden.—4,179 kw-hr. Range, motor.

New Hampshire

E. W. Rollins, Rollinsford.—9,908 kw-hr. Motors, milking machine, water pump, refrigerator, many small motors, large lighting load.

Fred A. and James A. Dodge Farm, Rollinsford.—3,547 kw-hr. Water pump, milking machine, cream separator, iron, vacuum cleaner, washing machine, bottle washer, grindstone, lights.

Clifton Hayes, 6th St., Dover.—3,263 kw-hr. Brooder heaters, grain mixer, water pump, washing machine, iron, heater, toaster, vacuum cleaner, lights.

Sumner D. Sterling, 6th St., Dover.—7,054 kw-hr. Water pump, milk refrigerator, grindstone, milking machine, range, mangular motors, iron, vacuum cleaner.

Strafford County Farm, Dover.—9,908 kw-hr. 2 water pumps, laundry motor, bread mixer, meat chopper, butter churn, exhaust fan, cream separator, 3 electric irons, vacuum cleaner.

New Jersey

Little Flower Monastery, Newton.—Over 2,000 kw-hr. Pumps, 2 refrigerators, general farming and dairying, lights.

Samuel Montrose, Vernon.—Over 3,000 kw-hr. Washer, refrigerator, brine pump, water pump, milking machine, lights, iron, vacuum cleaner.

Ralph Williams, Hamburg.—Over 3,000 kw-hr. Washer, milker, lights, vacuum cleaner, 2 irons.

Jake L. Pittinger, Jerseyville Road, Howell.—5,143 kw-hr. 3 motors, milking machine, dairy refrigerator, house refrigerator, furnace stoker, water pump, iron, washing machine, lights.

Irving Owens, Bradvelt Rd., Holmdel.—3,431 kw-hr. Poultry farm, no list of appliances.

J. H. Becker, Freehold Rd., Morganville.—3,666 kw-hr. Truck farm, no list of appliances.

T. McCampbell, Red Bank Rd., Holmdel.—3,881 kw-hr. Truck farm, no list of appliances.

H. C. Scudder, Trenton Junction Road, Trenton.—11,616 kw-hr. Pump, bottle washer, filler, refrigerator, separator, pump, lights.

T. B. Boss, Route No. 4, Trenton.—5,723 kw-hr. Lights, milking machine, pump.

Thomas Harvey, Atlantic Ave., Columbus.—6,024 kw-hr. Lights, water pump, refrigerator, cutter.

John V. Bishop, Columbus Road, Columbus.—34,395 kw-hr. Lights, milking machine, pump, compressor for ice machine, corn cutter and general utility.

Wood Brook Farms, Plainfield Ave., Metuchen.—12,754 kw-hr. Lights, ice crusher, bottle washer, can washer, separator, saw, elevator, pasturizers, bottle filler, bottle conveyor.

Lester Collins, Union and Collings Lane, Pensauken.—36,278 kw-hr. Lights, refrigerator, 2 pumps.

Matthew Suydam, Franklin Park Road, New Brunswick.—7,761 kw-hr. Lights, refrigerator, pump, ice machine, portable motor.

Howard F. DeCou, Kings Highway and Church Road, Colestown.—3,519 kw-hr. Lights, pump, fruit sorter, fruit polisher, water pump, irrigation pump.

New Mexico

New York

Park & Pollard Co., Inc., Batavia.—6,907 kw-hr. Lights, pumps, 2 motors, refrigerator, milking machine, washing machine, separator.

Warren Hawley, Batavia.—4,197 kw-hr. Lights for house and barn, incubator, pump.

Arthur E. Minor, Batavia.—3,049 kw-hr. Lights in house and barn, 2 motors, range, refrigerator.

N. C. Shiverick, Avon.—14,035 kw-hr. Lights in house and yard, range, 2 motors on pumps, furnace motor, air pump motor.

J. W. Wadsworth, Jr., Groveland.—10,724 kw-hr. Lights in barns, owner's house and 2 tenant houses, range, motor on carrier, refrigerator, feed grinder.

Markham & Puffer, Avon.—21,561 kw-hr. 3 motors, air pressure motor, 2 motors in dairy barn, refrigerator, washing machine, lights, mangle, fan, motor on pump.

Jerry Wadsworth, Geneseo.—10,025 kw-hr. Refrigerator, range, water pump, milking machine; house, stable and grounds lights.

James J. Wadsworth, Geneseo.—3,583 kw-hr. Feed grinder, refrigerator, water pump, lights in house and stable.

Herbert Wadsworth, Avon.—7,904 kw-hr. Saw mill, feed grinder, lights in house, stable and grounds.

C. A. Rogers, Bergen.—5,227 kw-hr. Water pump, incubators, feed grinder, saw and grinder, refrigerator, 700-watt heater, general house and barn yard lights.

Kenyon Warner, Groveland.—3.785 kw-hr. Milking machine, water pump, washing machine, range, lights in house and stable.

Wm. Crandall, West Ave., Kendall.—3,933 kw-hr. Water pump, iron, vacuum cleaner, headlight heater, brooders and incubators, henhouse lights.

H. L. Hill, Knowlesville.—5,813 kw-hr. Steam table, coffee urns, dish washer, irons, fans, washing machine, water pumps, vacuum cleaner, kitchen aid and floor waxer

Clark Allis, Telegraph Rd., Medina.—Over 3,000 kw-hr. Water pumps, washing machine, water heater, exhaust fan, electric steam radiator fans, vacuum cleaner, headlight heater, iron, range, icebox, hotplate, waffle iron, curling iron, sewing machine, soldering iron, heating pad, vibrator, fireless cooker, transformer for doorbell, thermostat, battery charger.

North Carolina

F. D. Castlebury, Raleigh.—9,075 kw-hr. Refrigerator, water pump, lights for home and barns.

North Dakota

Moher and Moher, Devils Lake.—3,628 kw-hr. 3-h.p. motor, miscellaneous household appliances.

Ohio

P. Paumier, Chapel St. Extension, Louisville.—7,500 kw-hr. Water pump, washer, sweeper, iron, radio, brine circulating pumps, pasteurizing machine, bottling machine, bottle washer, water pump, milking machine, refrigeration plant, clipping machine, ventilating fan, lights in house and all outbuildings.

M. B. Shellabarger, Route No. 16, Dayton.—4,856 kw-hr. Refrigerator, brine pump, deep well pump, concrete mixer, line shaft, milking machine, washing machine, bottle washer, household appliances.

A. E. Wildman, Route No. 1, Selma.—3,611 kw-hr. 10 h.p. on ensilage cutter and blower, 10 h.p. on feed grinder, 3 h.p. on pumps and various household appliances.

Herbert Markey, Route No. 13, Dayton.—7,596 kw-hr. Water heater, range, motors on pumps, milking machine and small household appliances.

Donald D. Curtis, Route No. 13, Dayton.—4,366 kw-hr. Incubator, ventilating fan, ice machine, motor on pump, household appliances.

C. E. Loker, Route No. 2, Germantown.—4,628 kw-hr. Motor on feed grinder, ensilage cutter, elevator, 5 h.p. on corn sheller and sacker, range, motors on pumps.

Oklahoma

S. A. Marshall, Route No. 9, Oklahoma City.—9,000 kw-hr. Refrigerator, water pump, milking machine, range, various household appliances.

T. M. Townsend, Route No. 9, Oklahoma City.—3,000 kw-hr. Range, brooders, household appliances. (Is adding feed grinder and refrigerator.)

Harry Naylor, Route No. 10, Box 363, Oklahoma City.—12,000 kw-hr. Milking machine, pump, separator, cooler, range.

John Welter, General Delivery, El Reno.—3,600 kw-hr.

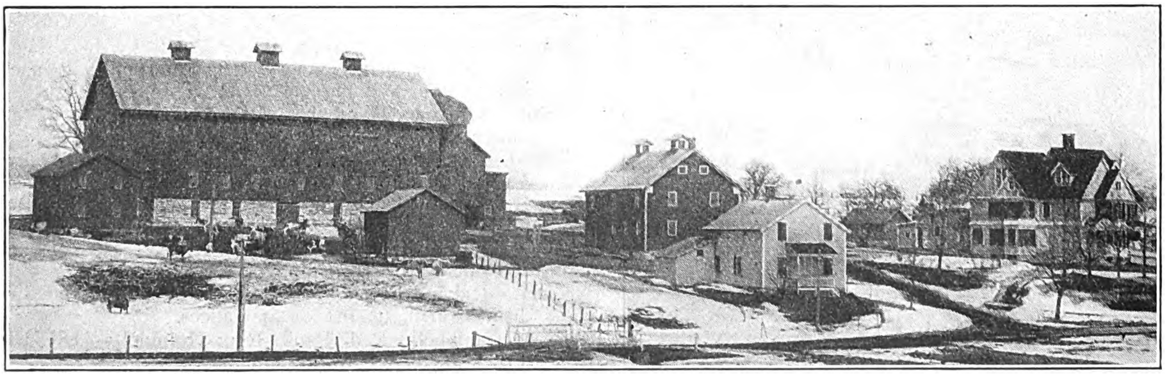

FIG. 16—THIS NEW YORK STATE FARM USES AN ELECTRIC REFRIGERATOR, RANGE, WASHER, BATTERY CHARGER AND FLATIRON.

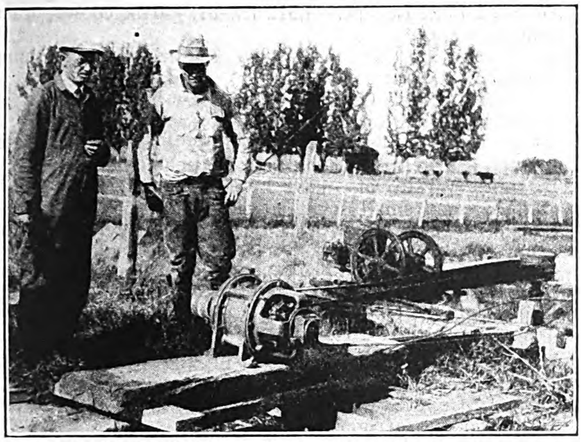

FIG. 17—SUPPLEMENTARY IRRIGATION WATER SUPPLY IN OREGON—THE MOTOR REQUIRES NO WATCHING.

Pumps, feed grinders, house refrigerator, range, household appliances.

J. C. Bostick, Ardmore.—6,000 kw-hr. Refrigerator, pump, milking machine, feed grinder, silo filler.

W. H. Hedges, Ardmore.—3,000 kw-hr. Milking machines, water pumps (is adding 5-h.p. motor for filling silos and grinding feed, also a range, and large refrigerator for milk cooling purposes).

Motor Woods, Ardmore.—3,000 kw-hr. Refrigerator, milking machine, water pump.

Ed Hoar, Carrier.—3,000 kw-hr. Range, refrigerator, various household appliances.

Oregon

Iron Hill Orchard, Inc., Route No. 3,—Salem.—5,978 kw-hr. 3-h.p. motor on pump, 5-h.p. general utility motor for general farm work, various household equipment.

John J. Roberts, Route No. 3, Salem.—26,459 kw-hr. Hop ranch using service in 3 ranch houses, small motor for pumping, utility motor for cutting feed, 7 15-h.p. motors for fans during hop drying season.

F. W. Durbin & Son, Route No. 6, Salem.—39,736 kw-hr. Lights in home, dairy barn, outbuildings; milking machines, refrigeration plant, pump motor, motor for feed grinding, motor for hay hoist, and usual farm equipment.

Brophy Hop Ranch, Route No. 2, Salem.—3,992 kw-hr. 15-h.p. motor driving centrifugal pump used for irrigation.

P. Corpstein, Route No. 2, Turner.—3,195 kw-hr. Lights, water pump, 7½-h.p. motor on circulation fan during prune drying season.

T. A. Livesley Co., Route No. 8, Salem.—26,136 kw hr. Lights in house, ranch buildings, 1 50-h.p. and 2 25-h.p. motors on pumps for irrigation.

Lloyd A. Lee, Route No. 6, Salem.—19,903 kw-hr. Hatches chickens. Service in house as well as operating incubators, brooders, small pump motors.

A. L. Lindbeck, Route No. 6, Salem.—3,010 kw-hr. Chicken farm. Service in house as well as operating incubators, brooders, small pump motors.

J. M. Nichols, Route No. 6, Salem.—3,938 kw-hr. Dairy farm using electricity in home as well as small motor operating water pump, 2-h.p. motor for feed chopping.

F. H. Richter, Ontario.—3,274 kw-hr. Range, 2 water heater, toaster, iron, washing machine, 1-h.p. water system, refrigerator, 1-h.p. milking machine, 1/6-h.p. bottle washer, ¼-h.p. separator, ¼-h.p. circulating pump.

C. Shelton, McMinnville.—3,173 kw-hr. Lights, heating, small motor, toaster, percolator, washing machine.

J. A. Campbell, Route No. 2, Amity.—4,134 kw-hr. Lights, range, motor.

R. L. Harris, Route No. 1, Sheridan.—4,963 kw-hr. Motor, incubators, electric appliances.

J. E. Panck, Route No. 1, Tigard.—3,901 kw-hr. Lights, range, incubators.

H. A. Dryer, Route No. 1, Tigard.—4,279 kw-hr. Lights, range, motor, milking machine.

Pennsylvania

B. D. Miller, Bethany.—29,222 kw-hr. 8 water pumps, 2 milking machine, 3 2-h.p. motors for creamery use, 1 5-h.p. motor for ice plant, range, lights, appliances for farm home and help's home.

Geo. A. Konkle, Mill Creek Rd., Route No. 2, Montoursville.—5,307 kw-hr. Milking machine, bottle washer, milk aerator, water pump, grain grader, range, washing machine, iron, curling iron, radio.

Allendale Farms, Inc., Route No. 3, Montoursville.—18,474 kw-hr. Ice crushing machine, refrigerator, milking machine, cooling and standardizing machine, milk bottle washer, lights, appliances in home.

Mill Brook Farm, E. M. Archy, Prop., Mill Hall.—4,811 kw-hr. Milking machine, refrigerator, ¼-h.p. motor, lights, appliances.

Robt. Pittinger, Pond Rd., Bethlehem.—3,228 kw-hr. Range, lights and appliances.

Chas. Eichlin, Route No. 2, Perkasie.—3,514 kw-hr. Range, water pump, brooder, lights, washer, cleaner, household appliances.

Chas. H. Price, Jr., Main St., Telford.—3,229 kw-hr. Range, incubator, lighting brooder houses, washer, cleaner, household appliances.

Heston R. Leidy, Souderton.—3,576 kw-hr. Range, water pump, lights in brooder houses, washer, cleaner, household appliances.

H. F. Rittenhouse, Franconia.—3,055 kw-hr. Range, water pump, washer, cleaner and household appliances.

W. F. Rosenberger, Route No. 1, Hatfield.—4,835 kw-hr. Range, refrigerator, water heater, water pump, thresher, washer, cleaner, appliances.

Ray Belle Farm, W. E. Erdell, Prop., Allentown.—3,570 kw-hr. 2 pumps, range, toaster, percolator, iron, 125 lights, ¼-h.p. motor, refrigerator.

Wm. Wenz, Wenz Farms, Breinigsville.—7,232 kw-hr. Feed

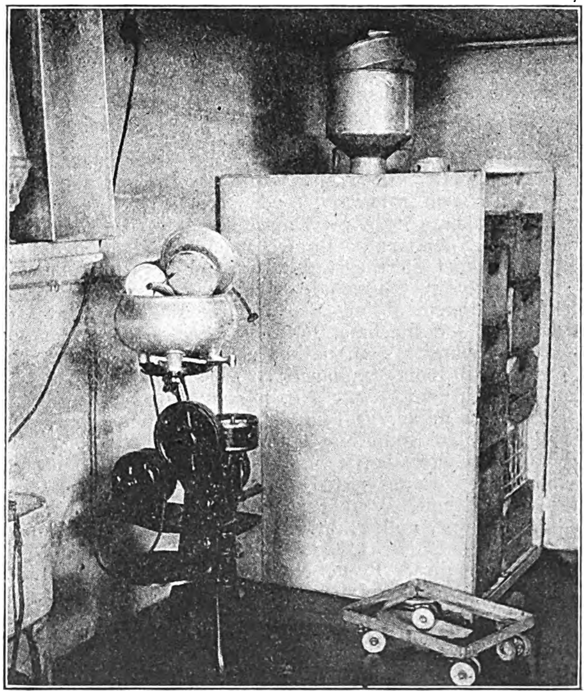

FIG. 18—AN ELECTRIC SEPARATOR IN USE ON AN OREGON FARM.

grinder, milking machine, bottle washer, cream separator, pump, range, refrigerator, milk cooler, washer, iron, toaster, percolator.

V. M. Schmoyer Farm, Minesite near Macungie.—3,041 kw-hr. Range, pump, iron, washer, percolator.

J. W. Silvas & Sons, Route No. 1, Greensburg.—Over 3,000 kw-hr. Milk cooler, bottle washer, bottler, household appliances, water system.

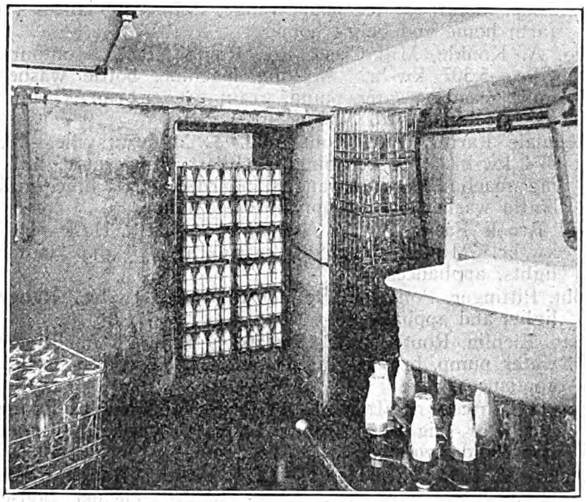

FIG. 19—COOLING 22,000 POUNDS OF MILK PER MONTH ELECTRICALLY ON A PENNSYLVANIA FARM.

H. E. Steel, Route No. 5, Greensburg.—Over 3,000 kw-hr. Milk cooler, bottle washer, bottler, household appliances, water system.

J. W. Patterson, Star Route, Apollo.—Over 3,000 kw-hr. Milk cooler, bottle washer, bottle, household appliances, water system.

W. J. Zimmerman, Leechburg.—Over 3,000 kw-hr. Milk cooler, bottle washer, bottler, household appliances, water system.

Geo. Rutter, Carmichaels.—Over 3,000 kw-hr. Milk cooler, bottle washer, bottler, household appliances, water system.

W. H. Farrar & Sons, Route No. 4, Midway.—Over 3,000 kw-hr. Milk cooler, bottle washer, bottler, household appliances, water system, range.

J. N. Loffert, Route No. 4, McDonald.—Over 3,000 kw-hr. Milk cooler, bottle washer, bottler, household appliances, water system, range.

C. E. Honsaker, City View Dairy, Masontown.—Over 3,000 kw-hr. 5-h.p. motor on ice machine, 3-h.p. motor on washer and sterilizer, 2-h.p. on milker, miscellaneous small motors, household appliances.

Michael Rathgeb, Route No. 3, Greensburg.—Over 3,000 kw-hr. Ice machine, bottle washer, bottle filler and capper, water system, milker, churn, separator, line shaft for small tools, appliances.

Wm. Reifschneider, Route No. 1, Arnold.—Over 3,000 kw-hr. range, milker, full line of household appliances.

Joseph L. Bauer, Route No. 2, Jeannette.—Over 3,000 kw-hr. Milker, cooler, bottle washer, bottler, small household appliances, water system.

Mrs. Jane Elliott, West Brownsville.—Over 3,000 kw-hr. Ice machine, milker, separator, water heater, household appliances.

Frank S. Laughead, Route No. 5, Uniontown.—Over 3,000 kw-hr. Range, refrigerator, milker, household appliances.

S. B. Eckert, Goshenville.—3,376 kw-hr. Lights, pump, refrigerator.

Harry Collins, Rocky Hill.—8,008 kw-hr. Range, refrigerator, milk cooler, water pump.

Mrs. Wm. Boyle, West Chester.—3,246 kw-hr. Water pump, lights.

Helen Reed Fox, Lenape.—4,512 kw-hr. Milk cooler, water pump, lights.

Chas. E. Mather, Lenape.—9,846 kw-hr. Water pump, lights, refrigerator.

Paul Snyder, West Chester.—26,714 kw-hr. 2 motor ice machines, 1 motor general power, water pump.

Margaret Dallett, Westtown.—3,968 kw-hr. Range, water pump, refrigerator, lights and household appliances.

M. L. Jones, Westtown.—4,892 kw-hr. Refrigerator, lights, water pump, small farm power.

H. M. Kelse, Westtown.—3,001 kw-hr. Refrigerator, water pump, lights.

Samuel Horner, Malvern.—4,081 kw-hr. Range, lights, refrigerator.

Wm. I. Mirkil, Malvern.—4,383 kw-hr. Water pump, range, lights.

John F. Lewis, Morstein.—4,037 kw-hr. Water pump, lights, refrigerator.

Wilmer B. Cox, Malvern.—4,306 kw-hr. Range, lights, water pump, refrigerator.

Arthur Pierce, Willistown, Malvern.—9,525 kw-hr. Range, water pump, 2 refrigerators.

A. Merritt Taylor, Sugartown, Malvern.—4,845 kw-hr. Range, water pump, lights, refrigerator, household appliances.

G. Brinton Lucas, Malvern.—3,079 kw-hr. Refrigerator, water pump, lights.

Delchester Farms, Edgemont.—36,025 kw-hr. Milking machine, washer, water pump, bottle washer, sterilizer, separator, ammonia machine, bottle filler, lights in one barn—milking machine, lights and water pump in another barn, clipper motor, blacksmith shop, plainer motor, saw motor and forge motor—9 tenant houses with lights and appliances.

John Hockel, Limerick.—Over 3,000 kw-hr. Range, lights.

C. D. Marshall, Laurel Locks Farm, Pottstown.—15,876 kw-hr. 3 fans, refrigerator, 3 motors for filling silo, milker, thresher, corn husker, pump, creamery.

Dorothy Cadwalader, Charlestown Twp., Route No. 3, Phoenixville.—4,825 kw-hr. Milk cooler, pump, lights.

R. H. R. Toland, Cedar Run Farm, Route No. 2, Phoenixville.—7,246 kw-hr. Milk cooler, pump.

G. W. Heuer, Trooper Rd. Trooper.—6,786 kw-hr. Milk

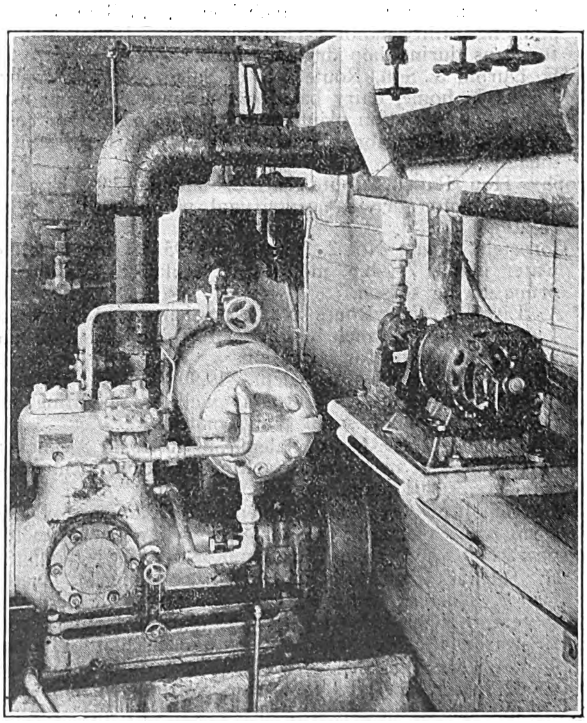

FIG. 20—ELECTRIC DAIRY REFRIGERATOR INSTALLATION ON A FARM IN PENNSYLVANIA.

cooler, refrigerator, 2 pumps, sweeper, washer, iron, radio, lights.

James A. Staley, Ridge Pike, Eaglesville.—5,854 kw-hr. Washer, milk cooler, bottle washer, iron, sweeper, radio.

Daniel Buckley, Skippack, Pike, Broad Axe.—3,941 kw-hr. Range, refrigerator, washer, cleaver, iron, motors, lights.

Thos. Berger, State Rd., Valley Forge.—7,362 kw-hr. Range, refrigerator, washer, ironer, cleaner, iron, pump, milk cooler, lights.

F. H. Hargass, Valley Forge.—4,950 kw-hr. Refrigerator, motors, water pump, washer, iron, cleaner, lights.

I. R. Lindle, Valley Forge.—5,647 kw-hr. Motors, refrigerator, washer, cleaner, iron, lights.

C. B. Wood, River Rd., W. Conshohocken.—12,624 kw-hr. Refrigerator, motors, water pump, lights.

Leo. Angove, Akeley.—5,840 kw-hr. Range, refrigerator, washing machine, iron, mangle, warming pad, battery charger, waffle iron, curling iron, vacuum cleaner, sewing machine, radio, pump, motor oil burner, milking machine, chicken house lights.

J. B. Moore, Garland.—7,895 kw-hr. 2 milking machines, water system, separator, barn lights, 2 residence lightings, ensilage cutter, creamery (power and lights), refrigerator, radio, iron.

Willis Bisbee, Perry Highway, Union City.—3,450 kw-hr. 3½-h.p. motor and gas station.

W. H. Shreve, Meadville Rd., Union City.—7,774 kw-hr. 3½-h.p. motor, milk farm.

L. D. Shreve, Route No. 6, Union City.—3,390 kw-hr. Motors, range, lights.

E. E. Wheeler, Waterford.—3,000 kw-hr. 4-h.p. motor, range, lights.

John Forsythe, Clearfield.—5,472 kw-hr. Lights in 3 barns, range, feed chopper, 2 pumps.

H. H. Tompson, Route No. 56, Sharpsville.—10,175 kw-hr. Refrigerator, bottle washer, water pumps, milking machines, range, lights.

W. H. Crawford, Mercer.—4,319 kw-hr. Lights, milking machine, water pump, small motor.

F. L. Fay, Greenville.—3,982 kw-hr. Lights, range, water pump, refrigerator.

Chas. Koonce, Clarksville.—3,060 kw-hr. Lights, small motor, refrigerator, pumps.

O. C. Neel, Route No. 36, Fredonia.—3,060 kw-hr. Lights, range, pump.

St. Paul's Orphans' Home, Greenville.—15,775 kw-hr. Lights, water pump, ironer, motors.

Dr. Frederick Taylor, Pulaski.—3,751 kw-hr. Range, washer, sweeper, refrigerator, toaster, radio, commercial refrigerator, dairy ventilation, milking machine, 2 water pumps, ensilage cutter.

H. G. Haskell, Cossart.—7,099 kw-hr. Oil burner, cream separator, bottle washer, agitator in pasteurizing tank, lights.

Rhode Island

Geo. W. Madison, Potowomut Rd., East Greenwich.—6,048 kw-hr. Refrigerator, milking machine, small dairy apparatus and pumping machine, household appliances, radio.

P. C. Peterson, Greenville Ave., Johnson.—3,240 kw-hr. Water pump, milking machine, chicken house lights and lights in house and barn.

Wyman Whitman, Hope Ave., Oaklawn.—6,276 kw-hr. Refrigerator, water pump, milking machine, lights, household appliances.

Fred L. Williams, Scituate and Seven Mills Rd., Scituate.—3,720 kw-hr. Water pump, refrigerator, range, appliances, lights for barn.

R. L. Knight, Hope Ave., Oaklawn.—4,068 kw-hr. Milking machine, water pump, household appliances, range.

South Carolina

St. J. A. Lawton, Charleston.—18,192 kw-hr. Lights for home and dairy, 2 household refrigerators, 1 dairy refrigerator, milking machine, water pump for livestock and dairy.

Coburg's Dairy, Charleston.—19,836 kw-hr. Lights for home, signboard and dairy, refrigerator for dairy, water pump for home and dairy, milking machines, bottle washer, separator, churn, ensilage cutter, wood saw.

H. F. Barkerding, Charleston.—23,370 kw-hr. Lights for house and dairy, refrigerator for dairy, water pump for home and dairy, milk cooler.

T. M. Whittemore, Charleston.—6,774 kw-hr. Lights for house, and poultry house, 2 refrigerators for home, water pump for home and livestock, range.

South Dakota

Ernest Johnson, Sioux Falls.—4,414 kw-hr. Milking machine, refrigerator, feed grinder.

C. W. Thompson (Woodlawn Dairy), Sioux Falls.—11,158 kw-hr. 2 milking machines, feed grinder, silo filler.

B. E. Cornue, Sioux Falls.—4,886 kw-hr. Milking machine, refrigerator, range, water pressure system.

Geo. L. Renner, Sioux Falls.—4,638 kw-hr. Refrigerator, range.

F. I. Renner, Sioux Falls.—3,541 kw-hr. Range, milking machine.

John Parker, Sioux Falls.—3,151 kw-hr. Milking machine.

O. Benson, Sioux Falls.—3,352 kw-hr. Milking machine, pumps.

Tennessee

R. L. Peters, Farragut.—12,900 kw-hr. Lights, range, milking machine, milk cooler, water pump.

J. Q. Shephard, Cleveland Pike, Chattanooga.—8,156 kw-hr. Lights, range, refrigerator, water pump, feed cutter, milking machine, (is installing complete refrigeration plant for dairy).

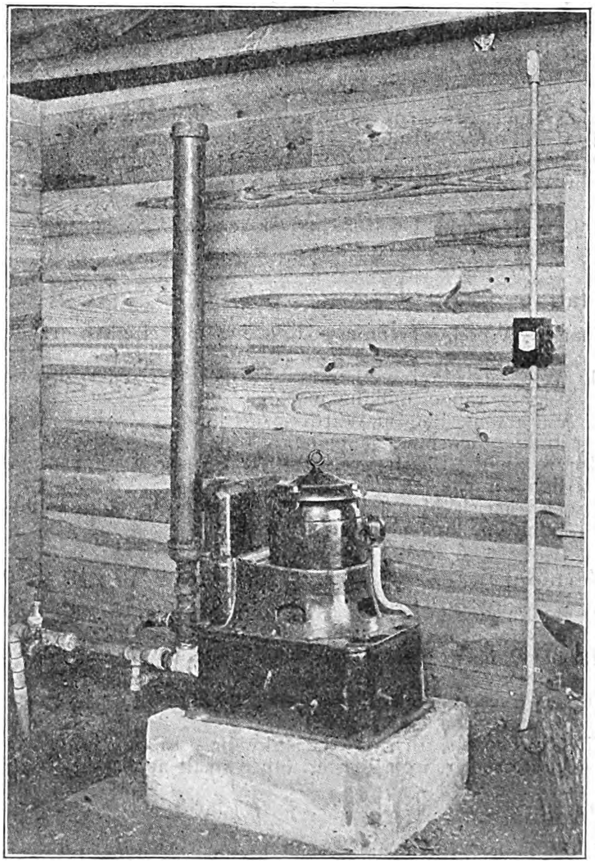

FIG. 21—DEEP WELL ELECTRIC PUMP ON DAIRY FARM IN TEXAS.

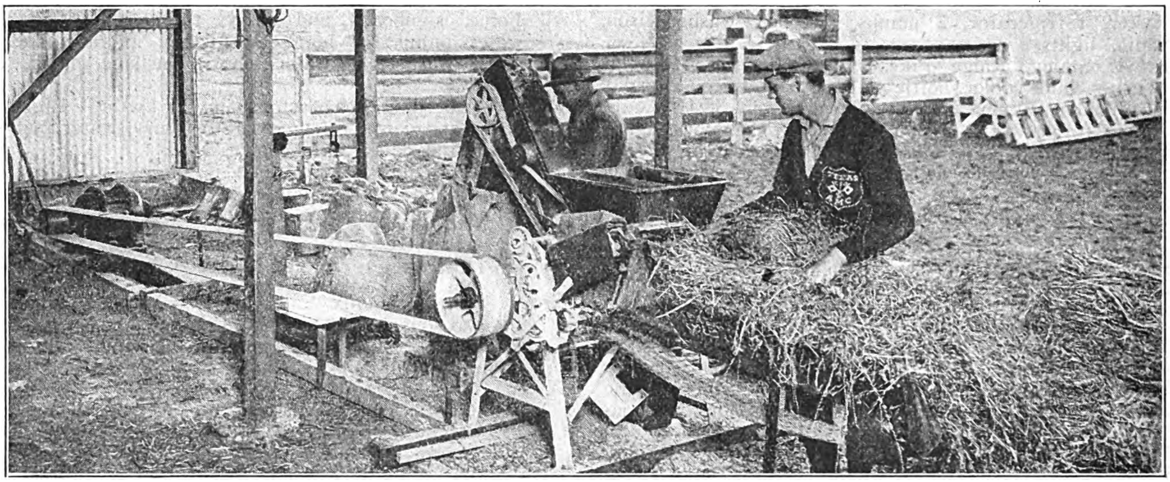

FIG. 22—ELECTRICITY ASSISTS TEXAS FARMERS IN ELIMINATING WASTE IN THE PREPARATION OF ALFALFA FOR DAIRY FEEDING.

Garnett Andrews, LaFayette Rd., Chattanooga.—53,410 kw-hr. Lights, range, water heater, refrigerator, water pump, milking machine, feed cutter, dairy refrigerator.

J. Walter Cummings, Wauhautchie.—45,058 kw-hr. Lights, range, dairy refrigerator, milking machine, water pump, feed cutter, line shaft driving miscellaneous equipment.

Edgar L. Brinkley, Signal Mountain.—4,240 kw-hr. Lights, range, refrigerator, water pump, spray pump.

Texas

C. J. Davis, Corsicana.—5,436 kw-hr. Cotton and stock farm.

C. R. Hoffman, Denton.—5,742 kw-hr. Poultry farm.

F. A. Wisse, Muenster.—4,224 kw-hr. Grain and stock farm.

Louis Duke, Sherman.—4,440 kw-hr. General farm.

H. R. Mctuley, Misquite.—4,284 kw-hr. Cotton farm.

D. A. Bolfing, Waco.—5,800 kw-hr. Truck farm.

John W. McFarlane, Palestine.—Over 3,000 kw-hr. General farm.

J. J. Wainwright, Crystal City.—Over 3,000 kw-hr. General farm.

Utah

Charles Wood, Trenton.—3,679 kw-hr. Lights, range, pump.

H. W. Ballard, Jr., Benson Ward.—Over 3,000 kw-hr. Lights, range, milking machine.

E. A. Parsons, Benson Ward.—3,069 kw-hr. Lights, range, milking machine, pumping.

Morris Smith, Burch Creek.—7,314 kw-hr. Lights, range, lights in chicken coops.

Joseph Parrish, Mountain Green.—Over 3,000 kw-hr. Lights, range, milking machine, pumping.

Vermont

D. B. Parmelee, Bristol.—3,827 kw-hr. Lights, heat motors, iron, toaster, radio, vacuum cleaner.

Harlan Palmer, New Haven.—6,027 kw-hr. Lights, incubators, 6 fans, vacuum cleaner.

Russell Everest, New Haven.—4,622 kw-hr. Lights, range, toaster, iron.

Thorpe Thomas, Bristol.—4,234 kw-hr. Lights, heat, vacuum cleaner, iron, toaster, other small appliances.

Virginia

E. E. Zeller, Richmond.—8,930 kw-hr. Motors, refrigerator, milking machines and booster, water pump, grain fan, washing machine, lights, vacuum cleaner, toaster, fan, iron.

J. Scott Parrish, Richmond.—13,339 kw-hr. Water pump, brine pump, 3 refrigerators, separator, lights, range, fans, 3 irons, 2 waffle irons, washer, toaster, cleaner.

W. J. Burlee, Richmond.—9,150 kw-hr. Motor, water pump, hay hoist, curling iron, fan, toaster, waffle iron, cleaner, lights.

J. H. Parker & Sons, Portsmouth.—5,187 kw-hr. 2 motors saw, lights.

B. H. Darden, Norfolk.—29,390 kw-hr. Motor for silo filling, refrigerator, water pump, milking machine, brine pump, bottle washer, milk cooler, lights.

Washington

George J. Coulter, Route No. 7, Box 57, Seattle.—4,939 kw-hr. Lights in henhouse 3 hours a day, 2 small motors for cutting straw and hay, brooders, range, water heater, household appliances.

Hollywood Dairy Farm, Woodinville.—63,138 kw-hr.

FIG. 23—ELECTRIC MOTORS CUT DOWN LABOR, DRUDGERY AND COST OF PRODUCTION ON WESTERN WASHINGTON POULTRY FARMS.

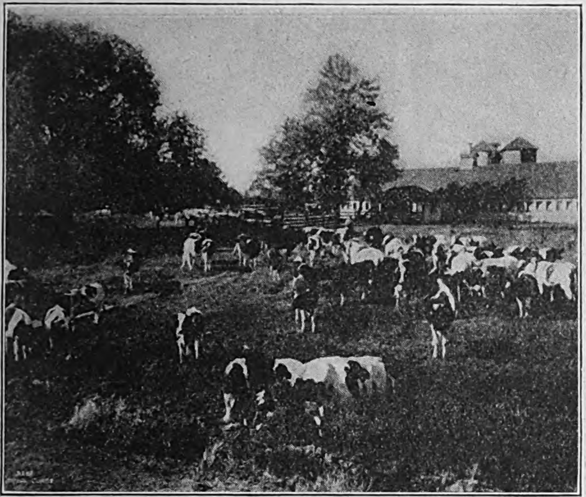

FIG. 24—AN ELECTRIFIED WASHINGTON DAIRY FARM.

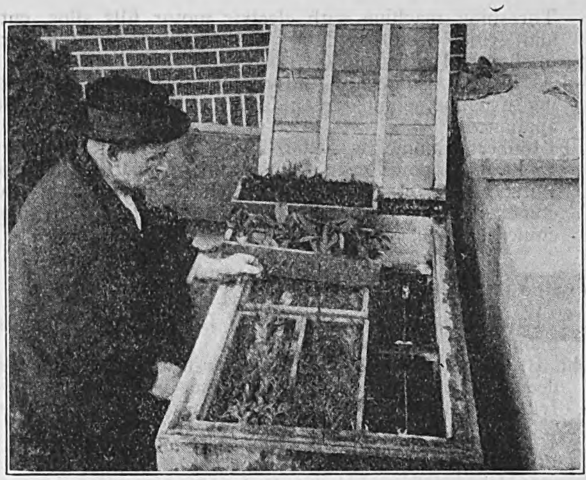

FIG. 27—ELECTRIC HOT BED AND NURSERY FRAMES EMPLOYED BY A WASHINGTON NURSERY.

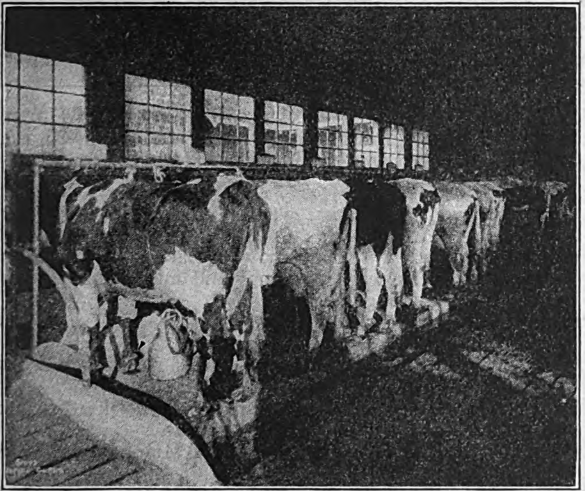

FIG. 25—ELECTRIC MILKERS IN USE ON A DAIRY FARM IN WASHINGTON.

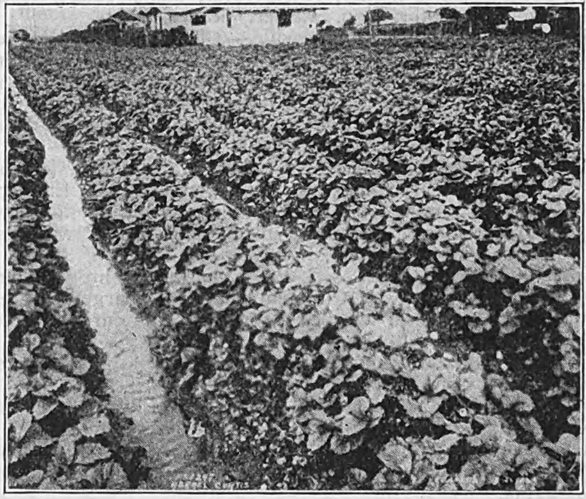

FIG. 28—ELECTRIC PUMP IRRIGATES THIS STRAWBERRY FIELD IN WESTERN WASHINGTON.

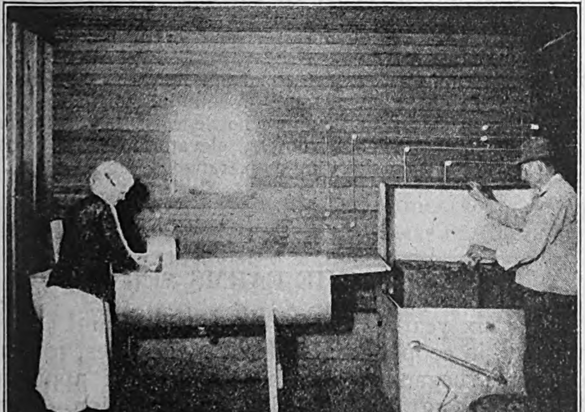

FIG. 26—ELECTRICITY HEATS WATER, RUNS BOTTLE WASHER AND STERILIZES DAIRY UTENSILS ON WASHINGTON FARM.

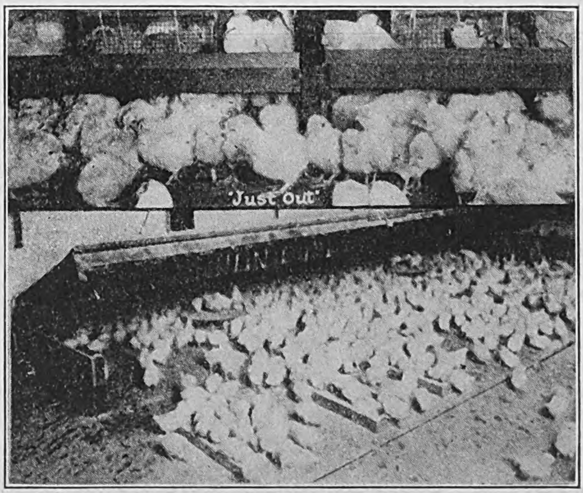

FIG. 29—1000-CHICK ELECTRIC UNDERHEAT BROODER AT THE WESTERN WASHINGTON EXPERIMENTAL STATION.

Threshing machine with electric motor fills silos, cuts and grinds feed for dairy, elevates feed, small motors in shop and milk room.

Peder Halkjar, Enumclaw.—More than 3,000 kw-hr. Milking machine, pump, cream separator, range, household appliances.

F. F. Joubert, Enumclaw.—6,067 kw-hr. 20-acre farm, milks 15 head of cows year round, milking machine, pump, water heater, cream separator, grindstone, washing machine, machinery in shop, 6 motors running farm machinery, range, iron.

West Virginia

A. S. Paull, Wheeling.—4,189 kw-hr. Lights, motors, pumps, mangle, refrigerator.

John B. Garden, Wheeling.—11,330 kw-hr. Lights, motors, deep well pump, cistern pump, water heater, range, refrigerator.

Wisconsin

L. G. Anderson, Rockdale.—3,444 kw-hr. Range, brooders, irons, separator, automatic pumps, cleaners, lights.

George Stillmacher, Route No. 3, Ripon.—3,072 kw-hr. Feed grinder, milker, refrigerator, pump, range, separator, incubator, iron, washer, cleaner, lights.

H. C. Hemmingway, Janesville.—3,492 kw-hr. Range, pumps, milker, separator, bottle washer, battery charger, iron, toaster, cleaner, waffle iron, sewing machine, lights.

Charles Mead, Route No. 4, Ripon.—3,492 kw-hr. Range, pump, iron, water heater, incubator, separator, dishwasher, battery charger, lights.

Martin Hoppert, Route No. 4, Sheboygan.—14,484 kw-hr. Water system refrigerator, bottle washer, G. E. mercury arc rectifier, oil burner, milker, vent fan, toasters, water heaters, separator, ultra violet lamp, washers, brooder, irons, heaters, lights.

George Tabbert, Route No. 3, Ripon.—3,192 kw-hr. Milker, feed grinder, water system, battery charger, water heaters, washer, cleaner, iron, toaster, curling iron, lights.

George L. Hamon, Route No. 3, Juda.—3,492 kw-hr. Range, washer, iron, lights.

J. H. Grenzow, Route No. 3, Juda.—3,476 kw-hr. Range, water heater, water light, iron, washer, lights.

W. J. Dougan, Beloit.—13,368 kw-hr. 7 motors, washer, irons, cooker, cleaner, dishwasher, sewing machine, lights.

W. N. Preston, Route No. 3, Juda.—3,192 kw-hr. Range, water system, hotplate, cleaner, toaster, iron, washer, lights.

David Stevenson, Lodi.—3,024 kw-hr. Pumps, milker, battery charger, separator, washer, cleaner, toaster, curling iron, 2 irons, lights.

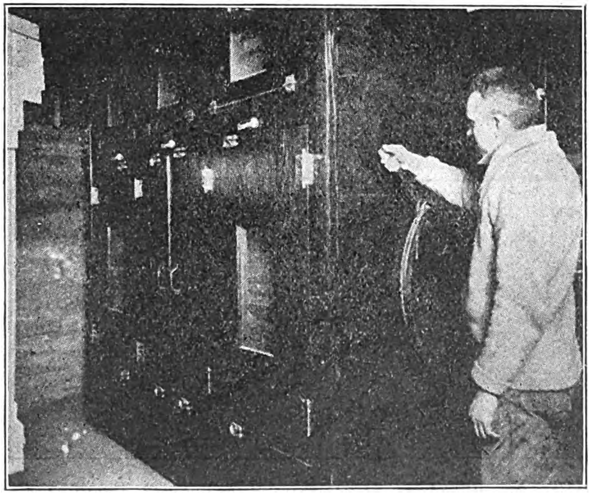

FIG. 30—15,000-EGG ELECTRIC INCUBATOR IN USE ON A WASHINGTON FARM.

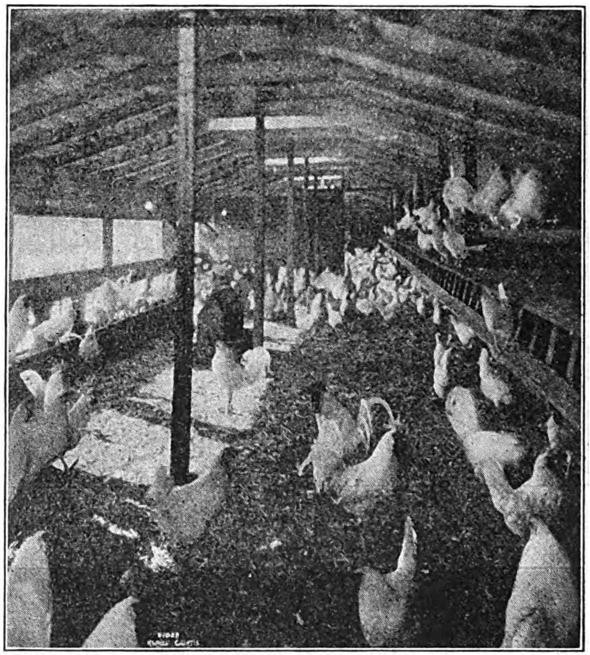

FIG. 31—A WESTERN WASHINGTON POULTRY HOUSE WHERE ELECTRIC LIGHTS INCREASE PRODUCTION 30 PER CENT WHEN EGGS ARE HIGH.

Fred Pabst, south of Oconomowoc Lake.—30,528 kw-hr. Motors for can washer, pumps and miscellaneous dairy farm uses, 2 ranges, lights.

Pleasant Valley Farm, Highway 59, near Genessee Village. —27,782 kw-hr. Motors, range, lights.

Owen Rowlands, N. S. Rd. ¼ mile west of Bethesda Station.—45,680 kw-hr. Motors, range, lights.

Pleasant View Farm, Genessee Village.—24,199 kw-hr. Motor, butter washer, ice machine, lights.

D. W. Norris Farm, Orchardview, Mukwonago.—4,787 kw-hr.

D. W. Norris Farm, Evergreen Farm, Mukwonago.—7,229 kw-hr. Motors for pumps, line shaft, saw, ice machine, dryer, miscellaneous motors, range and lights.

D. S. Williams, Bethesda Station, Route No. 9, Waukesha. —75,520 kw-hr. Motor for silo filler and feed grinder, 35-h.p. of miscellaneous motors, as milking machines, ice machine, air compressor and bottling equipment, range, lights.

Brookhill Farm, on Genessee Road one mile east of Brookhill.—61,800 kw-hr. Motors for milking machines, ice machine, ice crusher, pumps, bottle washer, bottler and filler, box conveyors, blower, elevator, washer, separators and line shaft in shop, range, lights.

Wyoming

COUNTING THE FARMS SERVED

Some six years ago, the electric light and power industry, in cooperation with other agencies, for the first time began giving the problem of applying electricity to agriculture serious consideration. During this six-year period not only have many new and practical uses for electricity on the farm been developed, but company lines have been extended to more additional farm customers than during all previous history combined. In fact the increase is between 150 and 200 per cent.

This record might be taken as something of which to be proud, something that would merit the approval of an interested public, especially when it is taken into consideration that many of the difficulties of electrifying the farm have been dissipated and it looks today as if even more rapid progress can be maintained in the future. Due, however, to negligence on the part of electric light and power companies in maintaining records pertaining to rural service, it is likely, to say the least, that the industry is not receiving the recognition which this development merits.

Companies have nearly trebled the number of farm customers served and put electricity to work performing a multiplicity of agricultural jobs but the figures with which to tell the story are woefully inadequate. In other words, the industry has accomplished a meritorious development, but through failure on the part of individual companies to keep records, few outside the industry know about it.

The Statistical Department at N. E. L. A. headquarters has long endeavored to get member companies to report essential facts regarding farm service. The Association's statistical sheet asks the member companies to supply number of farms served, kilowatt hours consumed, and revenue received, but only a few of the companies are making this return to headquarters. If the figures received at headquarters were taken as an accurate reflection of the number of farms served in the United States a sorry looking record indeed would be presented.

When this information first was asked for many companies made inquiry as to just what constitutes a farm and N. E. L. A. headquarters supplied them with the definition of a farm as used by the Bureau of the Census, reading in condensed form as follows:

> A farm is any place of three or more acres to produce agricultural products; or any place three acres or less where the yearly revenue from agricultural products is more than $250; or any place three acres or less where the owner or tenant devotes his entire time to agriculture.

Even this, however, failed to produce satisfactory results. There is one state which has some 20,000 or 30,000 farm customers, but which shows on the statistical returns as having something like a thousand, all due to companies failing to make this report.

The Accounting National Section is doing all in its power to get accounting departments of member companies to segregate farm business on their books so that the data desired will be continuously available, but there are still many companies which are not supplying this information. It is particularly desirable to obtain accurate record of the number of farms served.

In November, 1928, the Chairman of the Rural Electric Service Committee asked the Chairmen of the Rural Committees of each Geographic Division to supply a count of farms served in each respective division. Returns have been received and are presented here from all states heard from—a total of 31 states. These 31 states show a grand total of 383,730. This is fairly accurate, as the figures from many states represent an actual count, and where the figures are based on an estimate these estimates were made only after a careful investigation. It is significant that the number of farms reported to N. E. L. A. headquarters by these states is only a minor fraction of the number reported by the Chairmen of Geographic Rural Committees. Here is the tabulation:

NUMBER OF FARMS SERVED BY ELECTRIC LIGHT AND POWER COMPANIES

Alabama	6,550
Arizona	900
Arkansas	*
California	62,720
Colorado	3,872
Connecticut	*
Delaware	*
Florida	*
Georgia	*
Idaho	7,216
Illinois	13,284
Indiana	15,163
Iowa	13,817
Kansas	2,830
Kentucky	7,000
Louisiana	*
Maine	11,878
Maryland	*
Massachusetts	*
Michigan	12,500
Minnesota	10,500
Mississippi	*
Missouri	3,760
Montana	663
Nebraska	2,067
Nevada	1,200
New Hampshire	*
New Jersey	11,800
New Mexico	225
New York	47,800
North Carolina	*
North Dakota	1,000
Ohio	30,575
Oklahoma	*
Oregon	11,428
Pennsylvania	27,105
Rhode Island	*
South Carolina	*
South Dakota	2,500
Tennessee	*
Texas	*
Utah	10,114
Vermont	*
Virginia	5,000
Washington	34,443
West Virginia	4,525
Wisconsin	20,885
Wyoming	410
Total	383,730

*No report.

The above tabulation is indicative of a splendid development during these last six years. At the time this work first was seriously undertaken there probably were fewer than 200,000 farms receiving this service. In the above table, which may fairly be dated as of Dec. 31, 1928, 31 states show 383,730 The Rural Electric Service Committee wishes to be conservative in its figures. In attempting to estimate the total for the 48 states, the Committee takes into consideration that many of the states which have the most farm customers are included in the above total. The 17 missing states constitute more than one-third of the 48 states, and if the number of farms served in these 17 states kept pace with the other 31, the grand total would be close to 600,000, but the Rural Committee is willing to be conservative and content with estimating that the total number served is well in excess of 500,000.

These incomplete returns are published here for several reasons:

1. To show the general public, which has been interested in this pioneer field from the very start of the investigations, that some real progress is being made.
2. To bring forcibly to the attention of the Chairmen of the Geographic Divisions who have failed to obtain a count, the necessity for obtaining such figures.
3. To bring the attention of member companies to the importance of filling out the farm information called for in the N. E. L. A. Statistical Sheets.
4. To show manufacturers of electric and farm equipment, as well as electric light and power companies, what kind of a market is developing for their products and where that market is.

It is the hope of the Rural Committee that before another year has passed the electric industry will have put itself in a position to have readily available at all times accurate information in regard to the farm business just as it has now accurate figures pertaining to residence, commercial power, and other phases of the electric business.

REPORT OF MEMBERSHIP COMMITTEE

By HOWARD K. MOHR

Chairman, Membership Committee

(For Committee Personnel See Appendix 4)

NATIONAL ELECTRIC LIGHT ASSOCIATION, MEMBERSHIP REPORT, MAY 29, 1929

Class of Member	Membership March 6, 1929	Membership May 29, 1929	Net Changes Since March 6, 1929	Changes During the Period New Members	Changes During the Period Cancellations	Membership May 31, 1928	Net Changes, One Year†
A	752	721	31*	5	36	770	49*
B	15,286	15,350	64	1,448	1,384	14,758	592
C	105	107	2	3	1	119	12*
D	405	417	12	35	23	393	24
E	2,523	2,676	153	309	156	2,517	159
F	405	427	22	38	16	342	85
G	658	762	104	131	27	668	94
H	131	138	7	8	1	115	23
I	67	76	9	9	..	60	16
	20,332	20,674	342	1,986	1,644	19,742	932

NOTE: *Denote decrease; decrease in Class "A" membership due primarily to mergers and consolidations.
†Approximately.

REPORTS OF
ACCOUNTING NATIONAL SECTION COMMITTEES 1928-1929

(For Personnel of Committees see Appendix 4)

Executive Committee

J F Ford, *Chairman*

Convention Address by Chairman Ford (see p. 75)

Budget Committee

B S Rodey, Jr, *Chairman*

No Serial Report

Classification of Accounts Committee

H C Hasbrouck, *Chairman*

No Serial Report

Corporate Finance Committee

Oliver E McCormick, *Chairman*

No Serial Report

Customers' Records Committee

Douglas Brown, *Chairman*

Serial Report, Pub. No. 289-74—Development of Customers' Accounting Machines (see p. 276)

Fixed Capital Committee

J A Rockwood, *Chairman*

Serial Report, Pub. No. 289-79—Use of a Fixed Capital Records System for Insurance and Taxation Purposes (see p. 287)

General Records Committee

K B Crumb, *Chairman*

Serial Report, Pub. No. 289-63—Filing Corporate Documents (see p. 303)

Purchasing and Storeroom Committee

W G Young, *Chairman*

Serial Report, Pub. No. 289-55—Public Utility Salvage Methods (see p. 291)

Statistics Committee

Harry A Snow, *Chairman*

Pub. No. 289-81—N. E. L. A. Statistics (Not published in Proceedings)

DEVELOPMENT OF CUSTOMERS' ACCOUNTING MACHINES

This Serial Report of the Customers' Records Committee, Accounting National Section, has been prepared in response to a demand for information from member companies which are planning to install mechanical accounting appliances, or to extend their systems of mechanical accounting. It is based on 41 replies to a questionnaire sent to 87 leading manufacturers of such equipment.

This report is confined to a description of the machines on which information was received. No attempt has been made to pass judgment on the merits of individual machines.

The Committee acknowledges its indebtedness to Eldon E. Taylor of The New York Edison Company, Chairman of the Mechanical Accounting Machine Appliance Committee, Metropolitan New York Section, under whose direction this report was prepared.

Introduction

At the meeting of the Customers' Records Committee, 1927-28, held in Chicago early in the fall of 1927, there was considerable discussion regarding various mechanical devices used by member companies in connection with the keeping of records in accounts receivable departments. Several new applications were described, and general interest seemed centered on this subject. Committeemen representing territories, including medium sized cities, towns and rural communities, expressed a thought that, if the representatives of companies operating in the large cities would report their experiences with the use of various machines, this information would be of great value. They felt that with their large volume of work such offices were usually first to introduce new equipment, and also that nearly all manufacturers of such devices maintained agencies and service departments within these metropolitan districts, thereby providing a better opportunity of obtaining or observing the latest improvements.

General

Were it not for the application of machinery to the handling of the enormous amount of clerical work involved in the operating of a large accounting department, a much greater number of employees would be required to produce equal results in the same time, much greater working space would be needed, and operating costs so increased that rates to the consumer would necessarily have to be higher.

The development and application within the past few years of mechanical devices used in connection with public utility office accounting has opened a field of almost unlimited scope for study, yet very little has been offered, excepting perhaps on billing and bookkeeping machines, in the way of detailed reports describing the various kinds of equipment. It seemed best that the purpose of this Committee should be to cover thoroughly the description, operation and usefulness of as many kinds of mechanical accounting devices as possible, even if some of these machines were used for purposes that only contribute in an incidental way to the general system of keeping customers or accounts receivable records. Therefore, it was first thought that for this year's work it would be advisable for the Committee to confine its reports to practical operating experiences and not go too deeply into investigations concerning new or untried equipment.

To carry out this plan a letter was sent to all Members-at-Large and Geographic Representatives requesting that they in turn write to the various companies in their districts requesting data on the different machines now in use, and detail of any special or unusual equipment or uncommon application of standard machines. The response was fair, but only three companies submitted sufficient descriptive detail, the remainder merely furnishing lists of the machines owned.

A questionnaire was also sent to all known manufacturers of mechanical accounting devices of generally conceded importance, some 87 in number. Forty-one replies were received, of which 36 were for publication. The information therein contained forms the basis of this report.

Recommendations

The present Committee feels that there is a decided need for accurate, up-to-date information on mechanical accounting methods and, therefore, recommends that its work be continued in future years.

REPORTS

Classification

For convenience the general subject for this year's work has been subdivided as follows:

1. Adding and calculating machines.
2. Addressing machines
3. Autographic registers and duplicating machines
4. Billing and bookkeeping machines
5. Cashiers' equipment
6. Mail room equipment
7. Tabulating machines
8. Miscellaneous.

(Excerpts in quotation marks, others composed from data supplied.)

Publication No. 289-74, Serial Report, Customers' Records Committee.

I—Adding and Calculating Machines

The Barrett

LANSTON MONOTYPE MACHINE CO., TWENTY-FOURTH AT LOCUST, PHILADELPHIA, PA.

This machine is an adding, listing and calculating, key set, crank operated portable outfit, of a base size about 9 x 12 in., featuring visible set-up and printing on narrow ribbons only.

New developments are under way but are not available.

The Corona

PORTABLE ADDING MACHINE CO., 703 E. WASHINGTON ST., SYRACUSE, N. Y.

Portable Model

"This is a seven bank adding machine, compact in design and construction and weighs only 16 lb. It is provided with repeat and error keys, total, sub-total, non-print and non-add keys. It is equipped with an optionally split keyboard, permitting two adding operations to be carried on at the same time, if desired, and has automatic ribbon reverse and a capacity of 99,999.99. The printing sectors are mounted directly on the adding sectors, and the printing is accomplished by the printing press method; that is, the platen is pulled forward to make contact with stationary printing sectors, thus assuring accurate printing of any item entered in the machine.

Office Model

"An office model of the Corona Adding Machine is about to be put on the market. This model has nine banks of keys, but accumulates ten columns in the total, or, in other words, it has a capacity of 99,999,999.99. It is equipped with automatic subtraction feature and with total, sub-total, non-add, repeat and error keys. The general type of construction follows very closely that of the portable model described above. The machine is almost completely inclosed, thus protecting the mechanism from dust and dirt. It weighs 25 lb. and is, therefore, portable for ordinary office use. In neither the portable nor the office model is use made of the dash pot type of governor. The governing principle of Corona Adding Machines is a flywheel and clutch construction, which is used merely to cushion the return stroke of the handle, and has no direct connection with the adding operations.

Accounting Cashier

"The Corona Accounting Cashier consists of a combination of a Corona Adding Machine (the portable model) a cash drawer and a Hanna Register, which provides a complete accounting system for all types of small businesses. With it is furnished an accounting system consisting of ledger sheets, individual customer's accounts, etc. By the use of this accounting cashier and accounting system, a business can exercise a complete control over its operations with a minimum of accounting effort."

Sundstrand

GENERAL OFFICE EQUIPMENT CORP., 342 MADISON AVE., NEW YORK, N. Y.

This company offers a machine of the portable ten numeral key type, one hand touch method control, visible printing, direct subtraction, prints credit balances, automatic placing of numbers in proper position and multiplication shift, gives automatic sub-totals and is manually or electrically operated

Victor

VICTOR ADDING MACHINE CO., 3900 N. ROCKWELL ST., CHICAGO, ILL.

A desk type adding machine using narrow and wide carriages; 6, 8 and 10 column; visible adding dials and printing, direct automatic subtraction printing minus sign (—) on tape, one stroke totals printed in red; sub-total, non-add and repeat keys; and rapid handle action manually operated.

Comptometer

FELT & TARRANT MANUFACTURING CO., 1713-35 N. PAULINA ST., CHICAGO, ILL.

This is a non-listing, portable, full keyboard adding and calculating machine, so constructed that it will add, multiply or divide in more than one column at the same time, thereby allowing the depression of any number of keys simultaneously. The full depression of a key registers the amount of the figure indicated. An automatic safeguard prevents partially depressed or incompleted upstroke and accidental touching of adjacent keys from registering wrong amounts by locking until the correction is made.

Mercedes

RALPH C. COXHEAD CORP., WOOLWORTH BUILDING, NEW YORK, N. Y.

The Mercedes Calculating Machine is used for multiplication and division work. It is an automatic, electrically operated machine, and in order to get a result of a multiplication or a division, it is merely necessary for the operator to insert the proper factors. The motor starts and stops with each problem automatically. While the machine is working out one problem, the next multiplier can be set so that the instant the first answer is given the machine can be started for the next. While dividing, the quotient can be written down as the figures are produced, as the operator's hands are free from manipulation of the machine. These features allow the machine to be kept in continuous operation.

The Mercedes is used for statistical work, such as prorating, percentages and cost work. For example, in prorating, the results are given exactly to the penny, so that it is unnecessary to force a balance. Sub-totals and totals may be obtained immediately without mental effort.

There are a variety of models ranging from the very small Melitta model to one known as the Duo-Special, which consists of two machines operating in unison and capable of solving ten calculations simultaneously.

Record

DOTY BUSINESS MACHINES CO., 912 BUENA PARK TERRACE, CHICAGO, ILL.

This is a calculating machine with flexible keyboard and a semi-automatic sliding carriage carrying two sets of accumulator dials. It is of a high speed type either manually or electrically operated and uses non-metallic gears to reduce the noise. The speed is controlled by adjusting a screw, and a universal motor is used. A special set of nine keys govern the motor control for multiplication or division. Division may be performed by either "building up" subtraction or by throwing in "automatic division latch," which method reduces the mental action of the operator to almost zero.

Rapid

THE RAPID CALCULATOR CO., AMERICAN AND CAYUGA STS., PHILADELPHIA, PA.

This is a compact, portable, lever set calculator weighing about 12 lb. It is operated by a two way crank turned forward for addition and multiplication and backward for subtraction and division.

United Listing, Multiplier and Calculator

UNITED ACCOUNTING MACHINES, INC., 716-28 SIDNEY ST., ST. LOUIS, MO.

This is strictly a calculating machine, which prints the entire problem and result on a straight line, taking but a single operation to make a calculation. Several improvements have been added recently. The machine is especially designed for rapid multiplication. After setting the two factors on the keyboard, a single depression of the motor bar will cause the machine to compute the product automatically and to print both factors and result in a single line, accumulating the totals of the product allowing subtotals to be taken at any point or non-added items to be inserted and printed. Division can be performed as rapidly as multiplication by using the reciprocal method. Direct subtraction is controlled by a key. The cycle of operation requires from two and one-half to three seconds.

This machine readily adapts itself for payroll, cost accounting, inventory, pro-rations and distribution work where percentages are to be determined of a total.

Monroe

MONROE CALCULATING MACHINE CO., INC., ORANGE, N. J.

"The Monroe Adding-Calculator is a non-listing machine.

"Among the recent improvements and developments in Monroe Adding-Calculators is the new standard model, which has been termed the Series "3." It is manufactured in two sizes—8 x 8 x 16 and 10 x 10 x 20, and is equipped with the new automatic start-and-stop motor on electrically operated models.

"Besides the features of the Series '1' and '2' Monroes, there are the distinctive features given below:

> *Left-Hand Upper Dial*—An upper dial which registers in black and red figures (as Series "1" models).
>
> *Right-Hand Upper Dial*—An upper dial which registers in black figures and contains a tens-carry mechanism as Series "2" models).
>
> *Operation*—Both upper dials operate simultaneously, registering either in the same direction or in opposite (complementary) directions.
>
> *Clearance*—Both upper dials may be cleared simultaneously, or left-hand dial only may be cleared. Clearance is accomplished by the regular one-hand clear-out crank, a small lever, convenient to the crank, controls the clearance of the left-hand dial ("on" position) or both dials ("off" position).
>
> *Usefulness of Dials*—In the extension of invoices the various prices may be set on the keyboard and multiplied by the number of items. After each multiplication, the left-hand upper dial only is cleared, allowing the total items to accumulate in the right-hand upper dial, while the total amount accumulates in the lower dial.
>
> In figuring percentages that two items are of the total, one is divided by the total, and its per cent appears in the left-hand upper dial while the complement, or the percentage for the other item, appears in the right-hand upper dial.
>
> An outstanding feature of this model is that it adds, subtracts, multiplies or divides without requiring the setting or changing of levers. The levers, however, permit the machine to handle involved calculations in a simple manner with a minimum number of operations.

"Besides the Series '3,' the Full Automatic Monroe has been developed recently:

> *Model KAA*—This is the latest development in "one-hand" operation without sacrificing the features of flexibility and simplicity.
>
> *Automatic Multiplier Keys*—These are built into the machine on the extreme left of the keyboard. In this logical position there is no possibility of interference with the use of the keyboard, plus (+) and minus (—) bars, etc.
>
> *Automatic Multiplication*—When an amount is set on the keyboard, a mere touch of the proper multiplier key causes the machine to operate the required number of times. On completion of the last revolution, the multiplier key restores to normal position, whereupon the carriage automatically shifts into the next column position. Meanwhile the finger is placed on the next multiplier key to be employed, and as soon as the carriage shifts, the key depresses by the touch of the finger, the process of multiplication continuing without the slightest interruption. Thus the speed is just as rapid as if the entire multiplier were all set up at one time. The upper dials give visible proof of accuracy. When the zero key in the multiplier row is depressed, the carriage automatically shifts one column to the right.
>
> *Full Automatic Division*—With the dividend in the lower dials and the divisor on the keyboard, the operator merely pushes the division control key into the upper position, and the machine, with lightning speed, automatically performs the entire division without any further effort on the part of the operator.

"If the multiplying keys are deemed unnecessary, for the particular type of work for which the machine is purchased, it is possible to take advantage of the new KAS models which function the same as the regular Monroes, but with the added advantage of having automatic division."

OTHER ADDING AND CALCULATING MACHINES ON THE MARKET

Machine	*Manufacturer*
"Add-Index" ..	Add-Index Corp., Grand Rapids, Mich.
"Ellis"	Ellis Adding Typewriter Co., Newark, N. J.
"Hayes"	Hayes Adding Machine Co., Denver, Colo.
"Federal"	Colts Patent Fire Arms Mfg. Co., Hartford, Conn.
"Peters"	Peters-Morse Mfg. Corp., Ithaca, N. Y.
"Wales"	Allen Corp. of Philadelphia, 309 S. 15th St., Philadelphia, Pa.
"Allen"	Allen Corp. of Philadelphia, 309 S. 15th St., Philadelphia, Pa.
"Brunsviga". ..	Allen Corp. of Philadelphia, 309 S. 15th St., Philadelphia, Pa.
"Gardner"	Gardner Calculator Co., Ebensburg, Pa.
"Ensign"	Ensign Co., 385 Broadway, New York, N. Y.
"Millionaire" ..	W. A. Morschhauser, 1 Madison Ave., New York, N. Y.
"Madas"	W. A. Morschhauser, 1 Madison Ave., New York, N. Y.
"Marchant" ...	Marchant Calculating Machine Co., Oakland, Cal.
"Peerless"	Peerless Calculating Co., 63 Park Row, New York, N. Y.
"Tim Unitas" .	Tim Calculating Machine Co., 299 Broadway, New York, N. Y.

II—Addressing Machines

Addressograph

ADDRESSOGRAPH CO., 901 W. VAN BUREN ST., CHICAGO, ILL.

The addressograph is perhaps well known by all companies, and detail of its construction, purpose and operation seems uncalled for in this report. However, the following excerpts from the maker's report may be of interest

"While the first plates that were used were one-piece plates, more complex accounting methods gradually led to the development of sectional plates, which makes possible embossing the name, for instance, on a section by itself, the address on another section, the folio or account number on a third, etc. When a subscriber moves, the name section is removed from the plate, and the name of the new tenant at that address is substituted. In the same way account numbers can be changed without disturbing the other data on the plate.

"Postal card bills can be handled as readily as any other type.

"Daters on the Addressograph printing to the right of the name and address insert the meter reading dates, discount dates, etc.

"Besides the regular impression from the subscriber's plate, these bills are printed with dates—in two colors if desired—in a position entirely remote from the main imprint of the Addressograph. This is done with what is termed as auxiliary printing attachments that can be supplied on the automatic models of the public utility Addressographs.

"Another use public utilities, banks and many other corporations make use of Addressograph equipment is the imprinting of their dividend checks. Dividend models of the Addressograph will imprint the name, address, amount, serial number, dividend number, date and even the signature—in three colors at a single operation. Two color ribbons can be used to print the amount in red and the balance of the check in black. The signature attachment prints direct from ink—of any color.

"Various other imprints can be made on public utility bills, checks, etc.; for instance, a numbering attachment can be supplied to print one number on the entire bill or to print the same number of each of several stubs.

"Addressograph 'short-cuts' are not dependent on the size of a public utility. There is an equipment for every size corporation—for the little one that has but 50 monthly bills, to the large corporation which must run a million bills in triplicate every month. Thirty-five different styles of address plates furnish a suitable address plate for every requirement."

OTHER ADDRESSING MACHINES ON THE MARKET

Machine	*Manufacturer*
"Elliott"	Elliott Addressing Machine Co., Cambridge, Mass.
"Federal"	Federal Addressing Machine Co., Buffalo, N. Y.
"Pollard-Alling"	Pollard-Alling Mfg. Co., 222 W. 19th St., New York, N. Y.
"Rapid"	Rapid Addressing Machine Co., Roselle, N. J.
"Speed-O-Feeder"	Speed-O-Feeder Mfg. Co., Cleveland, Ohio
"Wallace"	Wallace Addressing Machine Co., Inc., 116 W. 14th St., New York, N. Y.

III—Autographic Registers and Duplicating Machines

The Derby

THE DERBY LETTER MACHINE CO., INC., FLATIRON BUILDING, NEW YORK CITY.

"*Model* 750—This machine writes form letters in imitation of typewriting, using a metal stencil, or address plate, 'fills-in' the name, address and salutation at the same time it types the body of the letter—through the same ribbon, in one operation.

"Two operators, one feeding the paper and the other changing the stencils, can write over 750 filled-in letters an hour.

"Using same stencils which fill in the letters, same machine addresses envelopes, or any mailing piece up to 17 in. long, 10¾ in. wide and ⅛ in. thick.

"These stencils are embossed on a Graphotype and can be used in the Model 750 Derby Letter Machine with or without frames.

"'Body' of the letter can be 'set' in Foundry type, Monotype, Multigraph type, Multigraph Monotype, or Linotype. 'Chase' so constructed as to permit equal shading of all lines in letter—long or short.

"*Model* 1500—This is the same as Model 750, except that it uses six-line Pollard-Alling type of plate for filling-in and addressing, and requires one operator instead of two, the stencil feed being automatic.

"Stencils embossed on Graphotype require no frames or trays, and are kept when in use or idle on a wooden spool, 1800 to the spool.

"Speed of operation: 1500 filled-in letters or addressings an hour.

"*Model* 3000—Same principle as Model 1500. Power-driven. Semi-automatic paper and envelope feed.

"Speed: 3000 filled-in letters or addressings an hour."

OTHER AUTOGRAPHIC REGISTERS AND DUPLICATING MACHINES ON THE MARKET

Machine	*Manufacturer*
"Dupligraph"	Addressograph Co., Chicago, Ill.
"Multigraph"	American Multigraph Sales Co., Cleveland, Ohio.
"Mimeograph" ...	A. B. Dick Co., Chicago, Ill.
"Ditto"	Ditto Incorporated, Chicago, Ill.

IV—Billing and Bookkeeping Machines

Burroughs

BURROUGHS ADDING MACHINE CO., DETROIT, MICH.

"Burroughs Adding Machine Co. has added a number of new models to its line of customers' accounting machines, and has developed a number of new mechanical features. Approximately 100 machines or variations are being manufactured for customers' accounting.

"*Multiple Register Machines*—These new machines are so designed that they will carry from fifteen to twenty totals. These compare with previous machines that were limited to carrying six totals, and thus have a wider range in meeting the requirements of utilities whose billing problems are more complicated. The new machines will not only add and subtract vertically and horizontally, but will also carry long totals.

"One feature of the new machines is a special motor bar that prevents the amount of single line bills from adding in the section reserved for bill totaling. This new motor bar adds to the automatic operation of the machine, and accordingly speeds up the work. Heretofore, when it was desired to obtain a bill total in cases where both gas and electricity were included on the same bill, or when it was desired to add merchandise and arrears to the bill at the time of putting on the current charges, it was necessary to go through the operation of totaling out each single line bill. With the special motor bar this is unnecessary.

"A feature of perhaps even greater importance than the special motor bar is a 'keyboard selection of register' for the new multiple register machines. By means of this feature separate totals may be carried even though the figures are all entered in one vertical column. This applies, for example, in cases where the utility wishes to show the consumption account of electricity, light, power and gas in one vertical column, yet requires separate totals for purposes of proving the charges and obtaining the necessary statistical information. The same is true of charges. Electric charges, gas charges, merchandise charges and previous balances may be entered in the same column of the bill, but carried in separate registers of the machine.

"Another feature is a motor bar lock, the purpose of which is to supply automatic proof of accuracy. At the time of billing, the present reading, the previous reading and the consumption is set up in the keyboard from the meter book. If the consumption does not exactly cancel the difference between the two readings, the machine automatically locks, thus immediately warning the operator that an error has been made. This is an optional feature, possessing marked advantages for some billing plans. Where the long proof of meter readings and consumption is used, machines are not equipped with the locking device.

"Motor bar controls for the new machines have been so designed that it is possible to reverse completely or change the normal operation of the machine at certain points, so as to provide for unusual operations. For example, when the carriage is in a certain position, amounts entered on the keyboard may normally add in a predetermined register, but when a special motor bar is used they may add in another register or not at all.

"It is pointed out that the new multiple register machines, besides assisting in proving charges, also assist in obtaining statistical information, even in instances where it is necessary to carry separate totals for each schedule, or each rate step when rates are of a complicated demand nature. All necessary proof of charges, statistical information by classes of service, and data for rate analysis, frequently can be obtained automatically at the time of billing and ledger posting.

"*Special Machines and Features*—For utilities desiring to keep a more complete ledger than could be obtained automatically with machines previously available, a new model has been developed. This machine provides for showing consumption by steps on the ledger, as well as on the bill. The ledger in this case is a carbon copy of the bill, and the proof sheet is a carbon copy of the ledger. By this means, all automatic features of machine operation have been retained.

"For utilities desiring to show various charges on the bill, such as consumption charges, demand charges, meter rent charges, merchandise, arrears, etc., in a horizontal line, a skip tabulating or column skipping mechanism has been perfected. This eliminates the necessity of tabulating into certain columns that might not happen to be active on a particular bill.

"For utilities having complicated rate structures for their larger power accounts, a type of machine has been developed that will do all the calculating required. This machine will figure the difference between the meter readings, figure out the kw. demand, the demand charges, the various steps, the charges at each step, and the total bill.

"For handling final bills for large concerns, three other new models of machines have been developed.

"For small utilities or branch offices of large utilities, an inexpensive type of machine is now being built in several models or variations. The lowest priced model writes the bill and proof sheet in one operation and posts the ledger at another operation.

"For auditing cash collections and making distribution to the proper ledger controls, a number of new machine features have been perfected. While the work varies considerably with different companies, the new features were designed to increase the automatic operation of machines.

"For handling sales analysis, such as sales by lines of business and sales by units of consumption or groups of consumption, a number of new machines have been built. These new machines were especially made to handle this work when the requirements are of such a detailed nature that the information cannot be obtained as a by-product of the billing operation.

"A special low-priced calculator is now being built for proving work after billing and ledger posting, and also for obtaining statistical data. This calculator was designed to meet the demand for a small machine. It has a capacity of 9,999.99 and weighs under 7 lb.

"Two other developments are a new application of present machines for the handling of customers' accounting ledger controls, and a plan for using one-time sheets of flatfold carbon, or continuous carbon rolls, in connection with billing and posting.

"*Chair*—A chair for machine operators is also among the new developments of the Burroughs company. This chair is constructed to place the operator at the proper position before the machine and at the same time to insure the operator's correct posture from the standpoint of health.

"*Cashier*—In connection with the collection of customers' accounts, many utilities will be interested in the new combination adding machine and cash drawer recently placed on the market by the Burroughs company."

Dalton Accounting Machine

REMINGTON RAND BUSINESS SERVICE, INC., 374 BROADWAY, NEW YORK, N. Y.

"The Dalton Division of this company is carrying on studies and development in this class of machines, and will soon have some to offer, but at the present time (April 3, 1928) no machine is ready for sale."

Elliott-Fisher

GENERAL OFFICE EQUIPMENT CORP., 342 MADISON AVE., NEW YORK, N. Y.

"Elliott-Fisher is a writing, adding, subtracting and cross-computing accounting machine with a flat writing surface. It makes rapid and accurate collation of forms of various sizes and shapes remarkably easy.

"*Writing Machine*—For writing cut forms—card records, requisitions and so forth, regardless of size or thickness. Especially adapted for heavy manifolding. Electrically or manually operated.

"*Automatic Feed*—Developed for writing single or multiple copies in continuous length forms. Either roll, superfold, interfold or fanfold forms may be used. As a completed set of forms is removed from the machine, the next is automatically brought into writing position.

"This machine also is available with a double platen or writing surface, accommodating two or more different sets of forms.

"Suitable for writing connect, disconnect, change of name, or other orders of this nature. Electrically or manually operated.

"*Universal Accounting Machine*—Adds, subtracts, cross-computes and furnishes written mechanical proof of all postings, as well as columnar and cross totals of every column of figures affected by postings.

"Adaptable to merchandise and miscellaneous billing. Electrically or manually operated.

"*Public Service Accounting Machine*—Designed for public utility consumer billing, this machine accommodates both quantity and decimal figures. It automatically subtracts meter readings, giving consumption; adds the charges, subtracts discounts, adds arrears merchandise, and so forth, with mechanical proof of accuracy. At the same time it accumulates columnar totals of readings, consumption, steps, charges, etc. Also it will write the bill—ledger if one is used—abstract or recapitulation in one simultaneous operation, proving the accuracy of each figure.

"This machine is of extreme flexibility, due to unit assembly. It is adaptable to any system and can be easily adjusted to take care of any change in rate or system.

Magazine Feed Public Service Machine—This has the same general characteristics as the foregoing machine, but is developed for writing two forms only—bill either single or in duplicate, and bill register or abstract sheet.

"Bills in cut form are fed to writing position and ejected automatically. The register sheet, either in cut form or in continuous length, is also fed and spaced mechanically.

"The feeding of a bill, ejection of completed bill and spacing of register sheet is accomplished faster than the operator can turn over a page in the meter book.

"All the clerk has to do is write. Due to the fact that unproductive motions are eliminated, this machine has high production possibilities and is adaptable to any modified or ledgerless plan."

Remington

REMINGTON RAND BUSINESS SERVICE, INC., 374 BROADWAY, NEW YORK, N. Y.

"The Remington Front Feed Billings and Bookkeeping Machine has been developed for public utility customers' accounting. Efforts have been made in the designing of this machine to incorporate features essential to secure the best possible results. A brief description of each of these features may serve to illustrate the application of this machine to public utility bookkeeping requirements.

"Visibility—This feature assures accuracy and makes it possible for the operator to know that the various amounts are being written in the proper positions.

"Easy and Rapid Insertion of the Bills—The bills are inserted from the front to end stops which provide automatic and mechanical registration.

"Automatic Spacing of Register Sheets—The register sheets are spaced automatically. As the carriage returns, the sheet is mechanically spaced to the next position.

"Adaptability—Due to the rate structures and other conditions, it is essential that it be possible to adapt a machine to each individual requirement in order to secure the necessary distribution and classification of consumption, revenue and other charges.

"Simplicity of Operation.—Clerks who are familiar with the work may be taught how to operate the machine and eliminate the necessity of depending on trained operators."

Underwood

UNDERWOOD TYPEWRITER CO., 30 VESEY ST., NEW YORK, N. Y.

Principles of Construction of the Underwood and Its Operation

"The operating units of the Underwood Billing and Bookkeeping Machines—the writing section, the adding and subtracting mechanism, the tabulating mechanism, the registers, and different widths of carriages are in-built parts of every machine; however, the machine embodies flexible principles of construction that will permit not only of changing paper-handling devices, but its 'set-up' (the way the machine is set to perform the work) as well. The machine itself is used as a base upon which to build the necessary mechanical devices to facilitate and simplify the work of handling various styles of forms.

"Therefore, regardless of the system in use, the system being contemplated, or how it may be changed after machines are installed, the Underwood can be adapted to fit.

Distinctive Features

"Writing Mechanism—The writing section of the machine is the Underwood Standard Typewriter. The typewriter, however, is an integral part of the machine and not merely an attachment.

"Standard Keyboard—The keyboard is stationary—the first essential of a machine for speed, accuracy and ease of operation.

"ALPHABET KEYS—Essential in heading accounts and for writing other descriptive matter. This feature eliminates the necessity of extra typewriters for this purpose, or doing such work with pen and ink. It insures neat, clear and legible records. (If not required, the alphabet keys may be covered.)

"NUMERAL KEYS—Ten figure keys of the typewriter constitute the numeral keyboard. The same keys are used for writing amounts and numbers of all kinds, such as dates, folio numbers, meter numbers, account numbers, etc.

"TABULAR KEYS—The tabular keys instantly move the carriage to the exact decimal position in any column. Mistakes on the part of the operator are mechanically indicated and instantly detected by the numeral keys automatically locking. The operation of a tabular key serves to lock the carriage in correct decimal position in the column.

"On such work as public utility billing the tabulating mechanism is made to work automatically, also to skip several columns at a time. Therefore, the operation of tabular keys is unnecessary.

"Adding and Subtracting Mechanism—This section is an integral part of the machine. The parts are encased, and are made sufficiently large in size to insure durability and to hold adjustments.

"The adding and subtracting mechanism is operated by motor power (not by finger power) at the time the motor automatically trips. The numeral keys serve only to set up certain conditions in this section, which record figures automatically in the registers when the machine cycles.

"While the machine automatically adds and subtracts, as called for by the 'set-up,' the mechanism may be reversed at will by the use of two control keys at the front of the machine marked 'SUB' and 'CR Key.' This feature permits the operator to correct errors and justify totals while in the midst of his work, not waiting until the end of a run.

"Electrically Operated—The motor is one of the important features of the machine. It performs the bulk of the physical work and allows the operator to devote all his attention to maintaining speed and accuracy.

"Automatic Carriage Return and Line Spacer—The motor not only operates the adding and subtracting mechanism, but also returns the carriage at the end of each line and automatically spaces the paper to the next line of writing. This relieves the operator of all heavy, burdensome work and permits continuous, concentrated effort without fatigue.

"Registers—Visible registers make all totals visible at all times. The numerals on the dials are unusually large and clear and easily read. This feature of visibility is one of the most important, for it insures speed and accuracy.

"Reverse dials may be used in any one or all registers. This feature does away with the necessity of mentally figuring complements. (This refers particularly to a machine in use where the company will not permit differences between meter readings to be shown on the meter reader's sheet, and when the meters turn over.)

"From one to seven registers may be had in an adding and subtracting section, each register having a capacity of 9 wheels—$9,999,999.99 or 999,999,999 whole numbers. From one to six registers may be had with a capacity of 12 wheels in each register—$9,999,999,999.99 or 999,999,999,999 whole numbers.

"In each of the above cases any or all registers may be split to give two or more totals, either in money, whole numbers or mixed.

"An exclusive feature is that any or all registers may be used to give either vertical totals of columns or cross-balances on the line. This feature enables the operator to secure a line audit, or mechanical proof, of work at the time it is done.

"Being capable of computing more than one cross-balance or total on the same line simultaneously is valuable in the case of combination bills, bills on which discount is shown, or in rendering completely machine-calculated bills, as in the case of showing total for service plus merchandise charges and arrears and total net.

"Another outstanding feature is the star key (which prints the symbol of proof) and an elimination key on each register.

"The star key proves the result, in the case of writing meter readings and amounts on electric bills. This feature of localization of errors to a particular bill at the time they are made is a most valuable aid to speed and accuracy in billing.

"The elimination key enables operators to prevent incorrect amounts from recording in the registers. Eliminating errors when they occur saves time. There is an elimination key on each register.

"The Indicator—This automatically operated device indicates to the operator in advance the operation the machine

is about to perform, and the color in which the figures will be printed—black or red.

"Continuous Proof Record—The continuous proof record is a safeguard against errors. It is a proof sheet in a continuous strip that unrolls as the cylinder is spaced, and reproduces the figures that have been entered on bills. It serves as a check on the accuracy and efficiency of the machine operator, furnishes the means for making the rate proof, and may be kept as a permanent record.

"Proof Sheet Attachment—This device handles separate sheets of paper, whereas the 'proof record device' handles a continuous roll.

"The proof sheet remains in the machine and is automatically spaced upon the return of the carriage to a new line. The operation of inserting a bill into the machine, therefore, automatically collates the form to the correct writing line on the proof sheet, without giving any attention to the proof sheet.

"Front Feed Attachment—The front feed attachment enables the operator to insert forms from the front of the cylinder instead of the rear. This speeds the work in many applications of the machine. The attachment also permits the insertion of a sheet or card without interfering with others forms that may be in the machine."

New Developments

"Ribbon-Copy Device—The ribbon-copy attachment consists of a single ribbon carried in front of and parallel to the cylinder moving from and onto stock ribbon spools located above and over the cylinder ends. It may be easily removed or attached to stock machines without altering them in any way.

"This device makes a ribbon-copy instead of a carbon-copy, and can be equipped with 'blind' so that the ribbon will not offset on back of original unit. It also permits typewriting on original and not on duplicate by lifting ribbon above writing line.

"Selective Totals—Another late improvement in the adding and subtracting mechanism permits writing several amounts in the same column on the bill, but automatically segregating these amounts into separate totals in independent registers.

"This feature provides for using narrow bills which fit the standard small-sized window envelope; instead of the customary long horizontal bill." In other words, charges for service, amounts for arrears, both service and merchandise, installments for merchandise, coal adjustment, fixed charges, flat rate charges, etc., may all be written in the same column.

"Adjustable Paper Gage and Cutter—This new feature permits having bills printed on continuous stationery, with as many coupons attached as desired, addressed on the Addressograph. In other words, all bills for one route would be in one continuous strip or roll of paper, which would facilitate handling and keeping them clean. It is necessary to insert only one bill for each route. As a bill is completed it is cut off with the adjustable paper gage and cutter, and the next bill is left in correct writing position automatically.

"This feature offers the quickest method of handling bills, as it eliminates inserting them into the machine, with the exception of the first bill of each route.

"Tabulating Machine Punch—This device may be attached to the back of the Underwood machine, and automatically punches either Powers or Hollerith tabulating machine cards at the time bills are written."

OTHER BILLING AND BOOKKEEPING MACHINES ON THE MARKET

Machine	*Manufacturer*
"Moon-Hopkins'	Burroughs Adding Machine Co., Detroit, Mich.
"National Accounting".	National Cash Register Co., Dayton, Ohio.

V—Cashiers' Equipment

Brandt Automatic Cashiers

BRANDT AUTOMATIC CASHIER CO., WATERTOWN, WIS.

"Brandt Automatic Cashiers (coin changing and coin paying machines) eliminate the necessity for mental computation and physical selection of return change in all money transactions. The machines are provided with keys from one to ninety-nine cents inclusive and, according to the model being used, pay either the exact amount shown on a key or the difference between the amount shown and the tender received.

"A subtracting keyboard model is used at customers' account windows and returns the difference between the amount shown on any key and one dollar or smaller tenders. To handle a transaction where $5 is tendered for a bill of $4.21, the operator presses key 21 and the Brandt pays 79 cents return change. This eliminates mental calculations of return change, insures accuracy and speeds up customer service.

"A payroll model pays the exact amount shown on any key, directly into the pay envelope. Key 21 on this machine pays 21 cents, not 79 cents as in the case of the subtracting keyboard type. One Brandt operator can supply fractional coins to envelopes as fast as three clerks can count and enclose paper currency. This model is also used in general cashier's windows for cashing payroll vouchers and paying out money against various presentations at this window."

Coinaudit and Mon-E-Meter

PNEUMATIC SCALE CORPORATION, LTD., NORFOLK DOWNS, MASS.

"Coinaudit is a machine in which is combined all of the operations of sorting, counting and placing in packages all sizes of hard money from the penny up to and including the half dollar. These operations are fully automatic; a quantity of mixed coin is poured into the hopper of the machine, the starting button is pressed and the machine proceeds to separate the various denominations of coins, dropping each lot of coin into its own particular tube into a convenient paper wrapper. Counters give the exact number of coins passing through the machine. Machine separates and counts the coins at a speed of about 250 a minute. The machine is small and compact and sufficiently large to take care of the needs of all banks and commercial houses, with the exception of probably a few of the larger institutions.

"The Mon-E-Meter machine is designed to count any one denomination of coin at a very rapid rate. The money must first be sorted—all denominations kept separate. The machine is adjustable to these various denominations. It will first count the pennies, then just by pressing the filling tube the machine is automatically set to count the nickels, and so on. The coins pass through the machine with amazing rapidity, the rate of speed being 2000 coins counted per minute.

"Both machines are electrically operated, the necessary current being drawn from any ordinary electric light outlet."

Cummins Duplex Receipting Perforator
also
Cummins Check Endorser and Check Signing Machine

CUMMINS PERFORATOR CO., 4740 RAVENSWOOD AVE., CHICAGO, ILL.

"The accomplishments of the Cummins Duplex Receipting Perforator are that in one operation the machine receipts the customer's bill, dates and initials the cashier's stub and cuts off the stub from the bill. The machine is capable of handling up to five bills per stroke.

"The advantage of the electrically operated machine over the hand-operated machine is the additional speed possible because the operator has both hands free to handle bills and also has the work table attached to the machine, and instead of using his hand to operate the lever, the machine is tripped by a touch of the foot.

"The Cummins Check Endorsing Machine is designed to be used in connection with the adding machine in the proving of clearings and in connection with the transit machine in writing collection letters or in distribution department when charging out to clearings or transit—the endorsement becomes a part of the above-mentioned operations, the machine taking the place of the work table of either machine and as the checks are turned they are dropped into the hopper of the machine instead of being stacked.

"After tripping the machine and being endorsed, the checks are deposited face down in the stacker, and in the order in which they were run, and, as the only way by which one can get a check through this machine without endorsing it is by putting through two at a time, it is obvious that if this were done there would be no balance, and when the items listed were checked up and the unlisted one found it would also be found that the next one to it was not endorsed. If, on the other hand, there is a balance, then it is certain that every item is endorsed and all the time required for hand stamping endorsements and for checking for skipped endorsements is eliminated. The quality of the work will always be of the same and of the best for the reason that the machine is not only automatic tripping and stacking but also automatic inking.

"Such quantity checks as payroll, dividend, Christmas club, etc., are signed on the regular check endorser by simply substituting a steel engraved facsimile signature die for the regular endorsing die—with the additional features of a counting device and locks (if desired)."

Hoefer Change Maker

HOEFER CHANGE MAKER CO., 3700 E. 12TH ST., KANSAS CITY, MO.

"This machine is peculiarly adapted to the change-making requirements of public utility companies in that it delivers predetermined amounts or completes change transactions with equal efficiency. The coins required either in cashing a check, filling a pay envelope or paying the balance due in a change transaction in the accounts receivable department, may be delivered instantly by the aid of this device.

"The automatic safety lock guards against possibility of short-changing on account of an empty coin channel. Interchangeable delivery attachments delivering the coins either to the operator, directly to a pay envelope, or directly to the customer, assures giving the most efficient service possible at any station in the institution. Where not required continuously at any one station, the 'Hoefer' is adaptable to part time duty at any other station and will serve there with equal efficiency through the use of whatever type of delivery may be found to be most practical for the particular purpose.

"With 'split-change' keys, penny keys and standard even-change keys segregated and of different colors, but in close proximity to each other, key selection is confined to an extremely small area, so that the simple, comprehensive keyboard permits practically instantaneous location of keys. 'Split-change' is delivered by means of blue keys, pennies are delivered by means of red keys, while standard even-change amounts are delivered by means of white keys. The intermediate mixed change amounts are delivered by means of white and red keys operated either in succession or simultaneously. Mentally, the white key precedes the red key for predetermined amounts, while the red key precedes the white key for the balance due in a change transaction. In change transactions the mental process adheres to the time proven building-up method of adding enough pennies to make even money and then the balance. As the mental operation is performed simultaneously with a part of the manual operation, the manual operation actually determines the time required to complete a transaction.

"This machine makes no pretense of eliminating the mental calculation, as to do that absolutely necessitates a mental operation to precede the manual operation, and necessitates a mental calculation after the manual operation in case the operator is to check the change as it is delivered."

International Check Endorser

THE INTERNATIONAL POSTAL SUPPLY CO., 634 PROSPECT PLACE, BROOKLYN, N. Y.

"The Model 'K' International Check Endorser is an electrically operated machine capable of separating, endorsing and stacking checks at the rate of 250 per minute. The cabinet is made of oak, walnut, mahogany or special finishes and occupies a space 28 in. x 15 in. The dies are hand engraved on hardened steel, interchangeable, and can be equipped with specials with or without batch slot arrangement. A complete set of steel type for days, months and years is included, and no additional charges above the cost of the machine are made unless the number of type characters exceeds 100. A specially prepared ink is used to protect the life of the steel dies which is free from acids and injurious substances in the following colors: Black, carmine, blue, green and violet.

"The new improved Junior Model is an electrically operated single-feed device whereby the checks are fed one at a time by the operator and has been designed for organizations whose volume of checks do not warrant the installation of the automatic. It is compact and light, with base measures of 8¾ in. x 11 in. The specially designed metal adjustable stand can be supplied so that the endorser may be placed very close to an adding machine. desk or table."

Protectograph

THE TODD CO., ROCHESTER, N. Y.

"The electric Super-Speed Protectograph is generally used for the following purposes: (1) General expense checks, (2) divided checks, (3) payroll checks. It is a compact key set machine similar in some respects to the ten key adding machine keyboards. Checks may be fed singly or in sheets, the amounts set up by touching the keys with the fingertips returned for repeat work or instantly cleared for error and printed by touching the bar at the right.

"Inking is automatic for 1200 to 1500 checks when the duplicate ink roll may be inserted within a few seconds without soiling the fingers or work.

"The words 'exactly,' 'dollars' and 'cents' are printed automatically, and only the figures are touched on the keyboard. The last two figures set up automatically become the cents. Amounts from 1 cent to $999,999.99 can be printed and checks may be written at the rate of 100 to 1200 per hour."

The Signagraph

THE SIGNATURE CO., 3 S. WILLIAM ST., NEW YORK, N. Y.

"*The Check Signagraph*—The instrument consists of a table bed with folding extension leaf; across both run at front and back a light endless chain, actuated by sprockets and a crank handle. On rotating the handle, the chains, by means of evenly spaced lugs, carry two sheets of checks (previously laid on the extension leaf) under the writing frame, upon which are two parallel rows of five Waterman's Ideal fountain pens, spaced to cover the signature ground of the checks beneath. The writing frame, supported at each end by roller bearings, is, jointly with the pens it carries, under control of a monitor penholder or handle, which, when handled as a pen, causes all the pens to respond simultaneously to its slightest movement. The writer, after signing ten checks, rotates the crank handle, throwing the signed checks around, under and into a receiving tray, while at the same time a new set of unsigned checks are drawn under the pens for signing from the extension leaf. The instrument is easily adjusted for any size of check sheet not exceeding 18¾ x 9½ in.—which measurement is in excess of any requirement for a sheet of five checks—the usual width of individual checks being 3¼ in. Average signatures on this instrument will be about 5000 per hr. The output of a few writers has been 30,000 to 31,000 in a day.

"*The Junior Signagraph*—A compact instrument mounting five Waterman's Ideal fountain pens, enclosed in finished mahogany case, 20½ x 5½ x 11 in. Adapted for signing simultaneously and continuously five checks in sheet form and adjustable to any size of checks, not exceeding 3¾ in. in width.

"When opened for use the instrument swings out from the case, the open side of which forms a writing bed.

"The regulation of pens for spacing to signature spaces on checks is easily and quickly made. The tension of each pen can be adjusted to produce uniform action of all pens. When filled the five pens will make about five thousand signatures of length employed by average single pen writer.

"Results vary with length of name and rapidity of writer, 2000 signatures an hour being a fair performance."

Steel-Strong Coin Auditing Machines

THE C. L. DOWNEY CO., 941-43 CLARK ST.,
CINCINNATI, OHIO

"This company manufactures a large number of different types of coin auditing machines. Space in this report will not permit dealing with the models individually.

"A teller may deposit any number of coins directly into the hopper of the machine, which is operated through motor control, and such coins will be automatically carried through the machine, deposited into different receiving compartments and each coin registered so that the record of the amounts in dollars and cents is shown on meters at the top of the machine.

"Among the improvements reported are a 'triple check' on each package count; micrometer gage adjustment; adjustable setting of gages to overcome wear; visible coin feed; tapered wrapper stems; unit sort and count; combination gage control; revolving lock index, and many other features contributing to accuracy of count and reliability of operation."

Todd Check Signer

THE TODD CO., ROCHESTER, N. Y.

"The Todd Check Signer is a miniature offset press. It is made in two sizes. The standard 6-unit is employed for large payroll or dividend use, writing checks in sheets of 3, 4, 5 or 6. The single-voucher unit, devised for smaller issues of checks, signs in singles, doubles or vouchers.

"The signature impression, autograph and forgery-prevention background design is made by offset lithography. The signature design plates come in contact with a rubber blanket, which transfers their reversed impression in positive form to the paper of the check, a process which contributes to safety.

"Operated by an electric motor, the Todd Check Signer requires only the attention of one employee. It runs silently and smoothly, automatically recording the number of checks it signs, cuts apart and stacks.

"Two genuine pin tumbler Yale locks of the highest quality are furnished, a master lock and a subordinate lock. The master key is kept by the executive. The subordinate key is entrusted to the actual operator of the signer. It requires both keys to unlock the machine, as in a safety deposit box.

"Built into the Todd Check Signer is a check counter or meter, which permits the executive to take positive tally of all checks which have gone through the machine."

OTHER CASHIER'S EQUIPMENT ON THE MARKET

Machine	*Manufacturer*
"National"	National Cash Register Co., Dayton, Ohio
"Remington"	Remington Cash Register Co., Ilion, N. Y.
"F & E Changer"	Hedman Mfg. Co., 1158 Center St., Chicago, Ill.
"Staats"	George F. Clute Mfg. Co., 358 W. Madison St., Chicago, Ill.
"Abbott"	Abbott Coin Counter Co., 143 St. and Wales Ave., New York, N. Y.
"American Endorser"	American Perforator Co., 624 W. Jackson Blvd., Chicago, Ill.

VI—Mail Room Equipment

Baum Folding Machine

RUSSELL ERNEST BAUM, 615 CHESTNUT ST.,
PHILADELPHIA, PA.

"This machine will fold any kind of stock from onionskin to card, in size from 5 x 6 to 14 x 19 in., one, two or three folds.

"It has been installed in many electric lighting companies especially for folding electric light bills. (Note—In a few instances it was necessary to build the folder slightly special owing to the peculiar folds in the bills.) It also will fold letters, price-lists, pamphlets, booklets, etc.

"With automatic feed, its speed is about 6000 sheets (18,000 folds) per hr. It may also be fed by hand. It is operated by a small electric motor."

Lightning Letter Sealers and Lightning Letter Openers

THE BIRCHER CO., INC., ROCHESTER, N. Y.

"Lightning Letter Sealers are manufactured in two models —Model M motor operated, and Model K hand operated by a crank.

"The Model M Lightning Sealer will handle all standard envelopes—sealing neatly and cleanly, without placing moisture on the outside of the envelopes, at a speed of approximately 12,000 envelopes per hr. All parts are machined, and the machine is strongly built to give years of service. The feed is entirely automatic, and but one letter can pass through the machine at a time—assuring every envelope being sealed. After the flap is moistened it is forced in contact with the envelope by a barred roll, all envelopes being securely sealed.

"The hand-operated Lightning Sealing Machine, Model K, is the same in mechanical principle as the power operated Model M.

"Two models of Lightning Letter Openers are manufactured—one a high speed, power operated machine, and one for hand operation.

"The Model A-5 Lightning Letter Opener opens mail at the rate of 500 letters per min. without damaging contents; the machine has an automatic feed, is motor driven, and opens mail by shearing off the edge of each envelope by circular cutters as the envelopes are driven through the machine. This model is in general use by public utility corporations throughout the country, having been in use for years.

"The hand operated Model H Lightning Letter Opener is the same in mechanical principle as the power operated Model A-5. It has a speed of about 200 letters per min.

"The power operated Model A-5 is recommended where the incoming mail averages 1000 pieces or more per day; when the mail is of smaller volume, the Model H hand operated machine is entirely satisfactory."

McKay Mailing Machines

W. L. McKAY & Co., 111 N. MARKET ST., CHICAGO, ILL.

"The Reynolds Envelope Sealer is hand operated and hand fed. Its merit lies in its extreme simplicity. The moistening device is a steel cone which never wears out and always gives a uniform and sufficient supply of moisture. The feeding is simple. Although it requires a little practice, a beginner can feed this machine at the rate of from 50 to 75 envelopes a minute, while an experienced user will feed as high as 100 a minute, a speed that is sufficient for any normal mail. It is exceptionally convenient for general office mail because no adjustments are necessary for size or thickness.

"The Sealograph is offered in three models, Model A being hand fed and hand operated, Model B, hand fed and electrically operated, and Model C, automatically fed and electrically operated. These machines, like the Reynolds, have a metal moistening device, except that this one is a disk instead of a cone. The advantage of the cone is that a longer radius is attained with less difference of speed between the center and the circumference, but in the use of a disk the flap is extended at a less angle from the body of the envelope and, therefore, clings closer to the feed-rail. The Sealograph line offers also two sets of compression rolls as against one set in the Reynolds, and the Sealograph machines are gear driven, whereas the motion is transmitted in the Reynolds Sealer by chains. These differences, however, merely are a matter of design, and one is just as good as the other in so far as the function of the machine is concerned."

Sealometer

THE INTERNATIONAL POSTAL SUPPLY CO., 634 PROSPECT PLACE, BROOKLYN, N. Y.

"International Sealometer seals, imprints and meters mail in one operation. This machine is motor driven, has automatic feed and meets Government requirements.

"It is not necessary to purchase specially made envelopes for use in the Sealometer because it handles all standard envelopes, as well as odd sizes.

"International Postage Meter is a device for printing postage directly on mail matter, and does away with the application of adhesive stamps as well as loss of same.

"Meters are under Government control, being leased, not sold, to owners of Sealometer.

"Meters register 999,999 and are set by your local postmaster for amount of postage you pay, and when placed on Sealometers the hand engraved steel die and meter act in unison in stamping and registering 'Postage Paid.'

"When the meter has run its full count up to amount paid in, the register returns to zero and the printing device is locked automatically. The descending register will show how much postage is left in meter, so if a larger mailing is expected, meter may be taken to postoffice and additional amount of postage added to the amount left.

"It is not necessary to allow meter to run its full count before resetting."

Sague Inserting Machine

INSERTING AND MAILING MACHINE CORP., 11 PARK PLACE, NEW YORK, N. Y.

"For several years this company has been developing a machine, proposed for direct mail advertising, which will gather a number of inserts, open an envelope, put the inserts into it, seal it, and either stamp it or put on a printed indicia. After the inserts are put into the envelope, the envelope is automatically calipered to insure perfect work. In other words, if there is an insert missing, or if duplicates have been gathered, the machine will automatically stop.

"Machine of this kind, this company reports, are now in successful operation.

"The machines now in use were located in various places in order that they would operate under different conditions, and valuable experience would be obtained. In every instance they have measured up to the requirements.

"No effort has been made to advertise the machine, as it was desirable to first ascertain its commercial possibilities, based on actual experience. For more than a year this machine has given satisfactory performance. A modern factory at Easton, Pa., has been built for the manufacture of this device. As soon as special tools for making these machines are completed, production on a quantity basis will begin, and a competent sales and service organization will handle this business.

"The standard device will be a so-called 4-box machine; that is, it will feed an envelope and make from one to four inserts. However, machines can be built with more boxes; in fact, one has been made with eight boxes, and one of six boxes is now being built.

"The normal speed of the standard machine is 60 per min."

OTHER MAIL ROOM EQUIPMENT ON THE MARKET

Device	*Manufacturer*
"O. K. Opener"	O. K. Manufacturing Co., Oswego, N. Y.
"Elliott Sealer"	Elliott Addressing Machine Co., Cambridge, Mass.
"Mail-O-Meter"	The Postage Meter Co., Stamford, Conn.
"Multipost Sealer"	Multipost Co., Rochester. N. Y.
"Standard Sealer and Printer"	Standard Mailing Machine Co., Everett, Mass.
"Thexton Sealer"	W. L. McKay & Co., 111 N. Market St., Chicago, Ill.
"Cleveland Folder"	Cleveland Folding Machine Co., Cleveland, Ohio.
"Multigraph Folder"	American Multigraph Sales Co., Cleveland, Ohio
"Mack Postage Meter"	Mack Postograph Co., Los Angeles, Cal.
"Pitney-Bowes Meter and Permit Machine"	Pitney-Bowes Postage Meter Co., Stamford, Conn.
"Red Star Mailing Machine"	Red Star Appliances, Inc., Stamford, Conn.

VII—Tabulating Machines

No replies were received from the four companies written.

TABULATING MACHINES ON THE MARKET

Machine	*Manufacturer*
"Hollerith"	International Business Machines Corp., 50 Broad St., New York, N. Y.
"Electric Error Indicator"	The Signal Specialties Co., 4046 W. Philadelphia Ave., Detroit, Mich.
"Powers"	Powers Accounting Machine Corp., 474 Broadway, New York, N. Y.
"National Tabulator"	National Cash Register Co., Dayton, Ohio

VIII—Miscellaneous

Bostitch Fastener

Charles N. Smart, 261 Franklin St., Boston, Mass.

"The Bostitch Fastener is a light, portable desk machine, made of steel, cadmium and nickel-plated to prevent rust. It uses a ½-in. wide staple with ¼-in. long leg, made of 0.019 tinned steel wire, put up in cores, holding 210 staples attached to each other for convenient handling. One core of staples fills the magazine in the machine. The machine operates by a light pressure on the knob, forcing the staple through the work to be fastened together and clinching it on the underside. The clinch is turned in so that it will not pick up additional papers, but can be removed by bending the back of the staple slightly. This machine will fasten papers from two sheets up to forty sheets, depending on the texture and thickness of the paper.

"The Bostitch Style C is a heavier machine than the Standard Bostitch and stitches from two sheets to ⅜ in. in thickness, using different lengths and sizes of staples for various thicknesses. These staples are put up in the same manner, packed as the regular Bostitch, staples being attached to each other in the same way.

"A new model, foot operated table type, using the small size fasteners and constructed entirely of steel, is being placed on the market. This machine is easily and quietly operated, and can be used for such work as attaching delinquent notices to outgoing bills with greater speed than hand machines, as both the operator's hands are free to manipulate the papers."

McBee Metal Back Machine Binder

The McBee Binder Co., Athens, Ohio

"This machine will bind loose-leaf records into a book of any size up to 22 in. on the binding side, with no limitations on the other side. The unit consists of devices for forming and shaping, compressing and drilling the sheets. It is motor driven and equipped with four drills placed on a cross rod, and can be set to within 1 in. of each other, being so controlled that from one to four holes can be drilled at a time.

"Binders are made in various styles—particularly in plain board with canvas corners or full canvas covered with slate or brown colored canvas and paper lined. A metal back made of cold-rolled steel covered with canvas is formed and drilled by the machine.

"To bind into book form, a top and bottom cover with metal back are prepared and bound together by saw tooth binding nails. This makes a very permanent binder which, if necessary, can be unbound by a tool which is usually kept in the possession of the office manager.

"The machines are loaned (gratis) to companies who have a sufficient volume of permanent binding of records to warrant them contracting with this company to purchase a specified amount of material over a given period. Many other types of binders, both for active loose-leaf work and permanent records, are manufactured by this company, and the purchase of any other material or equipment whatsoever can be applied on the contract.

"The operation of the machine is simple and the upkeep cost practically negligible, as drills are the only accessory necessary."

Teletype

Morkrum-Kleinschmidt Corp., 1400 Wrightwood Ave., Chicago, Ill.

"Teletype is essentially a distantly controlled typewriter, operating like an ordinary typewriter and resembling it in many respects. The depression of a key on the keyboard of the Sending Teletype will cause the corresponding character to be printed on this machine, and at the same time will automatically typewrite the message on any machine or machines connected to this point by a system of wires.

"Systems can be arranged with any number of instruments located at any distances apart. The circuits can be arranged so that any desired interconnections between machines can be made. Machines are made in two types—the Page Type, which typewrites its message on a standard width sheet, and the Tape Type, which records its message on a narrow ribbon of paper.

"Teletype has the flexibility of telephone systems and the accuracy and permanency of the typewritten page."

Miscellaneous Equipment on the Market

Device	*Manufacturer*
"Dictaphone"	Dictaphone Corp., 154 Nassau St., New York, N. Y.
"Ediphones"	Thomas A. Edison, Inc., Orange, N. J.
"Remington Electric Typewriter"	Remington Typewriter Co., 374 Broadway, New York, N. Y.

THE USE OF A FIXED CAPITAL RECORDS SYSTEM FOR INSURANCE AND TAXATION PURPOSES

SUMMARY

This report is intended to give the utility executive a brief outline of the use of a Fixed Capital Records System for Insurance and Taxation Purposes.

A Fixed Capital Records System provides and perpetuates the data necessary for any company to enjoy the following advantages:

For Insurance Purposes

1. Full insurance coverage for any kind of insurance for the company's property at all times, providing a simple basis for the elimination of non-insurable property and automatically providing for necessary increases or decreases in insurable values to take care of additions or retirements of insurable property.
2. Complete inventory and cost data necessary to substantiate claims for loss.
3. Complete control of the payment of insurance premiums by elimination of the premiums for non-insurable property and property retired, and by the adjustment of premiums for changes in property which improve its insurance rating.

For Taxation Purposes

1. Complete data on the cost of the company's property subject to taxation in each political subdivision, providing a simple basis for the elimination of the cost of non-taxable property and automatically providing cost data on additions and retirements of taxable property. This serves as a check on the assessed valuation at all times.
2. Complete data on the number of units of property subject to taxation, such as poles, miles of wire, feet of mains, etc., in any locality at all times.
3. The data provided in 1. and 2 help to protect the company against the payment of excess taxes on any part of its property.

The details of how a Fixed Capital Records System provides and perpetuates these data are discussed in the various subheadings in the Report. The conclusions point out seven important items of insurance and taxation records which are provided by a Fixed Capital Records System at less cost than they could otherwise be obtained.

INTRODUCTION

A Fixed Capital Records System of some description has now been installed by many public utility companies, as it has been proved that the benefits derived from such records are no longer theoretical but are established facts.

There are many uses for such a system, one of the most valuable, and one that will reflect large savings, being the use of these records for insurance and taxation purposes.

Several types of Fixed Capital Records Systems of greater or lesser detail have been described in prior reports of this Committee. In general these systems provide records which segregate the units of the property in such a manner that the date of installation, description, location and cost in place of each individual unit, or the average cost in place of substantially identical units in each section of the property, can be readily obtained.

A completely detailed system obviously gives the greatest amount of data, but even the simplest Fixed Capital Records System will provide sufficient data and information for insurance and taxation purposes.

The purpose of this Report is to show how the records of a Fixed Capital Records System may be used to provide the data necessary for insurance and taxation purposes, and how these data can also be coordinated with, and used to regulate and control, insurance and tax records.

It is important in the case of any kind of insurance to know that all property which should be insured is adequately covered, and that the insurable values are neither too high nor too low, and likewise that the values of foundations, etc., which are excluded from coverage, are eliminated when determining insurable values. This guarantees ample protection and prevents payment of excess premiums. After having adequately covered the property with insurance, it is important that insurance be taken out or cancelled immediately when new property is added or old property retired. It is also essential that certain detailed records of insurable property be available so that in case of a loss, full claim for same can be readily and accurately determined and also substantiated.

In connection with taxation it is important for the company to have accurate records and values of its entire property, or parts of its property, subject to taxation, which are located in the various political subdivisions of the territory served, as well as a record of all property acquired or sold. The company will then be in a position to know at all times whether the assessed value or the taxes levied are reasonable and correct.

It is the experience of the various member companies who now maintain Fixed Capital Records Systems of their property that, since these records act as a complete detailed control of all physical property, they are easily coordinated with and used to perpetuate insurance and taxation records.

Within its scope this Report will discuss some of the problems arising in connection with insurance and taxation matters. It will also indicate certain

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detailed information which is essential for the correct solution of such problems and show the advantage of obtaining this information from a Fixed Capital Records System.

INSURANCE

Insurable Property with Descriptions, Locations, Etc.

In taking out any kind of insurance the first thing to determine is what property shall be covered. This is a matter of policy with each company, but when this has been definitely determined it is then necessary to provide such data and values as are required, in order to properly prepare the insurance schedule for the various policies or contracts. The value of the insurance to the insured depends largely upon the completeness and the accuracy of the facts given in these schedules, and it is, therefore, important that these data be obtained from a very reliable source.

For fire insurance it is necessary to give the definite location, complete description and the insurable value for each individual item or group of property being insured. A Fixed Capital Records System segregates the units of property in such a manner that these data can be readily obtained, and this is one of the important functions of such a system. The preparation of schedules for fire insurance purposes is, therefore, greatly simplified, as the information required is already available in a Fixed Capital Records System, and it is necessary to compile from the records of such a system only such data as are required for the particular item or section of property on which insurance is to be carried.

One of the most difficult matters, and one that is of considerable importance when taking out fire insurance, is to ascertain the value of such parts of the property being insured which are excluded from coverage, such as foundations of buildings and equipment, underground piping, equipment wholly or partially submerged in water, etc. The costs of all such sections of buildings or equipment are properly segregated in the records of a Fixed Capital Records System, and consequently it is an easy matter to exclude their values in preparing the insurable values. In this manner the insured is confident that insurance is being carried on the insurable value of only such parts of property as are actually covered by the policy.

It is apparent that the values of the units of property as shown in a Fixed Capital Records System are not always the values that will be carried on the insurance policy, for the insurable values must take into account the cost to replace the property at price levels existing at the time the insurance policies or contracts are executed, as well as the accrued depreciation on same. These values must be sound insurable values, neither too high nor too low, as values that are too high will cause the insured to pay an excessive premium without coverage, and values that are too low will not provide for sufficient coverage in case of loss.

The values shown in a Fixed Capital Records System are the original costs of the property at the date of installation or acquisition. However, these values do provide an accurate basis for determining the true insurable value for each unit of insurable property. The original cost of the various items of property to be insured may be adjusted to a reproduction cost basis by applying suitable price trend factors to the detailed unit costs obtained from a Fixed Capital Records System. Such a system also gives inventory details and quantities of material and labor which may be priced on a reproduction cost basis by applying current prices as of any date.

The reproduction costs new of insurable property can then be depreciated as desired. The field work done and the close study of the condition of the various items of property afforded by the maintenance of a Fixed Capital Records System, gives an excellent basis for determining the proper depreciation of each item—a far better basis than one which uses the theory involving the age of the item and its estimated life.

In cases where all or part of the fire insurance is carried on a Blanket Policy, it is a simple matter to use the records of a Fixed Capital Records System in accumulating the data for the particular kind of equipment included in such policies, as these records are so flexible that the information needed can be secured for any group of units, particular location, section or political subdivision of property.

Companies which do not maintain a Fixed Capital Records System usually have no adequate records which give readily the necessary information and details outlined above. They must, therefore, resort to other methods of obtaining inventories, descriptions and other data for determining insurable values. Such companies must base their values for insurance purposes either upon estimates made by their own employees or upon studies made by outside engineers. In both cases these estimates would probably be based on detailed studies made with the view of using them only for insurance purposes, and they would have to be made or revised each time the policy was renewed or revised. Such studies might be sufficiently accurate, but they would certainly cost more to make than if the data were supplied from a Fixed Capital Records System which is continuous in its operation.

The data and information required by insurance companies for automobile, boiler and other types of insurance is practically the same as that required for fire insurance; and as the record in a Fixed Capital Records System is set up in the same manner for each unit of equipment, it is obvious that it can be used to the same advantage and with the same benefits in preparing schedules for other insurance as for fire insurance.

Increases and Decreases in Insurable Property

Companies are continually making changes and additions to their property or retiring structures or equipment which are replaced or removed; therefore, if the proper coverage is to be maintained, the insurance records should also be changed to reflect the increase or decrease in the value of insurable property affected by these changes.

It has been stated that a Fixed Capital Records System constitutes a perpetual inventory of the physical units of property; therefore, if the insurance records are based on such a system, it is logical that they will immediately reflect every change in insurable property and the amount of coverage will also be corrected, the result being that insurance will be taken out for new property as soon as it is installed, likewise cancelled immediately on all property retired. As a consequence, the insurable values of the various items of property are revised automatically when the Fixed Capital Records are corrected and are not dependent on special inspection or studies, or whether someone happens to remember that certain property has been installed or removed. This results in complete coverage and eliminates the possible payment of insurance premiums on property long after it has been removed.

Improvements are continually being made to the property, many of which have a direct effect on the insurance rate. All such improvements are reflected in the operation of a Fixed Capital Records System; therefore, any improvements which will affect the insurance rate at a certain location are immediately reported to the insurance company, and as a result thereof the rate for the particular property is revised by the insurance underwriters, and proper credit allowed by the insurance company long before such changes would be found in a regular insurance inspection of the property.

Claims for Loss

When a loss occurs on any property covered by insurance, the insured wants to be in such a position that the claim presented covers the value of all the property destroyed or damaged, and it is at this time that the importance of having available reliable and accurate insurance records is realized.

From a physical inspection after a fire it is not always possible to ascertain the complete list of items destroyed, and, therefore, in order to prepare a claim for loss that will cover the maximum loss sustained, it is necessary that the records of the property destroyed are in sufficient detail that a complete inventory is available which will show all the items that were in existence prior to the fire.

The value of the property destroyed may be determined by means of estimates based on the present cost of replacing the property, but this value, if based on a complete, accurate and dependable record, is far more convincing than any estimate which may be made.

A Fixed Capital Records System is, without question, the best source for obtaining the data required in setting up and proving a claim for loss on any insured property, as such a system provides information which is complete, up to date, reliable and dependable in every way; thus all evidence of the property destroyed can be produced and the claim for loss easily substantiated.

TAXES

Taxable Property Segregated Into Units, Sections, Political Subdivisions with Descriptions, Values, Etc.

The property of any company may be subject to taxation in any of the political subdivisions in which it serves. It is also true that only certain items of property are taxable in cities and towns, and then again the property may be wholly tax exempt. Certain taxes levied are figured at so much per pole, or mile of wire, or foot of main, or any other unit and at various rates per year on property in different localities or on the total property owned by the company in any political subdivision.

It follows, therefore, that any company whose property is subject to taxation may keep complete and accurate records of its property at every location and in the various political subdivisions in which it renders service or owns property. The kind of detail which should be shown by such records depends entirely on the kind of taxes levied and the basis of their determination.

If the company's property in any locality is taxable at some annual charge per pole, per mile of wire, or per foot of main on the streets and highways, it is obviously necessary for the company to know the number of poles, miles of wire or other items existing on the streets and highways at the time the tax was levied. If the records are not accurate it is entirely possible for the company to be taxed for more of these items than it owns, for similar items not owned by it but owned by other companies, or for similar items which are owned but located on private property and which usually are not taxable in such locations.

In the matter of the value of any property subject to tax, except those items which may be taxed at a fixed annual amount regardless of their value, the company should have accurate and complete records of its cost to be used as a basis for checking or determining the proper assessed value used for purposes of taxation. With such records the company would be in a position to protect itself from inequitable taxation and would thereby save itself considerable expense, not only in taxes alone but also in the cost of proving what it considers a fair assessment of its taxable property.

The records of a Fixed Capital Records System provide all of the data pointed out above necessary for purposes of taxation. It has already been explained that such a system constitutes a perpetual inventory of the property in existence in any location and gives the total cost of such property at any date and, as such, offers a complete and accurate set of records which can be used in connection with taxation matters.

Increases and Decreases in Taxable Property

As in the case of insurable values of property, any extensions, additions or improvements to properties or retirements of property in a great many cases will affect the value or number of items of property subject to taxation. If a tax is levied on the number of poles in any locality or on other units of property, the net change in the number of such units in any year or other period of time, whether it be an increase or a decrease, is the factor controlling the increase or decrease in the tax. It is, therefore, important for the company to have accurate records of such changes, to protect itself against excess taxes and to provide the tax authorities with accurate data upon which they must be somewhat dependent when calculating the tax levied against the company.

In cases where an individual item of property may be taxed in a certain locality, or where the entire property within any political division is subject to taxation, it is equally important to have records which will show the increases or decreases in the value of such property.

The above changes in physical property are all recorded in any Fixed Capital Records System, and as such a system perpetuates these data, it can be used equally as well for taxation as for insurance purposes.

CONCLUSION

Although not designed to supply information and data for insurance and taxation records, a Fixed Capital Records System can be very easily adapted to, and used to great advantage in, regulating and controlling these records. The cost of maintaining insurance and tax records by coordinating them with the records of such a system is undoubtedly far less than the cost of making individual inspections and studies for similar purposes.

The value of using a Fixed Capital Records System for insurance and taxation purposes is, therefore, inestimable, as these records act as a complete control for all physical property and provide the following data, which are necessary for adequate insurance and tax records, thereby assuring full insurance protection at a minimum of cost and a definite check on all taxable property:

1. A complete and accurate description, perpetual inventory and record of cost of all property which should be covered by insurance of various kinds, or which is subject to taxation in any political subdivision.
2. A basis for excluding from insurable values the value of property not intended to be covered by insurance or parts of property excluded from coverage, such as foundations, etc., thus assuring correct coverage and eliminating the payments of insurance premiums on non-insurable property.
3. A basis for segregating and excluding the value of any property not subject to taxation, or for determining the correct number of units of property on which certain taxes are based.
4. Values of taxable property, which can be used as a basis to determine whether the assessment for taxation purposes is correct, thus preventing unjust tax assessments and the consequent payment of excess taxes.
5. A record of additions, betterments, improvements and retirements of property, thus providing an accurate and practically automatic method of revising insurable values or tax assessments and eliminating the possible payment of insurance premiums or taxes after property has been removed.
6. A basis for settlement of claims for loss against insurance of various kinds which guarantees that not only the full insurable value of every item of property destroyed or damaged will be included in the claim, but also that the amount of the claim can be substantiated.
7. Other information and details of property used in general in connection with the maintenance of proper insurance and tax records.

PUBLIC UTILITY SALVAGE METHODS

The subject of salvage and salvaging methods is so large that it would take more than a large book to contain all that might be written of its application to public utilities alone. It was determined, therefore, in this report to confine the discussion to some of the outstanding points which especially merited review, while through lack of space it would be necessary to omit any mention of items of perhaps equal importance. To those who have made a study of this subject some of the points discussed herein may seem elementary. It should be remembered, however, that some companies have not been able to work these matters out to their own satisfaction, and when they do it will be necessary to start at the beginning.

In order that there will be no misunderstanding of the terminology used in this paper it has been decided to define some of the more commonly used terms below:

Salvage Material.—Used material or apparatus which has been "rescued from waste" and which, after being sorted or graded is available for further use "as is," or may be reconditioned for further use.

Junk.—That part of Salvage Material which from its nature and condition is unfit for further use and whose monetary value lies in what can be realized from the sale of its component parts.

Reconditioning.—Putting used materials, merchandise or apparatus back into such a condition that it can be used for the purpose for which it was originally made.

Reclamation.—A general term embracing both Reconditioning and Salvaging.

Rehabilitation.—This term is used principally with reference to bringing run-down or obsolete buildings, plants and properties back into a satisfactory condition.

The whole subject of Salvage Work is much broader than is generally realized. To mention Salvage to the ordinary man is to bring before him a picture of a pile of scrap iron or copper wire, a few boxes or cans full of metals roughly sorted into various grades, all of which the junk men are periodically called upon to buy. This, however, is only one part of a broad subject which deals first with the conservation of materials and through this with the conservation of human energy. Salvaging means "rescuing from waste," but if the waste be forestalled and prevented through the efforts of a Salvage Organization, this intangible result is certainly to their credit.

It will not be hard to prove that this subject is of prime interest to companies of all sizes. Generally, the contention is that a small utility cannot afford to establish any definite department for this purpose. On the contrary, the small utility, if successfully operated, may not have a Salvage Engineer, but a so-called handy man, who actually sorts over the returned material from various parts of the system and repairs and puts back into the stockroom those items which he is equipped to repair. The opportunities for savings in this line are proportionately as large in the small utility as in the larger utilities.

As the company grows larger the salvage methods which were previously more or less satisfactory become inadequate. The company gets into a more diversified line of equipment and greater quantities of materials have to be salvaged. It is not a matter of choice whether they go into the salvage business or not, as the natural growth of the company and the progress of the electrical industry forces them into it. The policy which each company adopts in handling this matter is an important decision and one which will have an important bearing on their future success.

In some companies there may be important reasons why salvage materials, on their hands through no choice of theirs, may not be handled so as to bring the best returns. These are matters for executive decision, but for those who wish to realize the highest possible return from salvage materials there is a great field for lower handling costs and improved methods.

Although the smaller companies may get by satisfactorily by having one or more men spend part time on salvage, the amount of material handled by the larger companies demands that more attention be given to it. In practically every company the material naturally comes into the custody of the storekeeper, who, by his training and facilities, is best fitted to handle it. It is a storekeeping problem, therefore, to expand the facilities to give such material the proper attention and to develop a competent organization to supervise it.

One of the first points which will come to the mind of an aggressive salvage man in a public utility is to wonder whether he is receiving all the material that he should receive from the various jobs and whether the field conditions in connection with this work are what they should be. He has the choice of dealing with only what is turned over to him, or, on the other hand, of adopting an aggressive policy leading back to the source of the material.

True salvage work goes into all branches of the company where waste of material may be avoided or where material may be rescued from waste. Investigation will probably disclose that while no material is wilfully wasted, a great many chances to practise economies through salvage methods are missed through lack of education. The principles of salvage work will have to be sold to department heads and through them to their men in the field. One of the large utilities adopted an aggressive policy as an experiment, and the results were more than gratifying—they were startling. It was found that through contact with the field men of the various departments, they could be educated to use up materials with less waste and to salvage materials which were formerly wasted entirely. All this was done without lowering any standards of work and without appreciably running up the various departmental costs. Needless to say, the moral effect on the outside departments is an important item. One direct effect of this field work was that all usable material

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was consumed on the jobs, and that only junk materials and excess materials were returned for credit. It has also been noted that materials removed from property have come back to the storeroom in much better shape. This shows that the workmen had the proper policy impressed upon them and that they realized that the materials had a potential value for a further company use, or for resale. One of the experiments conducted by this utility was to give the Salvage Engineer complete supervision over the dismantling of a large substation. The removal of every piece of equipment, large and small, was done according to his ideas, and the work was so carefully done that very little good material was damaged. The general results were so surprisingly good that all large removal jobs are now closely supervised by the Salvage Engineer to prevent damage and loss of good materials. The Salvage Engineer does not hesitate to follow up any promising leads in connection with Salvage work. These leads often bring him to certain salvage operations which must necessarily be performed by other departments. In spite of this he compiles complete data on same, as the Stores Department and the company in general expects him to be completely posted on these matters. The various company departments are completely sold on the salvage question, and they are kept in touch with salvage available for their use through the medium of a monthly salvage catalog, issued by the Stores Department. The development of an adequate Salvage Headquarters and an efficient Salvage Organization has been an interesting process, which as it progressed opened up more and more possibilities.

The storing and selling of used equipment, not required for further company use, is a matter which should be given careful attention. Those in charge of the selling of such equipment should be careful not to allow handling and storage charges to accumulate to such a point that the transactions may show an actual loss. A definite policy should be adopted in which the following points should be embodied:

(a) Procure advance notice of machinery and equipment about to be retired.

(b) After determining that it cannot be used within the company, decide whether there is a possibility of sale outside. If there is, try to sell it on the spot, making concessions on price to cover expenses which would otherwise be incurred if you removed it yourself. If not, scrap it on the job and avoid handling expenses at Salvage Headquarters.

(c) Do not keep items of machinery or equipment for sale at salvage headquarters too long. If price reductions to somewhere near scrap price do not move the items, they should be scrapped promptly. Whatever your selling plan is, put it into action quickly. It is only by prompt and concerted action of those in charge of storing and selling surplus equipment that any satisfaction can be obtained.

The other extreme is to fill the warehouses with such material and perhaps erect new buildings to take care of the overflow. In this class of material at least the buying public will not wear a path to your door.

The selling of scrap metals, etc., is quite a different matter from selling used equipment and machinery. In the first place, a comprehensive scrap classification should be adopted, preferably the one which is generally used by the scrap trade. In this way the return on graded metals, etc., can be checked against the newspapers and trade journals, narrowing the element of chance to those items which, for various reasons, are sold ungraded.

The degree of refinement in grading scrap and the methods used in getting this result, brings us to the principal subject in this review. There may be considerable differences of opinion within the industry as to the wisdom and practicability of some of these methods, but the fact remains that they are being successfully employed by salvage men in some of our leading utilities. It is a matter of good judgment to keep a close watch on the costs of the various salvage operations and to avoid, if possible, all unprofitable operations.

REVIEW OF SALVAGE METHODS

Salvage materials can be divided into the following classes:

1. Junk.
2. Salvage Materials and Equipment for Sale.
3. Salvage Materials and Equipment for Further Use.

For the purposes of this review the work done by the storekeeping organization in putting back into stock items which are returned from the system on which no reconditioning has to be performed, is not classed as "Salvage Work" but is simply storekeeping routine. It is good storekeeping also to see that the odds and ends of new stock are properly used up, and it is upon this assumption that we start the discussion of salvage methods with matters somewhat beyond ordinary storekeeping routine.

This review will cover only the more important phases of the items which are selected for discussion. This whole subject may well come up for review every year so that the latest developments may be available for those who are interested.

Junk

Junk is defined in this paper as "Salvage Material which from its nature and condition is unfit for further use," and includes numerous metals and materials of all kinds and combinations. There is a natural flow of such material to the salvage headquarters if a proper working arrangement exists with the various company departments. It has been demonstrated and is strongly recommended that methodical arrangements for the collection of junk at the source are superior to the casual receiving of what the departments see fit to send in. The various departments should be given an adequate supply of cans, boxes or other suitable containers and instructed to use them for scrap metals, etc. These containers should be collected at regular intervals by the Salvage Department. Junk which cannot be placed in containers should be laid aside in some convenient place designated by the Salvage Engineer so that he can conveniently inspect same and arrange for its disposition.

After the junk has been collected into a central salvage headquarters, the next step is to sort it into grades preparatory to selling it. It is again emphasized that junk should be classified under names generally understood in the waste trade. The method of separating and grading scrap materials depends upon their condition when received and upon the amount of work which each company decides to do in order to prepare the materials for sale. Under the lowest form of grading (which is practically no grading at all) materials and mixtures of materials are sold "by the lot" or at arbitrary prices based upon guesswork. The seller of mixed lots in which two or more metals and other constituents are included may gage his values on analysis and may or may not receive a commensurate return. For those who wish to know exactly what they are selling and wish to obtain the highest return therefor, some of the methods in use will be explained in this review.

It is unreservedly advocated that every utility, regardless of size, have some central point in their Stores system through which salvage materials will be cleared. There will be certain exceptions, of course, where some items will be disposed of at the source, but even these should be under the same supervision. It is also advocated that the collection and the preparation of salvage for sale be centralized.

A Salvage Headquarters may be operated in connection with a warehouse, but it is preferable to have the salvage materials and the salvage operations separate from everything else. It should always be kept in mind that in preparing scrap for sale the salvage organization is pitting its equipment, labor and skill against that of the junk man, and that every operation must pay its own way. Equipment should be invested in judiciously after careful investigation of local conditions and possible savings.

Junk items will be reviewed below, together with the equipment and methods employed in connection with them.

Appliances, Electric

The public utility business is a comparatively new business as compared with others which have been in existence many years, but new as it is, continuous strides have been made in the last twenty-five years in the developing of new appliances for use in the home, factory and commercial institutions. The very nature of electricity is such that after these new appliances are brought on the market the public utility must adopt a very broad attitude relative to the education of their customers to these new developments through the demonstration of the new appliances. With the average housewife a newly developed electrical appliance, or piece of household apparatus, is somewhat of a mystery and consequently the housewife is very loath to purchase such an appliance or piece of household apparatus without a thorough trial, and this fact in itself crowds the public utility storerooms with many items of electrical appliances which have been used for demonstrating purposes. This condition of development and experimentation through which the electrical industry has been progressing, and will continue to progress in the future, should direct the attention of public utility executives to the need of some systematic method of reconditioning such used articles. After this reconditioning, further systematic efforts to place these articles on the lines as users of energy through its regular salespeople are of prime importance.

Many items of electrical merchandise are sold on an instalment basis, and in some of these cases where misfortune overtakes the prospective owners of these appliances it is necessary for the public utilities to repossess the items in question. Such articles when returned to stock are very often not in a condition which would attract purchasers, and this fact in many cases is the influence which governs the Sales Department in the return of such merchandise to the storeroom where, if constant vigilance is relaxed, it will be placed in some recess where in many storerooms it will acquire a continuously increasing layer of dust.

The Stores Department could with profit take upon themselves the responsibility for placing in a salable condition such merchandise that is in need of reconditioning to enhance its sales possibility. There are many items which come under this category. Washing machines, electric ranges, fans, vacuum cleaners, percolators, toasters and irons are among the many items on which reconditioning is necessary. The tools required for this are few in number and not expensive. In addition to the necessary wrenches, screw drivers, etc., a portable buffing outfit and paint-spraying machine could form the nucleus of the tools necessary for such an activity.

In the event that an electric property is composed of small towns, it would be entirely possible to recondition articles of merchandise at a central location where the necessary tools and help would be available. In the case of most articles on which reconditioning is necessary it is principally a case of giving the articles in question a thorough cleaning. On other articles, however, a paint job might be necessary, and in such cases the paint-spraying machine is a very useful appliance. One utility has utilized the services of an automobile enameling shop in connection with the reconditioning of electric washing machines. An electric washing machine can be reenameled at a very small cost in a color which would make it an attractive article of merchandise, rather than an item which would constitute a hindrance to the merchandise turnover.

It is quite obvious that the easiest sale of merchandise and appliances is the sale of new merchandise and appliances. The sale of a second-hand or shop-worn item requires more individual attention on the part of a sales representative than does the sale of a new appliance. It is necessary, therefore, that some branch of the company interest itself constantly in a systematic method of continually reconditioning items of merchandise requiring resale, and to constantly place before the salespeople the need for merchandising activity on the reconditioned articles available for resale. Many companies make it a practice to offer these items at attractive prices to employees before they are placed on public sale. This can be readily accomplished by the publishing periodically of descriptive lists.

The Stores Department is interested in the turnover of the total stock account, and it is from this standpoint that pressure may be brought by the Stores Department on the Sales Department to induce it to move these articles.

In some companies such a reconditioning of merchandising is already a part of the organization structure, and it may or may not be in the Stores Department; however, in other companies this part of the organization has either been overlooked or not felt sufficiently important to warrant the attention of executives, and in such companies where this kind of a service is not now existent it is suggested that it can be readily incorporated in the Stores Department of their business. Such an activity on the part of the Stores Department would not only reflect a profit but would serve to place on the active list many items of merchandise which are now on the inactive list.

Appliances, Office

It is inevitable that there will be a continual advance in the development of new office appliances designed to lighten the clerical burdens in our utilities. When new appliances are adopted, those which are replaced and whcih still have much useful life should be placed in the custody of the Salvage Department. If it is not possible to trade them in on the purchase of the new equipment, inquiry should be made as to whether it would be used elsewhere within the company and, if not, they should be placed on sale before they become obsolete.

Boxes and Crates

An appreciable part of the cost of goods received from vendors is represented in boxing and crating, and it is well worth while to partially offset this expense by salvage methods. A canvass of the company will probably enable the Salvage man to place the greater portion of the good wooden boxes and cardboard cartons for various uses within departments and for shipping and the remainder may be sold. Crating lumber may be cut up for other purposes such as grade stakes, etc.

Brick, Common

The reclaiming of second-hand common brick for further use is not always profitable. The cost of cleaning, hauling and handling, together with its restricted use, sometimes makes the proposition anything but attractive. Sometimes, however, the conditions are favorable and the Salvage Department should be guided by local conditions. It is always advisable to have a small quantity on hand for repair work and for such new jobs on which they may be used.

Burlap

In addition to its value as a junk item for sale, burlap may be put to good use within the company, such as protecting items for shipping or storage. In checking up the uses of wiping rags, one company found that a large amount was used in plugging pipes on construction jobs. It was found that scrap burlap was just as satisfactory for this purpose and a sufficient supply was reserved instead of being sold.

Cable, Lead Covered

Scrap cable is perhaps the largest and most valuable item of junk handled by public utilities, and as it contains two commodities, copper and lead, for which there is always a ready market, the methods of preparing it for sale should be carefully considered. There are three common methods now in use:

(a) *Sale based upon analysis.* The metal content may be approximately determined by analysis of samples. This method is fairly satisfactory if each size is weighed and sold separately with sealed ends and joints excluded. The great element of doubt under this method is the proper allowance to make the junk man for his labor in recovering the metals. He may be able to employ cheaper labor but is not in a position to develop machinery and methods as well as a public utility.

(b) *Mechanical Separation.* The copper and lead may be separated by mechanical means. This may be the crude hammer and knife, the motordriven rotary knives, which have been in use for several years, or some other mechanical equipment. It is doubtful if satisfactory costs can be effected and a large production handled with the machinery now developed. It must be admitted that the scrap trade prefer copper and lead produced by this method and the development of satisfactory machinery will be followed with great interest.

(c) *Separation by Furnace.* The reduction of scrap cable to its component metals by means of a furnace is the method used by a great number of utilities. This method has the great advantage of low cost per ton handled and the final elimination of the useless insulation, filler, etc., also a large production can be handled quickly and in a comparatively small space. These advantages more than compensate for the small percentage of metals lost in the burning operation. If the work is properly done the metals will command the highest market prices, and there will be the satisfaction of knowing exactly what is being sold and what it costs to produce it, which is not possible under the analysis method. A means has been found to eliminate the objectionable smoke produced in the furnace and is described elsewhere in this review.

The copper from cable will take the highest grading, and if it is desired to bale it this can readily be done on account of the annealing which it has undergone in the furnace.

The lead from cables always has a wide and ready market, and in many cases a great deal can be used within the company for various purposes. It should be cast in pigs of a convenient size for the trade. One company found a new market for its scrap lead by casting it in small pigs of a size designated by the customer.

The work of salvaging can be done so as to insure that the lead will be free from traces of metals other than those in the original composition of the cable sheath.

It has been found well worth while to separate the seals on the ends of the cables and the soldered ends of the cable joints on account of the tin content. One company makes it a practice to accumulate all the scrapped cable joints and run them in separate lots through their scrap furnace. The lead and solder is run off and the resulting mixture is segregated from the ordinary lead on account of being worth about 50 per cent more. The conductors with their sleeves are pulled out of the fire before they get too hot and the sleeves are melted off by dipping in a pot of hot lead. This allows the sleeves to be reclaimed for further use.

Cinders

The use of cinders for such purposes as fill for roadways, yards, etc., and as foundation for floors and sidewalks, has been long established. In some localities they are made into building brick and block with good success. The whole matter of cinder disposition might well be placed in the hands of a Salvage Engineer with the idea of finding uses within the company, getting the best possible revenue from the portion not needed for company use.

Conduit, Fiber

Pieces of fiber conduit returned from jobs are usually found to be broken or chipped on one or both ends. There is a machine on the market with which the ends can be squared off and properly tapered. In this way the waste of this material will be reduced to a minimum.

Drums, Non-Returnable

Drums make excellent containers for junk of various sorts, including oils, etc. The tops may be cut out and handles or eyes for lifting hooks should be put on. They should be painted a uniform color and stenciled to show their use and return instructions. Those which are not used in this way have a resale value which in some localities is as high as a dollar each.

Fire-Brick

Old fire-brick may be ground into calcined clay which may be mixed with raw or green fire-clay in preparing filler to be used in laying fire-brick. Machines are on the market which will grind the old fire-brick so that the product removed by air separation from the pulverizer will all pass through a 40-mesh sieve. The cost of the product so recovered is estimated at one-sixth the cost of new material and represents a handsome saving. Special attention should be paid to selection of bricks to be pulverized to insure that no unsuitable brick (such as those covered by slag) are used, as they would reduce the refractoriness of the calcined clay.

In addition to the above use a certain proportion of second-hand fire-brick may be used for backing in maintenance or new construction work.

Fittings

Second-hand pipe fittings of all kinds are usually reclaimable, but not always for their original purposes. Small valves can be satisfactorily reconditioned for well under 50 per cent of their original cost. The process is simple: Take down the valve and immerse in a good cleaning compound to remove all foreign substances. Reseat, put in a new disk and assemble the valve and you have an article practically as good as new. It is recommended that they be subjected to a standard test before being used again. Reclaimed pipe fittings can be used on temporary work, but they are not recommended for new work if they would lower the standard of construction. There are certain exceptions to this, as many fittings, especially the flanged fittings, are not injured by being put into service and taken out again. It is a good idea to have all second-hand fittings come to the Salvage Headquarters rather than try to work them off at various stockrooms as orders which can be filled with this class of material can be taken care of from one point more satisfactorily.

Furniture, Office

Every company has surplus office furniture at some time or other. Unless it is cleared through some central point, it is probable that chances for its further use will be overlooked and that unnecessary buys of new furniture will be made. Quite often the furniture needs repairing of a minor nature only, and one company has gone so far as to make up new tops covered with battleship linoleum for desks which are too badly gone for refinishing. These tops are quite presentable and can be made up for about one-fifth of the original cost of the desk.

In the event that the tops of the desks are in a fairly good condition, the desks can be thoroughly cleaned and the worn pieces can be filled with a wood filler colored to match the old finish. The desk can then be completely varnished or can be sprayed with lacquer by means of an air brush. It has been found that the use of lacquer for the refinishing of office furniture is much more desirable than a varnishing process. By the use of lacquer, which dries very quickly, the desk can be returned after refinishing on the same day on which it is delivered to the shop. Lacquer has also been found to be considerably more durable than varnish.

Drawers which do not slide properly are among the most common of troubles with office furniture, and this, of course, is a comparatively simple matter to repair, as in most cases it is simply a case of using a plane.

It is advisable for a shop to carry a good supply of high-grade casters, as in the very great majority of cases the furniture when received from the manufacturer does not have a caster which is of sufficiently good quality to give very long life.

Leather upholstering on chairs frequently requires repair, and, in fact, it is very often necessary to reupholster the chair. It will be found in connection with the repair of a chair that a leather dressing applied occasionally will prevent the upholstering from getting brittle and checking.

Wooden letter files are an item of furniture on which it is felt that not very much time or expense should be expended, as unless the repairs are comparatively minor, it would be a paying proposition to replace them with metal files in most cases.

One of the elements which is of prime importance in the repair of office furniture is that of time. Any utility which has its own shop equipped to repair furniture can accomplish this in about one-fourth the time required if the furniture had to be sent to an outside agency, repaired and returned by them, and this feature constitutes a great saving in time and prevents inconvenience to employees whose work would be interrupted during the repair. One utility kept a record of the relative costs simply from a money standpoint of the two options which a utility has, and found that the saving which can be secured through the repair of office furniture in connection with a shop for building maintenance is quite an appreciable item.

A well-equipped carpenter shop, which can be used also in connection with building maintenance, might well contain such articles of equipment as an air brush for lacquering, a circular power driven saw, jointer, band saw, a drill press or lathe, a buffing wheel used in connection with an emery wheel, etc. All of these articles of equipment, which are necessary in the repair of office furniture and equipment, are found very useful in the care and maintenance of a modern office building, and it would be readily found that the possession of such pieces of equipment will show a saving which is easily reconcilable with their initial cost and maintenance.

Hardware, Line

It requires adequate handling facilities and good judgment to properly inspect and pass upon the numerous items of line hardware which come back for credit. Braces, brackets, pins and bolts are the most common items to be handled. It is recommended that the reconditioning be done at a salvage headquarters rather than at a number of warehouses. In the ordinary routine of storekeeping it will be up to the various storekeepers to sort out the portion of returned hardware which is fit to be put back into stock, but even this operation should be periodically checked up by the salvage man to insure that no inferior material is being picked out. As a matter of policy no storekeeper should be allowed to junk any hardware regardless of its condition. This decision should rest with the salvage man alone.

Upon receipt of hardware at salvage headquarters, the salvage organization should first sort it over and scrap that part which is obviously unfit for further service.

Some of the cross-arm braces need only straightening, which can be done most successfully under a power hammer. Others need regalvanizing also, but this should be done only if the cost is well under the cost of new braces.

The bolts frequently have the threads slightly burred and can be reconditioned by having a nut or a die run over them. Regalvanizing of bolts is not recommended unless both cost and workmanship make it desirable.

All hardware that is discolored by the weather should be cleaned by immersion in some satisfactory solution before being re-issued. This will not add to its future life, but will improve its appearance, and should be adopted as part of the salvage policy.

The salvage man and the company engineers in charge of line construction and maintenance should be thoroughly in accord as to reclaimed material. The former should not attempt to make a big showing by causing a large amount of really inferior material to get back on the company lines, and the latter should be reasonable to the point of accepting material which is suitable for further use.

Lamps, Incandescent

Companies which furnish free renewals are confronted with the problem of handling and disposing of the old burned-out lamps. Most companies insist on destroying these lamps so that they cannot be put to improper use. One company uses a small rock crusher which smashes the lamps and the bases, afterward using a motor-driven sifter to reclaim the bases, which are a good quality of light yellow brass.

Lumber

The extent to which it is economical to salvage second-hand lumber is a debatable question. Whatever methods are decided upon usually have to be applied at the source. The reason for this is obvious, as lumber is very easily damaged and unless care is exercised in removing it from service it will be rendered useless. Heavy timbers are in demand at all times in short lengths for cribbing, blocking, etc. Reclaimed lumber will make satisfactory crates, boxes, etc., if it is not in condition to be used again for building purposes.

Metals, Ferrous

The degree to which ferrous scrap should be sorted and graded is a question which calls for an intimate knowledge of the metals themselves, their handling costs and local conditions. One extreme is to sell it all in mixed lots and the other is to separate it into all of the classes provided in the commonly used scrap classifications. Most companies compromise by grading large lots only and selling the balance as mixed lots.

In utilities operating over large territories it is questionable whether it would pay to concentrate the ferrous scrap at a central location on account of the transportation costs, and there are not usually facilities at the source for grading and storing it. The sorting of ferrous scrap so as to get the highest return calls for experienced help, otherwise there will be numerous rejections and controversies with the buyers. Local conditions and company policy govern this matter to a great extent, and it will merit review at a later date.

Metals, Non-Ferrous

The greatest values in junk materials lie in this general class. These metals are used in electrical and mechanical equipment of all kinds, and its reclamation from junk apparatus is a real problem.

The simplest form of reclamation consists of segregating and grading those items which are composed of one metal only and are ready for sale in the same condition they were received from the jobs. Copper, brass, lead, aluminum, etc., are the principal metals referred to.

The great majority of electrical and mechanical equipment is composed of combinations of different metals and other substances, each one presenting a different problem of reclamation. Some of the assemblies can be dismantled economically with simple tools like a hammer, a screwdriver, or a wrench, and such work, if under competent supervision, presents no particular problem.

In addition to the two classes mentioned above, we have those which require special equipment in order to reclaim the component metals and put them in marketable condition, such as will command the highest market prices.

The principal items in this third class are insulated wires and lead-covered cables. As far as is known there is no satisfactory mechanical means of removing the weatherproof covering from wire. Machines are in use and have been described in previous reports which will cut the lead sheath from cables, and also in successive operations will cut the insulation from the conductors, but neither the speed of operation or operating costs have proved satisfactory.

The one practical method of reclamation of wire is by fire. Wire may be burned in the open where local conditions will permit, but this is not possible in most cases. Several companies are reclaiming the metals in wires and cables by the use of furnaces, one of which is described and illustrated in this review.

Besides wires and cables there are combinations too numerous to mention, some of which require study as to whether it pays to make a separation, but it will be found that it usually pays if the salvage department has trained men and proper equipment.

In all the work of preparation of non-ferrous metals for sale it should be kept in mind that the highest possible grading should be attained if consistent with preparation costs. As an example of this, one company has found additional customers for copper by sorting it as requested by certain factories, and in no case has the extra labor in preparation been a noticeable item.

Oil, Automobile

Crank case oil drained from cars may be reclaimed by oil separators which remove the objectionable liquids and solids. This work must be done well as the damage that might be done by inferior motor oil is too well known to need explanation here.

Oil, Transformer and Switch

The cleaning and drying of transformer oil in the field as a routine matter should not be considered as a salvage operation, but rather as a detail of electrical operation.* It does become a matter for the salvage organization, however, when dirty oil is removed from electrical apparatus and replaced with new oil, and the former is returned for disposition. All returned oil should be inspected, cleaned and tested before being re-issued. It should be needless to emphasize the need for avoiding the mixing of the various grades of oil, and close cooperation is necessary between the salvage organization and the using departments from the time the dirty oil is removed in the field until it is put back into use.

Paper

The qualities of paper used by public utilities are so numerous that the grading of scrap paper is not recommended, except in special cases.

It has been demonstrated that, unless rigid methods are adopted in the saving and collection of paper, a large proportion of it will be wasted. Proper receptacles must be provided, and mechanical balers should be used where it seems advisable. Regular collection and sale should be provided for to keep the paper cleaned up, and it will be found that the increased revenue will be well worth the effort.

Pipe, Iron

Every utility uses a considerable amount of iron pipe, and scrap pipe is an important salvage item. It should, in every case, be brought into the salvage department for inspection to determine its condition and final disposition.

The salvage department may employ a pipe machine to good advantage, cutting off the old threads or damaged pieces, re-threading, and coupling the pipe to standard lengths.

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*See "Storage, Handling, Inspection and Testing of Insulating Oils," (Publication No. 289-48), Serial Report, Electrical Apparatus Committee, N. E. L. A.

Nipples may be manufactured out of scrap pipe not needed for other purposes, but it is hard to compete in this respect with modern factory machinery. This work could be done to good advantage, however, on time which would otherwise be wasted.

Since the general tendency is to make up pipe railings by welding rather than use railing fittings, practically all scrap pipe of railing sizes can be used up to good advantage.

Poles, Wooden

It is difficult to find a market for old wooden poles which are not good enough for further use as poles or guy stubs. There is a certain demand each year for a small number of poles from various sources, such as rural telephone companies, but to most companies of any size the disposition of the poles is a real problem. They must be picked up from the streets and highways from which they are removed, and many companies are compelled to sell them or give them away for firewood. One company has the poles sawed to 4 ft. lengths and burns the pieces in a special boiler to heat a large warehouse and garage.

Rags, Wiping

The collection and laundering of wiping rags has been tried by several companies with varying success. The work can be done by their own equipment or by outside laundries at a satisfactory cost. One thing, however, is clearly apparent—the rags must be of a good size and quality to stand several trips to the laundry. Proper receptacles must be provided for dirty rags, and the using departments must cooperate to prevent their loss.

Steel, Structural

Angles, channels and various shapes of structural steel are always in demand. There is, however, a feeling among engineers and construction men that the average piece of second-hand structure is too expensive when prepared for further use, and this is probably true if the steel comes to them direct from the job. Where a salvage department is maintained, it is well worth while to remove various appendages so that the steel may be handed out again clean and ready for use. Through cooperation a steady market for this class of scrap may be found, and that part which cannot be used again may be disposed of without delay.

Tools

Tools of various kinds can be economically repaired at a central point equipped for such work. While most using departments maintain facilities to make minor repairs and adjustments, there is no doubt that a great many tools from various parts of the company are discarded rather than be reconditioned. This is due to lack of supervision, lack of facilities, or a lack of knowledge of values and a salvage man will find many chances for savings in this field.

Torches and firepots are generally badly misused in the field, and it is well worth while for companies using these in large numbers to adjust and repair them instead of returning them to the factory. This puts them back into service quicker, and incidentally a campaign of education among the users would result in less abuse of these tools.

One public utility, on account of the lack of information as to just how much saving was involved in the reconditioning of tools, conducted a three months' test in one division of the company, which was of average size, during which period of time no tools were allowed to be thrown away under any circumstances. Very careful records were kept of the tools repaired, the cost new, the cost of repair, and the saving secured. Table I gives the results of this survey.

TABLE I

ANALYSIS OF COST OF RECONDITIONED MATERIAL

Name and Item	Cost New			Cost of Repair Saving			
	No.	Each	Total	Labor	Material	Total	Saving
Standard earth augers	6	$7.50	$45.00	$1.80	0	$1.80	$43.20
No. 2 socket framing chisels, 2″ cutters	7	.87½	6.12	.23	0	.23	5.89
No. 3 new easy belt and rivet (pairs)	5	6.75	33.75	.90	6.53	7.43	26.32
No. 200 A 4½′ cant hooks	16	2.39	38.24	1.80	15.80	17.60	20.64
No. 297 2½″x5′ lug hooks	6	2.30	13.80	.73	4.86	5.59	8.21
No. 869 9′ digging shovels	72	2.88	207.36	24.30	97.04	121.34	86.02
No. 861 9′ digging spoons	24	2.88	69.12	8.10	31.92	40.02	29.10
No. 1092 D handle shovels	18	1.35	24.30	5.40	4.74	10.14	14.16
W712 Woods ditching spades	17	2.67	45.39	4.61	12.29	16.90	28.49
No. 3-B steel squares wrench	5	2.40	12.00	0	0	0	12.00
12″ adjustable crescent	9	1.53	13.77	0	0	0	13.77
Axes Fall City, 3-4 lb	18	2.00	36.00	3.38	6.00	9.38	26.62
No. 2 machinists hammers	18	.87	15.66	2.03	2.58	4.61	11.05
No. 300 safety first nail hammers	6	1.96	11.76	.72	.66	1.38	10.38
No. 819 pike poles	8	3.11	24.88	.50	.05	.55	24.33
6′ cross cut saws	5	5.60	28.00	1.35	1.25	2.60	25.40
4½′ cross cut saws	5	3.60	18.00	.90	1.25	2.15	15.85
No. 93 Sterling hand saw	11	3.75	41.25	1.35	.20	1.55	39.70
45472 installing bars	4	2.21	8.84	.30	3.00	3.30	5.54
4613 electric lanterns	3	9.00	27.00	.45	0	.45	26.55
Total	....	....	$720.24	$58.85	$188.17	$247.02	$473.22

Salvage Furnace

It will be of interest to salvage men generally to learn that one of our member companies has succeeded in developing a salvage furnace in which weatherproof wire, lead-covered cable, etc., can be reduced without the objectionable smoke usually producd by such an operation. Smoke of this kind is objectionable to any community, and this has in many cases compelled utilities to dispose of wire and cable just as it came from service, and sacrifice the greater return which would be possible if they removed the insulation.

Fig. 1, 2 and 3 show the general construction of the furnace. In burning weatherproof wire it is necessary to keep the oil burner in front of the checker-work going throughout the burning operation. In burning cable the oil burner is kept going only for the first five minutes and is then shut off.

In both classes of material there is a dense smoke produced in the primary combustion chamber. This smoke passes through the oil burner flame and the red-hot checker work into the secondary combustion chamber. At this point, due to the peculiar construction of the walls in the secondary chamber, the smoke, gases and a fresh supply of air are whirled around and thoroughly mixed and consumed before they leave the stack. The result is a white haze at the mouth of the stack, which not even a critical smoke inspection would classify as "smoke."

These results were reached only after months of experiment, in which almost every method of smoke prevention known to combustion engineers was tried out. These results, coupled with experiments in the field under actual working conditions, enabled the salvage engineer in charge of the work to accomplish a smokeless furnace.

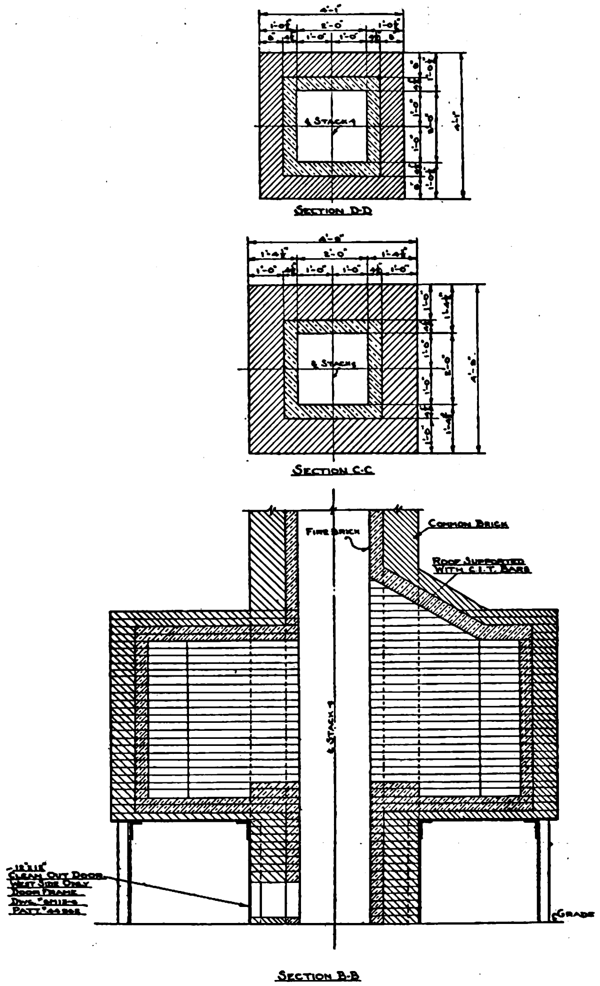

FIG. 2—LAYOUT OF INSULATION BURNING FURNACE.

METHOD OF LISTING, ADVERTISING AND SELLING

It is general practice to list the items of junk under some accepted classification and send same out for bids. Many companies have special forms for this purpose, on which all terms of sale are shown. Bargaining with junk dealers and others on mixed lots and incorrectly described materials is an undesirable method, as it makes it impossible to compare the prices obtained over a period of time. It should be needless to state that the seller should establish a reputation for accuracy in the segregation, weighing and grading of junk. This will result in broadening the market and establishing direct contact with the ultimate users instead of selling everything through junk dealers.

Salvage Materials and Equipment For Sale

The second class of salvage to be considered is that material and equipment, which cannot be classed as junk as it is still good for its originally intended uses. It may be surplus new unused material which was never applied to the jobs for which it was intended, or it may be material removed from property because of obsolescence or inadequacy. In either case it still has certain service left in it for the right parties.

Much equipment should be sold "as is" and "where is" as soon as possible after it is taken from service and listed. This is a very desirable procedure as it avoids overhead and handling charges, and should be followed whenever possible. If it is necessary to remove the equipment to the salvage headquarters, it should be explained in the listing that it is offered "as is" and that no effort has been made to recondition it.

There is some equipment that would have a market if certain work were done on it. This work may consist of repairs to remedy damage or alterations to conform to later engineering practice. It is a matter of good judgment to know how far to go in this respect also after decision is made to make repairs or alterations, it may be wise to defer the actual work until it is certain that the equipment can be sold. There should be no possibility of spending money in this work, which would afterward be wasted through inability to find a market.

It is not recommended that the salvage department develop shops capable of doing extensive repairing and alterations, as it would be more economical to have it done in the general shops of the company, if any, or by outside firms.

Salvage Materials and Equipment for Further Use

The salvaging of materials and equipment for further use within the company is a very important part of salvage work. It not only obviates the outlay of new money for the purpose, but cuts down handling and overhead expense connected with the equipment, and makes it possible to realize the property value instead of sacrificing it for sale outside the company. Unfortunately all companies are not organized to handle this matter, occasionally resulting in new purchases on which substitutions could be made.

The only sure method of handling this is to have the purchase requisitions routed through the organization in charge of salvage operations. Each requisition should be scanned by employes trained in the knowledge of what is available and the possibility of substitution. By "substitution" is not meant the supplying of a different or inferior article but simply using something already on hand instead of purchasing. The salvage organization should endeavor to sell this idea to the various departments rather than have it forced upon the latter by executive order.

As in the case of equipment for sale, any extensive repairing or altering should be deferred until there is a certainty that there will be a use for the material. Common sense and engineering knowledge will be the guide as to how much will be spent to recondition equipment for further use.

Accounting Routine and General Summary

The establishment of a definite salvage headquarters necessitates some changes in the accounting routine, because if certain conditions are imposed

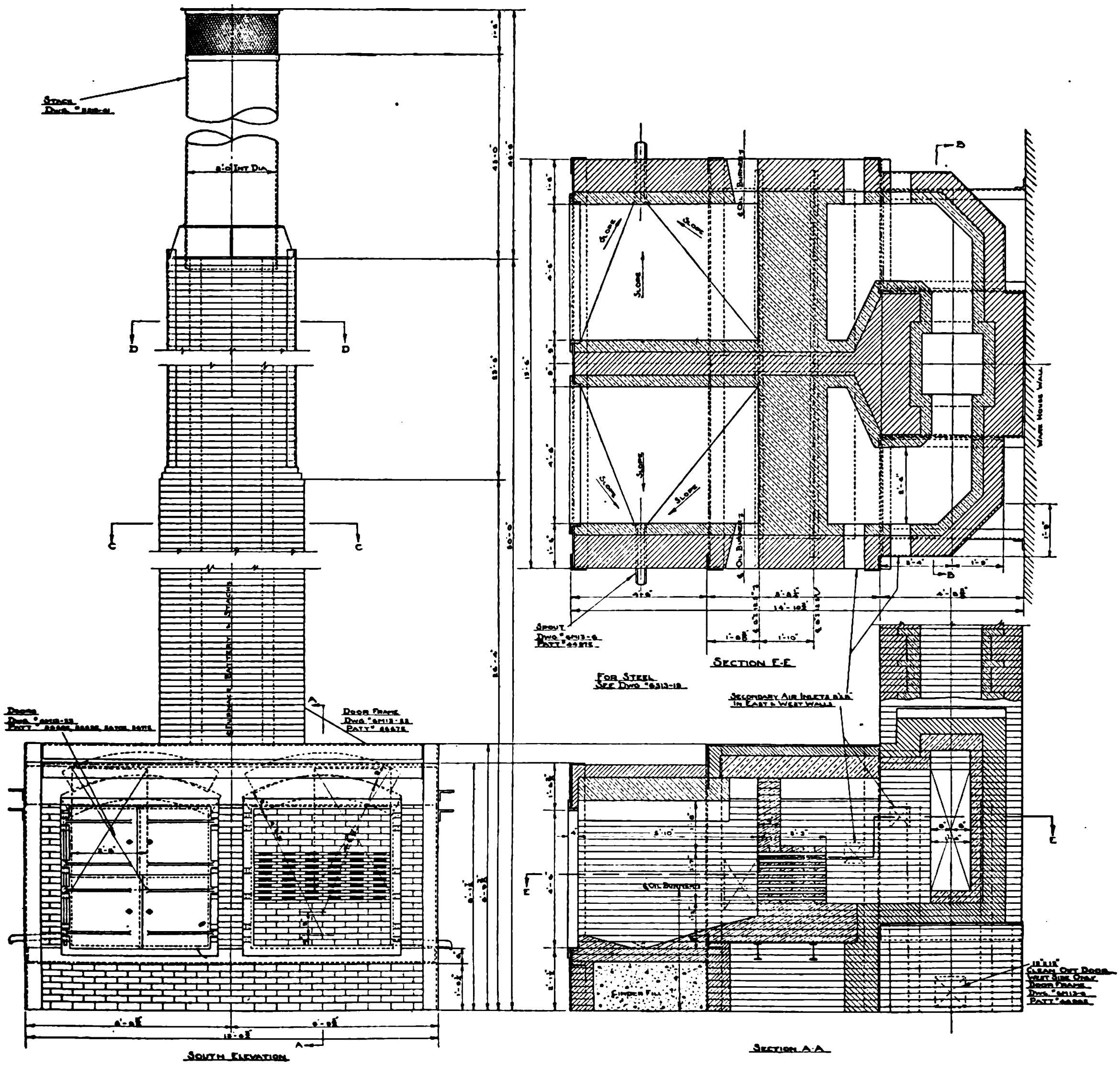
Stack
Dwg
INT DIA
D
D
C
C
Doors
Door Frame
Dwg
Patt
A
A
South Elevation
Spout
Dwg
Patt
Section E-E
For Steel
See Dwg
Secondary Air Inlets
In East & West Walls
Slope
Slope
Slope
Slope
Slope
Slope
Oil Burner
Oil Burner
Oil Burners
B
B
E
E
14'-10½"
1'-10"
Cinder Fill
Clean Out Door
West Side Only
Door Frame
Dwg
Patt
Section A-A
Ware House Wall

FIG. 3—LAYOUT OF INSULATION BURNING FURNACE.

upon them, clerical and physical costs will rise, thereby defeating the very reasons for which a salvage department is organized. The principal condition referred to is the obligation to keep each lot of scrap separate from other lots throughout all salvage operations, in order to apply the exact return to the jobs from which it came. The proper credit may be closely estimated upon receipt of material, but thereafter the salvage department must not be obliged to keep the various lots separate. The whole accounting routine of the salvage department should be very simply set up. Costs of the various operations upon which the salvaging policies are often decided should be based upon frequent field checks rather than upon a complicated system of accounts.

It is hoped that this review, in which so much is necessarily left unsaid, will serve the purpose of stimulating interest in this important work. It is recommended that this Committee and succeeding Committees continue the review, as each year cannot fail to bring out important new phases of the work. These reviews will be of service even to those companies who, at the present time, are prevented by company policy, lack of space and equipment, or other reasons, from practising certain salvage methods. They may employ some of the methods in a modified form, and if conditions and policies should suddenly change, they would be in a position to take advantage of the experiences of other public utilities.

FILING CORPORATE DOCUMENTS

In every business there is a multiplicity of records, the preservation of which is a vital necessity in the operation of that concern. The utility business is no exception; in fact, the nature of its business requires that its corporate documents, such as franchises, rights-of-way, licenses, permits, etc., be preserved permanently to assure that utility that its future operations may continue backed by the authorizations contained in these documents.

In the smaller utilities these documents have found as their place for filing the desks and cabinets of the various executives, but as the utility has grown in size and the scope of its operations extended, the necessity has arisen for a central point for filing these documents. Such a department might properly be termed "Department of Documents," wherein information of a corporate nature will be properly indexed, safely kept and promptly available.

Equipment

Equipment necessary for the filing of documents should be selected to meet local conditions. The one essential requirement is that the documents be contained in fireproof safes and steel cabinets.

Within the fireproof safe it is desirable to have legal size compartment fittings to provide for documents which are constantly referred to and which are considered as "alive" and "active." Papers which are valuable only as history can be filed in the "Dead File," the construction of which should be of such material that their protection from ordinary uses and deterioration will be assured.

In view of the fact that the key to the department is the index cards, they should be kept in steel cabinets which will afford them the ordinary protection of office records.

Assignment of Document Numbers

Every paper assigned to the department for safekeeping will be, before it is filed, assigned a number. In assigning these numbers, it is desirable to make a preliminary survey of the papers which may be assigned for safekeeping, and assign each classification a series of numbers so that upon the receipt of a document the number, which will eventually be assigned to it, will fall within the series previously designated for that class of information.

Assuming that within a definite period of time this department will receive approximately 40,000 documents which will be assigned an individual number, the following classification is suggested:

Conveyances	1,000	to	2,500
Abstracts	2,501	to	3,000
Opinions on title	3,001	to	4,000
Leases	4,001	to	5,000
Options to purchase	5,001	to	5,200
Mortgages to or by our companies	5,201	to	5,400
Indentures	5,401	to	5,600
Purchase contracts	5,601	to	6,600
Sale contracts	6,601	to	10,300
Construction contracts	10,301	to	10,600
Crossing agreements	10,601	to	11,000
Franchises	11,001	to	11,400
Ordinances other than lighting	11,401	to	12,000
Ordinances, municipal lighting	12,001	to	13,500
Rights-of-way	13,501	to	19,000
Water rights	19,001	to	19,500
Bills of sale or assignments	19,501	to	21,000
Chattel mortgages	21,001	to	22,000
Legislative action	22,001	to	22,500
Subscriptions	22,501	to	23,000
Decisions	23,001	to	24,000
Reports	24,001	to	26,000
Releases from liability	26,001	to	27,000
Secretary of State filings	27,001	to	27,200
Bonds	27,201	to	27,500
Certificates	27,501	to	30,000
Receipts	30,001	to	31,000
Correspondence	31,001	to	32,000
Agreements re water	32,001	to	32,300
Street lighting agreements	32,301	to	32,800
Municipal power agreements	32,801	to	33,000
General agreements	33,001	to	34,000
Court proceedings	34,001	to	35,000
Company activities	35,001	to	36,000
Affidavits	36,001	to	36,200
Lists	36,201	to	36,500
Tax matters	36,501	to	37,000
Joint use agreements	37,001	to	38,000
Licenses and permits	38,001	to	38,500
Resolutions	38,501	to	39,000
Blue prints or surveys	39,001	to	39,400
Notices	39,401	to	39,600

Indexing of Documents

In view of the fact that a document is assigned a number upon its receipt for filing, all identification of that document as to its name or contents is lost, except by reference to the index.

The indexing of documents may be according to the names of the parties concerned, locations of the property affected, the commodity sold or purchased, or may be indexed wholly according to general subject matter.

NAMES may be divided into individuals outside of the organization, may be corporations or the personnel of the parent organization and corporations acquired by or subsidiary to it.

LOCATIONS may be by section, township and range in rural territory; by street, avenue, boulevard, drive or place, or additions and subdivisions in cities, towns and counties; may involve lode or placer mining claims, ditches or reservoirs.

COMPANY HOLDINGS may be a generating plant, substation, office building or warehouse.

COMMODITY OR GENERAL SUBJECT may be contracts for the purchase of coal, meters, transformers or for tree trimming or highway lighting.

As an example for the above classification let us prepare the filing ticket for the warranty deed from John Jones, dated March 6, 1926, to the Electric Light & Power Company for the five acres in SE¼, Sec. 24, Township 3 So., Range 31 West, Davis County, site of Sparta Substation, all being part of the property acquired by purchase.

Publication No. 289-63, Serial Report, General Records Committee.

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CONVEYANCES

Warranty deed from *John Jones,* March 6, 1926, to *Electric Light and Power Company* for five acres in *SE¼ Sec. 24, Township 3 So., Range 31 West,* Davis County; site of *Sparta Substation.*

FIG. 1—INDEX CARD.

1 9 4 8

JULY* 10*th

Canton Franchise expires July 10, 1948. See Document 11804. Notify Vice-President in charge of Districts and District Manager.

FIG. 2—TICKLER CARD.

Each set of the underlined words heads a card with the number in the upper left-hand corner and containing the above information.

The master card reading "298—Conveyances" goes into the compartment indexed "Classification of Documents," and is checked against the last preceding card, which should be 297; when the paper itself is put in the safe it is also checked against the one last preceding, 297, thus providing two opportunities to detect error in filing.

The card "298—John Jones" goes into the compartment "Individuals and Corporations," minutely alphabetically divided; the next "298—Electric Light & Power Company" in the compartment "Our Companies and Officials"; the next "298—Range 31 West, Township 3 So., SE¼, Sec. 24" goes into the compartment "Range, Township and Section." The next card "298—Sparta Substation" goes into "Company Holdings" with a guide containing this name.

Thus indexed, no matter how asked for, whether by name of grantor, location by section, township or range, by name of the holding specifically or the property generally, it can be found. Inquiries for information contained in these documents or for the actual documents themselves may come from persons not directly connected with the company as well as its officers and employees.

Tickler Card System

If a document has been properly numbered and indexed according to the above procedure, there may be some particular subject matter about which it is desired to call to someone's attention at some future date. Franchises, leases, options, contracts, chattel mortgages, State and Federal licenses have definite expiration dates, sometimes fifty years in the future. Sufficiently in advance of the expiration dates notices should be sent to specific persons that payment should be made or some action should be taken; therefore, the necessity arises for a tickler card system.

As an example of this, let us assume that the Canton Franchise expires July 10, 1948. At the same time that the document is indexed and filed, a tickler card is made up. (See Fig. 2.)

Similar cards are made for Jan. 10, April 10 and June 10, 1948, respectively six months, three months, and thirty days in advance, and these filed under the year 1948 in a compartment divided by years. The present and next succeeding year's tickler cards are divided by months; the current three months divided by days, and to these notices are sent out each week or ten days for the items of the next succeeding ten days. As the compartments are emptied, the thirty-day dividers are moved back for the fourth next succeeding month. As time passes, the cards for the current period will come to the front, at which time the necessary action is taken to fulfill the requirements in the document.

Routine Payments

Leases for the offices, warehouses, pole-yards, retainers fees for legal and medical services, etc., and all requiring regular payments are on file. A record of these payments is kept in such a manner that by daily reference to this record the regular payments are not overlooked. Voucher requests for these are made sufficiently in advance so that payment may be made as scheduled. Yearly payments to the railroads on crossing and right-of-way agreements, franchise taxes to communities, rentals to the state and departments of the United States are made regularly. From this department the requests are forwarded to the department head concerned for his approval, after which they are sent to the Accounting Department for payment.

Chattel Mortgages

In some utilities the sale of merchandise on a time payment basis is carried on quite extensively. In these cases it quite frequently develops that it is desirable to place a chattel mortgage on the larger appliances sold.

The proper place for filing these mortgages after they have been recorded is in this department. As soon as they are received and indexed, a tickler card is made up which calls to the department's attention at the proper time that the chattel will expire within thirty days. When this tickler card comes to the front of the file, which is thirty days previous to the expiration of the chattel mortgage, a notice is sent to all parties concerned that the account should be paid in full by a certain date and requesting advice as to the status of the account. If the account has been paid in full a notation to that effect is made and a release is issued; if the account has not been cleared up and it is deemed advisable, an extension is filed. The follow-up procedure on the extension is the same as outlined for the original chattel.

Receipts for Loaned Documents

During the course of the company operations the necessity develops for the temporary removal from the files of certain documents.

Receipt cards showing document number and date taken are made up for all those taken out, the receipt immediately taking the place of the absent paper so that later inquiries may be directed to the party holding same. In this manner, then, the paper when once received by the department for filing is kept close track of and the chances for its loss or misplacement are slight.

A procedure of this nature provides a complete record of important transactions from their origin to their consummation. Of such importance is this department that it is desirable to install as its head an employee with legal training. In view of the fact that a number of the contracts and other important documents originate in this department it is important that its chief be qualified to draw up contracts, properly approve contracts which have been received for filing, and be conversant with the important points in various documents so that the company will be fully protected in its operations and activities in accordance with the provisions contained therein.

REPORTS OF
COMMERCIAL NATIONAL SECTION COMMITTEES 1928-1929

(For Personnel of Committees see Appendix 4)

Executive Committee

Marshall E Sampsell, *Chairman*

Convention Address by Chairman Sampsell
(see p. 41)

Commercial and Industrial Power & Heating Bureau

V M F Tallman, *Chairman*

Report presented at Convention (see p. 117)

Commercial Cooking Committee[1]

O Wilhelmy, *Chairman*

No Serial Report

General Power Committee[1]

H C Thuerk, *Chairman*

Serial Report, Pub. No. 289-38—Diesel Engine Power Costs (see p. 308)

Industrial Heating Committee[1]

J L Faden, *Chairman*

Serial Report, P-1—Electrically Heated Stereotype Pots as Load Builders (Not published in Proceedings)

Lighting Bureau

T O Kennedy, *Chairman*

Report presented at Convention (see p. 115)

Lighting Service Committee (1927-1928)

J Daniels, *Chairman*

Serial Report, Pub. No. 289-5—Lighting Service Manual—Part III (see p. 315)

Commercial and Industrial Lighting Committee[2]

J Daniels, *Chairman*

No Serial Report

Electrical Advertising Committee[2]

C J Eaton, *Chairman*

Serial Report, Pub. No. 289-9—Symposium on Electrical Advertising (Not published in Proceedings)

Home Lighting Committee[2]

W T Blackwell, *Chairman*

Serial Report, Pub. No. 289-119—Organization for Promotion of Home Lighting Service
(see p. 338)

Street Lighting Committee[2]

R J Malcomson, *Chairman*

No Serial Report

Merchandising Bureau

Frank D Pembleton, *Chairman*

Report presented at Convention (see p. 120)

Domestic Electric Range Committee

Frank A Coupal, *Chairman*

Report presented at Convention (see p. 123)

Merchandise Sales Committee

C L Harold, *Chairman*

Report presented at Convention (see p. 124)

Serial Reports

Pub. No.	
289-8	Domestic Oil Burners (see p. 349)
289-92	Electric Farm Equipment Market (see p. 428)

Refrigeration Committee

C L Dunn, *Chairman*

Report presented at Convention (see p. 122)

Water Heating Committee

Norman T Wilcox, *Chairman*

Report presented at Convention (see p. 123)

Customer Relations Committee

H T East, *Chairman*

No Serial Report

Promotional Rates Committee

E W Lloyd, *Chairman*

Pub. No. 289-93—Promotional Rates (see p. 437)

Wiring Sales Committee

A P Good, *Chairman*

Serial Report G-1—Selling Wiring (Not Published in Proceedings)

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[1] See Report of the Power Bureau—p. 117-120
[2] See Report of Lighting Bureau—p. 115-117

DIESEL ENGINE POWER COSTS

The subcommittee on Diesel Engine Power Costs published its first serial report (Publication No. 267-97) in September, 1927. It is the intention of the subcommittee to publish a similar report each year, which will contain data and information collected during the previous twelve months. The present report represents the second serial report on this subject.

Scope of Report

The Serial Report on Diesel Oil Engine Power Costs (Publication No. 267-97), which was published in September, 1927, presented operating data on a large number of plants located in this country and England. The report outlined rather completely a method of determining the costs of generating power with Diesel oil engines by applying the data recorded for these plants. It is, therefore, unnecessary to outline this method in this report. The information presented in this report on operating data and investment costs should be considered as supplemental to the information published in the 1927 report.

In this report are presented operating data and investment costs on a number of plants which have been obtained since the publication of the 1927 re-

TABLE I

OPERATING DATA AND UNIT COSTS OF DIESEL OIL ENGINE GENERATING PLANTS

Reference	Years Data Covers	Installation		Average Age of Engines	Average Annual Output Kw-hr.	Peak Load Kw.	Annual Load Factor in Per Cent	Yearly Use of Plant Capacity in Per Cent	Lb. of Fuel per Kw-hr.	Kw-hr. per Gallon of Lubricants	Maintenance and Repairs Mills per Kw-hr.	Misc. Supplies, Water, Etc. Mills per Kw-hr.
		No. of Engines	Total h.p. Installed									
J	2	3	980	4	1,382,813	....	23.0	24.0	....	....	2.68	0.85
T	2	2	700	2	990,470	541	20.9	24.0	0.850	1,060	....	....
F-1	3	4	1,850†	....	2,672,300	470	65.0	24.5	0.663	609‡	1.88	....
F-2	1	3	860	6	1,640,150	560	33.5	32.4	0.667*	980	3.09	0.23
F-3	1	2	560	....	1,357,300	....	....	41.1	0.790*	....	2.40	0.80
F-4	1	2	150	3	175,400	....	19.8	19.8	....	....	1.15	(Incl. under Repairs)
F-7	1	....	1,150	7	998,564	....	29.0	14.7	0.715*	....	7.00	(Incl. under Repairs)
F-8	1	....	1,135	5	1,175,580	400	33.6	17.6	0.780*	....	1.10	1.30
F-9	1	3	490	8	595,880	205	33.2	20.6	0.825*	867	1.61	3.78
G-1	1	3	850	6	2,694,900	....	63.0	53.8	....	....	2.00	0.80
G-2	1	....	225	....	739,200	....	....	55.6	....	....	1.45	(Incl. under Repairs)
G-3	1	....	360	7	180,000	....	....	8.5	....	....	2.60	(Incl. under Repairs)
G-4	1	....	300	1	692,940	....	57.0	39.2	....	....	7.55	(Incl. under Repairs)
H-1	1	4	3,450	3	13,577,643	....	....	66.5	0.670*	1,730	0.62	....
K-1	2	4	2,100	2	1,172,205	....	....	9.5	0.851	892	1.32	0.78
K-2	2	3	1,200	2	1,010,608	....	....	14.3	0.900	510	2.24	1.23
K-3	2	2	1,050	10	1,387,893	....	....	22.4	0.937	765	0.89	0.27
L-1	1	2	2,000	10	5,272,000	1,500	....	49.0	0.668	....	0.58	0.26
M-1	1	2	1,500	4	4,831,500	....	....	54.5	0.694	1,630	0.68	0.23
N-1	1	2	1,200	1	1,605,200	540	34.0	22.4	0.785	890	0.47	0.83
O-1	2	1	235	3	433,270	....	....	31.3	0.880	347	0.96	....
P-1	2	2	700	2	656,100	....	....	15.9	0.882*	1,215	0.61	1.11
R-1	4	3	1,400	3	597,000	375	....	7.2	0.728*	753	0.60	0.56
Total for 23 plants.....			24,445	....	45,838,916							

NOTES:

*Assuming fuel oil weighs 7.5 lb. per gal.

†800 h.p. unit in operation last six months only.

‡For 1927 only. (1925—424 kw-hr. per gal.; 1926—536 kw-hr. per gal.)

REFERENCE

J—Hiawatha Light, Power and Ice Company, Hiawatha, Kansas.
T—Cape and Vineyard Electric Company, Martha's Vineyard, Mass.
F-1—"Oil Engine Power," March, 1928, p. 187.
F-2 to F-4—Taken from operator's records.
F-7 to F-9—Taken from operator's records.
G-1 to G-4—Taken from operator's records.
H-1—"Oil Engine Power," June, 1928, p. 377.
K-1 to K-3—Taken from operator's records.
L-1—"Oil Engine Power," June, 1928, p. 360.
M-1—Taken from operator's records.
N-1—Taken from operator's records.
O-1—Taken from operator's records.
P-1—Taken from operator's records.
R-1—Taken from operator's records.

Publication No. 289-38, Serial Report, General Power Committee.

TABLE II

FUEL AND LUBRICATING OIL CONSUMPTION AND MAINTENANCE COSTS OF DIESEL ENGINE PLANTS LISTED IN REPORT ON HEAVY-OIL ENGINE WORKING COSTS (1926-1927) OF DIESEL ENGINE USERS ASSOCIATION OF ENGLAND

Reference No. of Plant	Years Data Covers	Installation		Annual Output Kw-hr.	Peak Load Kw.	Annual Load Factor in Per Cent	Running Plant Load in Per Cent	Hours of Plant Operation	Lb. Fuel per Kw-hr.	Kw-hr. per U. S. Gallon of Lubricants	Maintenance and Repairs Mills per Kw-hr.	Mis. Supplies, Water Etc. Mills per Kw-hr.	Type of Plant
		No. of Engines	Total Kw. Installed										
2	5	9	3,350	4,172,610	2,641	14.2	69.3	4,600	0.720	252	4.56	0.28	Utility-Auxiliary
3	5	7	2,710	3,698,490	2,055	16.1	66.3	8,760	0.749	738	1.64	0.24	Utility
5	5	7	1,730	1,954,027	916	12.8	59.2	8,760	0.773	827	3.76	0.58	Utility
6	5	2	325	1,449,398	255	51.0	66.8	....	0.671	595	1.68	0.28	Utility
7*	10	6†	1,080	1,420,911	716	15.1	64.2	7,586	0.736	413	4.76	0.42	Utility
8	5	6	1,210	1,385,098	667	13.1	60.8	8,760	0.786	1,345	2.96	0.38	Utility
9	5	3	1,125	1,337,554	850	13.5	64.2	3,452	0.709	1,140	0.34	0.12	Industrial
10	5	4	588	1,262,319	625	24.5	57.3	8,760	0.779	537	2.20	0.40	Utility
11	1	5	675	1,192,949	675	26.9	66.6	5,319	0.696	1,175	0.72	0.12	Industrial
12	5	3	600	1,190,140	529	22.7	82.2	3,762	0.653	632	3.00	0.18	Utility-Auxiliary
13	5	2	590	1,142,926	570	22.1	37.2	6,138	0.848	690	2.24	0.32	Utility
14	5	3	366	1,084,000	233	33.8	65.4	....	0.655	1,210	1.16	0.40	Water Pumping
17	2	2	573	931,150	475	30.5	63.8	4,947	0.633	1,083	0.94	0.18	Utility-Auxiliary
18	5	4	890	829,090	690	10.6	52.8	4,482	0.747	640	2.90	0.48	Utility-Auxiliary
19	5	5	835	696,710	475	12.5	63.2	6,364	0.703	982	1.06	0.24	Utility
20	5	4	495	652,119	440	15.0	62.8	5,000	0.651	690	1.04	0.24	Utility
21	5	3	670	643,394	600	11.0	63.8	3,500	0.694	827	2.54	0.38	Utility-Auxiliary
22	5	5	800	622,762	369	12.3	69.3	....	0.692	600	1.22	0.66	Utility
23	5	5	533	612,015	420	13.1	72.3	6,274	0.638	916	4.46	0.70	Utility
24	5	3	250	491,794	118	22.4	66.0	8,760	0.726	1,070	1.46	0.26	Hospital
27	5	5	317	395,475	184	14.3	58.8	7,360	0.770	476	1.06	0.70	Utility
28	1	2	249	368,050	233	16.9	53.5	5,196	0.632	642	0.44	1.34	Utility
29	4	1	295	362,710	225	14.0	33.7	3,650	0.826	458	1.00	0.90	Utility-Auxiliary
30	1	4	340	360,807	202	12.2	59.6	....	0.697	897	2.12	0.24	Industrial
31	5	2	350	341,025	308	11.0	74.8	1,750	0.677	731	3.18	0.08	Utility-Auxiliary
32	4	3‡	430	303,543	167	8.1	41.4	4,930	0.736	475	4.62	0.20	Utility
33	4	2	500	247,695	315	5.7	55.6	....	0.778	262	2.78	0.62	Utility-Auxiliary
35	1	1	150	229,740	147	17.5	74.2	2,065	0.647	758	1.94	0.24	Utility
36	1	1	162	224,136	161	15.8	72.8	1,901	0.618	418	1.06	0.44	Utility
37	1	3	335	217,221	200	9.3	52.8	....	0.768	618	2.00	....	Department Store
40	5	2	550	173,211	444	3.6	51.7	952	0.812	570	5.36	0.46	Utility-Auxiliary
41	3	1	100	154,690	100	18.6	52.8	2,926	0.797	787	4.08	1.30	Industrial
45	5	8	2,290	5,566,540	1,710	27.7	58.2	8,760	0.747	538	....	....	Utility
46	5	8	2,127	4,854,448	1,932	26.1	61.0	8,760	0.678	423	....	....	Utility
47	1	5	2,665	4,430,935	1,650	19.9	75.0	....	0.640	745	....	....	Industrial
48	5	9	2,226	4,147,130	1,654	21.3	62.6	8,760	0.702	523	....	....	Utility
49	5	8	2,310	3,242,145	1,050	16.0	68.2	8,760	0.746	412	....	....	Utility
50	1	3	1,710	2,708,044	980	19.4	66.2	....	0.675	1,340	....	....	Industrial
53	5	4*	780	890,640	329	13.0	44.2	8,754	0.903	313	....	....	Utility
54	1	3	282	669,440	275	27.2	51.8	8,760	0.825	539	....	....	Utility
55	3	2	295	506,420	155	19.6	39.0	....	0.828	1,303	....	....	Utility
22-26§	4	3	300	544,281	200	31.1	76.0	....	0.723	1,238	6.62	0.26	Railway
34-26§	3	1	75	65,100	74	10.1	10.1	....	0.688	253	9.82	....	Industrial
44-26§	2	4	800	2,063,789	594	39.7	62.6	....	0.684	479	....	....	Utility
Total..	173	......	39,033	59,836,671									

*See page 17, Report on Heavy-Oil Engine Working Costs (1923-24) and Reports for 1924-25, 1925-26, and 1926-27.

†Includes one 500 b.h.p. Semi-Diesel Engine.

‡Includes one Semi-Diesel Engine.

§Data obtained from 1925-26 Report only.

NOTE

Output, peak load, and load factors are for year 1926-27 only, except for plants marked (§).

Average age of engines—8.1 years.

Auxiliaries require approximately 3.0 per cent of energy generated.

3,810 kw. of capacity listed in table was installed during last year.

B.t.u. of fuel—approximately 19,000 to 19,500.

Plants Nos. 45 to 55 inclusive and 44-26 are overseas stations.

port. The last annual report of the Diesel Engine Users Association of England on Heavy Oil-Engine Working Costs (1926-27) has been abstracted and included in this report.

In the 1927 report data were given only for Diesel engine generating plants. In this report data are presented for a number of installations where the engines are connected mechanically to their loads. Investment costs for five of these installations are included in the report.

Operating Data

In Table I are given the operating results of 23 Diesel engine generating plants, having a total installed capacity of 25,000 b.h.p. and having a total annual output of 46,000,000 kw-hr.

Plants J and T of this table also appeared in last year's report. The data for these two plants in this report cover two years of operation instead of one year, as given in the 1927 report.

The data in this table, together with that appearing in Table I of the 1927 report, represent the operating results of 65 plants, having an installed capacity of 82,000 b.h.p. and an annual output of 190,000,000 kw-hr. These plants are all located in the United States.

In Table II are given the operating data of 44 plants recorded in the report of the Diesel Engine Users Association of England in its report on Heavy Oil-Engine Working Costs (1926-27). This table is similar to Table II in Publication No. 267-97, except that for most of the plants it covers five years of operation instead of four. In preparing Table II this year, all plants containing ex-submarine engines were omitted, as it was felt that these units do not represent the performance to be expected from engines designed for stationary service. Maintenance and miscellaneous cost items for all "overseas" plants have also been omitted. The table gives the results for 44 plants having an installed capacity of 39,000 kw. and an annual output of 60,000,000 kw-hr.

Table I of the 1927 report, together with Tables I and II of this report, present operating data on 109 generating plants, having a total installed capacity of 140,000 b.h.p. and an annual output of 250,000,000 kw-hr. Table III of the 1927 report shows data on 15 additional plants having an annual output of 24,000,000 kw-hr.

With this amount of data available, it is evident that values taken from the results of these 124 generating plants represent a fairly reasonable picture of what may be expected from the average Diesel engine generating plant.

Fuel Oil Consumption

In Tables I and II the fuel oil consumption for the 61 plants reporting this item varies from 0.618 lb. per kw-hr. to 0.937 lb. per kw-hr. In Table III the variation for the 15 mechanical-drive plants is from 0.668 lb. per kw-hr. to 1.660 lb. per kw-hr., a considerably higher variation than that of the generating plants.

TABLE III

OPERATING DATA OF MECHANICAL-DRIVE DIESEL ENGINE INSTALLATIONS

Reference No. of Plant	Installation				Net Equivalent Kw-hr. Output	Station Load Factor Per Cent	Lb. Fuel Oil per Kw-hr.	Maintenance per Kw-hr. Mills	Miscellaneous Cost per Kw-hr. Mills (†)
	No. of Engine Units	Date Installed	H.P. Installed	Equivalent K. W.					
1	4	....	2,060	1,375	4,735,000	57.8	0.760	1.40	0.57
2	7	2—1916 4—1918 1—1919	3,040	2,030	6,500,000	46.4	0.668	3.45	0.51
3	6	....	3,405	2,270	6,365,000	54.4	0.711	3.67	0.55
4	3	1924	400	270	1,067,000	79.5	0.764	5.63	1.06
5	7	2—1917 5—1921	3,240	2,160	5,160,000	37.0	0.690	3.09	0.54
6	6	4—1919 2—1924	2,275	1,520*	990,000	52.9	0.770	1.74	0.75
7	4	....	280	187	334,200	46.6	1.660	5.67	4.23
8	6	2—1917 2—1919 2—1923	2,275	1,520*	582,500	38.7	1.100	2.58	0.78
9	1	1922	750	520	1,542,000	43.3	0.790	1.28	0.98
10	2	1—1922 1—1915	615	410	1,172,000	36.2	0.774	1.41	0.90
11	1	1923	600	400	1,060,000	33.7	0.890	1.37	0.66
12	1	1922	600	400	1,835,000	61.0	0.730	0.93	0.46
13	1	1922	550	365	1,368,000	48.8	0.750	0.41	2.11
14	1	1922	200	135	389,000	24.8	0.870	1.98	1.18
15	1	1913	65	45	46,600	22.8	1.260	5.66	6.48
Totals....	51	....	20,355	13,607	33,146,300				

NOTE: Average age of engines—6.2 years (Plants No. 1 and 3 excluded). Data are for one year.
*Includes purchased power.
†Miscellaneous cost does not include purchased power.

TABLE IV

INVESTMENT COSTS OF DIESEL ENGINE PLANTS

Reference	Installation		Total Investment	Unit Investment		Date of Installation
	Engines	Generators		Per b.h.p.	Per Kw.	
M	2— 180 h.p.	2— 150 kv-a.	$36,600.00*	$102.00	$152.00	1925
N	2— 120 h.p. 1— 250 h.p.	2— 80 kv-a. 1— 185 kv-a.	60,157.95†	123.00	218.00	1914 and 1917 1923
O	2— 600 h.p.	2— 410 Kw.	155,000.00‡	129.00	189.00	1926
P	1— 240 h.p. 1— 360 h.p.	(Not given)	89,916.33‡	150.00	223.00	1927
R	2—2250 h.p.	2—1600 Kw.	674,200.00‡	150.00	210.00	1926
S	2— 750 h.p.	2— 500 Kw.	200,305.16‡	133.00	200.00	1923
T	2— 600 h.p.	2— 410 Kw.	206,500.00‡	172.00	252.00	1926 and 1927
V	1— 240 h.p. 1— 360 h.p. 1— 600 h.p.	1— 160 Kw. 1— 240 Kw. 1— 410 Kw.	169,700.00‡	140.00	207.00	1925 and 1926

NOTE

*Building not included.
†Not known if building is included.
‡Includes building.

REFERENCE:

M—"Power," December 15, 1925.
N—Taken from operator's records.
O—Taken from operator's records.
P—"Power Plant Engineering," September 1, 1927.
R—Taken from operator's records.
S—Taken from operator's records.
T—Taken from operator's records.
V—Taken from operator's records.

As pointed out in the 1927 report, consideration to the actual load conditions should be given before estimating the fuel consumption for a proposed plant.

Lubricating Oil Consumption

The 58 plants reporting lubricating oil consumption in Tables I and II show a variation in this item of from 252 kw-hr. per gal. to 1730 kw-hr. per gal. From an inspection of these data, it is apparent that the estimates in the 1927 report for this item are better than average performance.

Miscellaneous Supplies, Including Cooling Water

From Tables I, II and III it is apparent that the average cost for miscellaneous supplies, including cooling water, varies greatly between installations. The value of this item for any one installation depends upon a large number of factors, many of which depend upon the location of the plant.

Maintenance

In the 1927 report it was pointed out that maintenance costs are more nearly proportional to output than to initial investment. For this reason maintenance costs have been reported again this year in mills per kw-hr.

In Tables I and II of this report this item varies from 0.34 mills per kw-hr. to 9.82 mills per kw-hr.

In Table III of this report the variation for the mechanical-drive installations is from 0.41 mills per kw-hr. to 5.67 mills per kw-hr. We may safely assume from experience that in a generating plant about 90 per cent of the total maintenance cost is chargeable to the Diesel engine itself.

Attendance Labor

As was indicated in the 1927 report, the amount of attendance labor required in an oil engine plant varies considerably, depending upon conditions. It remains a fact, however, that experience has shown that competent labor must be employed if maintenance costs are to remain at a normal figure.

An inspection of the labor costs for 22 Diesel engine plants, the majority of which were operated by utility companies, shows a variation from 0.93 mills per kw-hr. to 16 mills per kw-hr. These data are shown in Table VI. These plants range in size from 165 b.h.p. to 3450 b.h.p.

For the purposes of determining total power costs the estimates of attendance labor given in the 1927 report are conservative.

Plant Investment

Tables IV and V show investment costs of Diesel engine installations. Table IV includes only generating plants, while Table V includes only mechanical-drive installations. In determining the investment required for a Diesel engine plant, it is important to remember that this should include an adequate building with facilities for repairing the units and sufficient auxiliaries so that there is a minimum possibilty of service interruption. Many estimated investment costs neglect to include these important items.

TABLE V

INVESTMENT COSTS OF MECHANICAL-DRIVE DIESEL ENGINE INSTALLATIONS

Reference No. of Plant	Installations				Total Investment	Investment per Installed H. P.
	No. of Engine Units	Installed H. P.	Date Installed	Equivalent Kw.		
4	3	400	1924	270	$51,800.00	$129.50
9	1	750	1922	520	90,175.00	120.20
11	1	600	1923	400	70,790.00	118.00
12	1	600	1922	400	61,830.00	103.00
13	1	550	1922	365	60,110.00	109.30
Totals..	7	2,900	....	1,955		

TABLE VI

ATTENDANCE LABOR COSTS IN DIESEL ENGINE PLANTS

Reference	Size of Plant in B.h.p.	No. of Units	Annual Output in Kw-hr.	Attendance Labor	
				Total Annual Cost	Mills per Kw-hr.
J	980	3	1,514,862	$3,800.00	2.51
F-2	860	3	1,640,150	8,250.00	5.03
F-3	560	2	1,357,300	6,980.00	5.15
F-9	490	3	595,880	4,850.00	8.15
G-1	850	3	2,694,900	13,960.00	5.20
H-1	3,450	4	13,577,643	15,845.00	1.17
K-1	2,100	4	1,470,500	4,200.00	2.86
K-2	1,200	3	1,203,000	4,570.00	3.95
K-3	1,050	2	1,675,685	4,230.00	2.53
L-1	2,000	2	5,272,000	4,900.00	0.93
M-1	1,500	2	4,831,500	10,550.00	2.18
N-1	1,200	2	1,605,200	7,000.00	3.74
P-1	700	2	656,100	4,800.00	7.32
R-1	375	3	460,000	3,120.00	6.80
A-2	340	2	563,685	4,740.00	8.42
B-2	530	2	778,310	5,065.00	6.52
D-2	330	3	317,442	5,065.00	16.00
E-2	1,500	3	5,833,230	14,550.00	2.50
G-2	165	1	680,293	1,640.00	2.42
H-2	2,000	4	6,331,937	9,225.00	1.46
J-2	1,500	3	3,959,033	8,960.00	2.26
S	260	2	335,400	4,880.00	14.50

REFERENCE

J to R-1 inclusive, see Table I.

A-2 to J-2 inclusive, 1925 Report of Sub-Committee on Diesel Engines of Great Lakes Division, N. E. L. A., page 11.

S—Taken from operator's records.

In Table IV are the investment costs of eight plants, six of which have been constructed within the past three years. If the data of this table are combined with that of Table IV of the 1927 report, the following median values are obtained:

MEDIAN VALUE OF UNIT INVESTMENT

No. of Plant	Per B.h.p.	Per Kw.	Remarks
13	$145.00	$208.00	Building included
3	102.00	152.00	Building not included
6	121.00	194.00	Not known if building is included.

Plants H and K-7 of the 1927 report and O, P, R, T and V of this report have been constructed during the past three years and the costs include buildings. The median values for these seven plants are $150.00 per b.h.p. and $210.00 per kw. These data indicate very clearly that the investment estimates given in the 1927 report are low and in most cases should be increased.

Table V gives the investment costs of five mechanical drive installations installed approximately five years ago. The median value checks fairly well with the data obtained for the generating plants when the time of construction is considered.

An investment estimate made in April, 1928, by one of the engine manufacturers for a 1050 kw. plant shows a cost of $131.00 per kw. and does not include the following items: Building and crane, real estate, fuel tanks and piping, foundations, common labor for erecting, cooling tower, interest during construction, engineering and overhead, including accounting, insurance and stores expense. When these items are added to the above figure, it is evident that the total cost of the complete plant will be around $200.00 per kw.

On page 350 of "Diesel and Oil Engineering Handbook" by Julius Rosbloom, the investment cost of a 500 b.h.p. Diesel plant consisting of one unit is given as $65,000.00. This represents a unit investment cost $130.00 per b.h.p., or $195.00 per kw., if proper allowance is made for generator efficiency. This includes a building and installation cost, but evidently does not include the cost of a generator, switchboard and wiring.

The following table, which appeared on page 932 of *Power Plant Engineering* for Sept. 1, 1927, gives the investment charges on a 600 b.h.p. plant erected in 1926. The plant contained two solid injection engines of 240 and 360 b.h.p. direct-connected to alternating-current generators.

INVESTMENT CHARGES ON A 600 B.H.P. PLANT

	Cost	Cost per Kw.
Engine 240 h.p. and 200 kv-a. generator.	$15,510.00	$97.00
Engine 360 h.p. and 300 kv-a. generator.	21,795.13	90.70
Building, foundations, cooling tower and fuel oil tank piers	18,099.35	40.25
Pipe, pipe fittings	5,772.10	14.41
Electrical material	6,252.34	15.62
Miscellaneous material	296.88	.74
Auxiliaries (pumps, compressors, etc.)	2,934.86	7.42
Transportation (freight and express)	642.74	1.60
Stores and storekeeping	520.40	1.30
Labor	5,537.00	13.82
Insurance on labor	376.96	.94
Interest during construction	1,230.26	3.08
General engineering and accounting	3,128.66	7.82
Overhead	5,819.54	14.52
Real estate	2,000.00	5.00
Total cost	$89,916.33	$223.00

In determining the investment cost of a particular plant, care should be taken that sufficient capacity is installed to adequately handle the load. The committee has had a number of Diesel plant layouts brought to its attention, in which not only was there no spare capacity provided, but the total installed capacity of the engines was less than the maximum demand of the load. Good engineering and economic considerations should dictate the installation of a plant slightly larger than actually required rather than one slightly smaller.

On page 3 of the serial report of the Prime Movers Subcommittee on Oil and Gas Engines, published in March, 1927 (Publication No. 267-24) is given a valuable discussion of investment costs. This discussion also appears on page 894 of the N. E. L. A. Proceedings for 1927 and should be read by those who wish to obtain reliable engineering and construction cost data on Diesel engine plants.

1. Name of Installation..

2. Location..

3. Units Installed—

	Date Installed	Brake H.P.	Size of Generator in K. W.	Diesel or Semi-Diesel
1.—	....	....	....	....
2.—	....	....	....	....
3.—	....	....	....	....
4.—	....	....	....	....

4. Total cost of Power Plant..
(Does this include building? ....)

5. Operating Data—	Year 19.....	Year 19...	Year 19...	Year 19...
(a) Kw-hr. generated....................	....	....	....	....
(b) Maximum load in kw...............	....	....	....	....
(c) Gallons fuel oil........................	....	....	....	....
(d) Price per gallon of fuel oil...........	....	....	....	....
(e) B. T. U. of fuel.........................	....	....	....	....
(f) Gallons of lubricants................	....	....	....	....
(g) Price per gallon of lubricants.........	....	....	....	....
(h) Total repair costs..................	....	....	....	....
(i) Miscellaneous supplies, water, etc.....	....	....	....	....
(j) Attendance labor..................	....	....	....	....

NOTE: Items (d) and (g) should be stated in cents per gallon.
Items (h), (i), and (j) in dollars for entire year.

6. Number of hours operated monthly..

7. What fixed charges do you charge on plant?..
(Interest, depreciation, taxes and insurance)

8. Remarks:..

Name and address of person obtaining information

....

....

FIG. 1.—SHORT FORM OF QUESTIONNAIRE.

Sources of Data

The committee is indebted to those who have made possible the publication of the data contained in this report. Data have been received from privately owned utilities, municipally owned utilities, manufacturing plants and Diesel engine manufacturers. During the coming year it is hoped that the committee will receive the same cooperation from these various sources of data.

The questionnaires prepared in 1926 for use by the committee and published in the 1927 report were found to require considerable time and effort to complete. A shorter form has been devised and is printed in the Appendix as part of this report. This new form has been found very satisfactory and will be used by the committee whenever it is impracticable to use the longer form.

The committee urges all power sales engineers to report both operating data and investment costs for Diesel plants located in their territories. The form printed in this report as Fig. 1 may be used for this purpose, or additional copies may be obtained from the Chairman of the Power Committee.

Bibliography

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LIGHTING SERVICE MANUAL—PART III

TEST SPECIFICATIONS

Introductory

This work was undertaken because of the general feeling that tests on diffusing glassware as commonly presented, made on only one sample, were not as representative of the product as they might be. It was felt that without unreasonable increase in cost, the manufacturers could present tests which would be comparative and, therefore, of more value to the engineers in the field. The chairman of this subcommittee was appointed from the Lighting Service Committee to assemble a committee for the purpose of studying the situation and recommending a standard procedure for testing. The original committee consisted of Messrs. Little, Keller and Fisher. Others were added from time to time as the committee's work expanded.

It was the original intention that this committee should first prepare testing specifications for diffusing glassware and then should go into the field of floodlight projectors and asymmetric reflectors for show window and billboard lighting if it seemed desirable to do so. The committee would have been unable to complete more than the procedure for glassware had it not been for the official action of the Association of Railway Electrical Engineers, who turned over to the Illuminating Engineering Society the work they had already accomplished through a subcommittee of their Committee on Illumination. L. S. Billau, Baltimore & Ohio Railroad, chairman, in drafting a procedure for testing floodlight projectors, with the request that the Illuminating Engineering Society continue this work. The personnel of the A. R. E. E. Subcommittee, consisting of Messrs Burnap (chairman), Beggs (replacing K. S. Weaver), Benford, Harrison and Little, was at once made a part of this subcommittee, with the result that we are able to present in this report a procedure for the testing of floodlight projectors which is, in principle, the same as that adopted by the Association of Railway Electrical Engineers.

The subject of the testing of asymmetric reflectors was taken up so late in the year and proved to be so difficult of solution that the committee has decided not to include even a suggested procedure in this report. It is recognized that the application of this type of reflector has, by custom, become a "rule-of-thumb" matter. It is also foreseen that any test which will give a fairly complete picture of the light distribution from such a reflector will be relatively high in cost. That such reports are desirable seems to be generally admitted, but there is no general agreement as to how elaborate or expensive a test is justified.

Several applicable methods have been published, namely: "Isocandles and the Asymmetric Lighting Unit," by F. A. Benford, *General Electric Review,* April, 1925; the "Use of Rousseau Diagram," by K. S. Weaver, *Transactions, I. E. S.,* May, 1927, and the "Efficiency of Asymmetric Light Sources" (Fluxolite Paper), by A. A. Wohlauer, *Transactions, I. E. S.,* May, 1928. A fourth method which proposes to record readings on a cylindrical surface has been proposed by R. S. Burnap.

The committee recommends that the study of this subject be continued, and that if practicable a standard testing procedure be developed.

Specifications for Testing Diffusing Type Inclosing Glassware

A—General

1. The specifications shall apply to all luminaires whose design includes a globe of diffusing glass which, together with its fitter, incloses the light source entirely, or nearly so. The use to which the luminaire is to be put makes no difference. This classification includes such luminaires as the "Glassteel," and enameled semi-indirect inclosing globes as well as ordinary inclosing globes, but does not include prismatic inclosing globes.

2. Testing shall be done by an impartial laboratory and the selection of globes for test shall be made or supervised by an impartial observer, either a representative of the laboratory or one selected by the laboratory. The report shall state by whom the selection was made.

3. A report of test made according to these specifications shall be plainly marked, "Tested according to I. E. S. Standard Specifications" and the laboratory by its signature certifies to this as well as to the correctness of the data.

B—Selection

1. If possible, at least 25 samples of one size (preferably the 200 watt) shall be selected at random as passed by the factory inspector, and weighed. The report shall state what percentage of those available were examined and weighed. From this lot six shall be selected, one representing the maximum, one the minimum, and four as nearly as possible the mean weight, and, as far as visual inspection can go, a fair sample of the product.

2. In case of breakage prior to test of any globe a single replacement sample of approximately the same weight shall be acceptable.

C—Physical Measurements

1. For each of the six samples the report shall include the weight in ounces.

2. For the single globe used for candle power and brightness tests the report shall include:

a. The overall diameter, (f).
b. The overall depth, (e).
c. Maximum diameter of neck, (h), see Fig. 1.

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* Publication No. 289-5, Serial Report, Lighting Service Committee.

D—Output

1. The lumen output for each of the six samples shall be measured in a sphere, or by equivalent method, and all six values shall be given in the report.

E—Candle Power Distribution

1. The report shall show for the luminaire of *mean output* and for the bare lamp used in the test, by a polar curve, the candle-power values at 0 deg., 90 deg. and 180 deg. from the nadir and at intervals of 10 deg., beginning at 5 deg. and ending at 175 deg., with the luminaire rotating, at a distance of at least 10 ft. The candle-power values for all points shall also be shown in tabular form for the luminaire, but not necessarily for the bare lamp.

2. Zonal lumens shall be given for the lamp alone, and for the luminaire for every 10 deg. zone, beginning with the zone 0 deg.—10 deg. These values shall also be summarized for zones 0 deg.—60 deg., 0 deg.—90 deg., 90 deg.—180 deg. and 0 deg.—180 deg. For each of these four zones the lumen output of the luminaire shall be expressed as a percentage of the total lumens of the bare lamp. The 0 deg.—180 deg. value represents the efficiency of the luminaire.

3. The tabulated values and curves shall be on the basis of the *rated* lumens for the lamp used as given by the lamp manufacturer.

4. The test lamp shall be selected to be a well-constructed lamp of standard type, and the correct size shall be determined according to the following table, unless otherwise specified by the manufacturer, in which case it shall be reported as an exception:

Diameter of Globe	*Wattage Rating of Lamp*
Under 10½"	100 (inside frost)
Over 10½ to 12½"	150 (clear)
Over 12½ to 15½"	200 (clear)
Over 15½ to 17½"	300 (clear)
Over 17½ to 20"	500 (clear)
Over 20"	1000 (clear)

5. If the globe is publicly and regularly sold or recommended by the manufacturer to be used with a particular fitter or type of fitter, it shall be sc tested and the characteristics of the fitter noted, but if not so recommended, it shall be tested under the following conditions. The manufacturer shall submit to the laboratory his publicity material for verification.

a. The globe opening shall be covered by a material having a neutral tint, a matte surface and a reflection factor of 30 — 40 per cent. The report shall state the value of the reflection factor. No other reflection factor is acceptable, except as noted above.

b. The cap-contact position (i. e., the distance from the cap-contact of the lamp to the plane of the fitter screws, d, in the diagram) shall be 1½ in. for the 4 in. fitter, 2 in. for the 6 in. fitter and 3 in. for the 8 in. fitter, and for all mogul base lamps, unless some other position is specified by the manufacturer of the globe and stated in the report.

6. The report shall contain a prominent note to the effect that the test results are reproducible only if the conditions of test, especially the light-center position, are maintained in use.

F—Brightness

1. The test shall include and the report shall show brightness values expressed in candle-power-per-sqare-inch for the luminaire of ***mean output*** at the points described as follows and shown on the diagram by corresponding capital letters:

a. With the photometer pointed as nearly as possible tangent to the luminaire in the horizontal plane passing through the light source.

b. With the photometer pointed toward the light source in the same horizontal plane.

c. With the photometer pointed horizontally, as nearly as possible tangent to the bottom of the luminaire.

d. With the photometer pointed horizontally, in a vertical plane through the luminaire axis, toward the brightest part of the upper third of the luminaire.

e. With the photometer pointed at 45 deg. from the nadir in a vertical plane through the luminaire axis toward the brightest spot visible when the globe is viewed in a direction approximately 45 deg. from the nadir.

f. With the photometer pointed vertically, parallel to the luminaire axis, toward the circumference where the horizontal plane through the light source intersects the globe.

g. With the photometer pointed vertically along the luminaire axis, offset, if necessary, to avoid an opening in the globe.

h. With the photometer pointed vertically, parallel to the luminaire axis, halfway between positions G and F.

i. With the photometer pointed horizontally, in the vertical plane through the luminaire axis, toward the same point defined as E.

j. With the photometer pointed vertically, parallel to the luminaire axis, toward the same point defined as E.

2. For readings at points E, I and J the luminaire shall be stationary, but for all other points it shall be rotated. The photometer or diaphragm shall be so adjusted that the field of view includes as nearly as possible one square inch of projected area of the luminaire.

G—Other Data to Be Recorded

The report shall also include:

1. The trade name and maker of the globe or complete luminaire.

2. A description of the test lamp, including watts, volts, bulb, base, service, filament construction, and lumen output.

3. A cross section drawing of the globe or luminaire to scale showing dimensions and light-center position for test and points at which brightness readings are made.

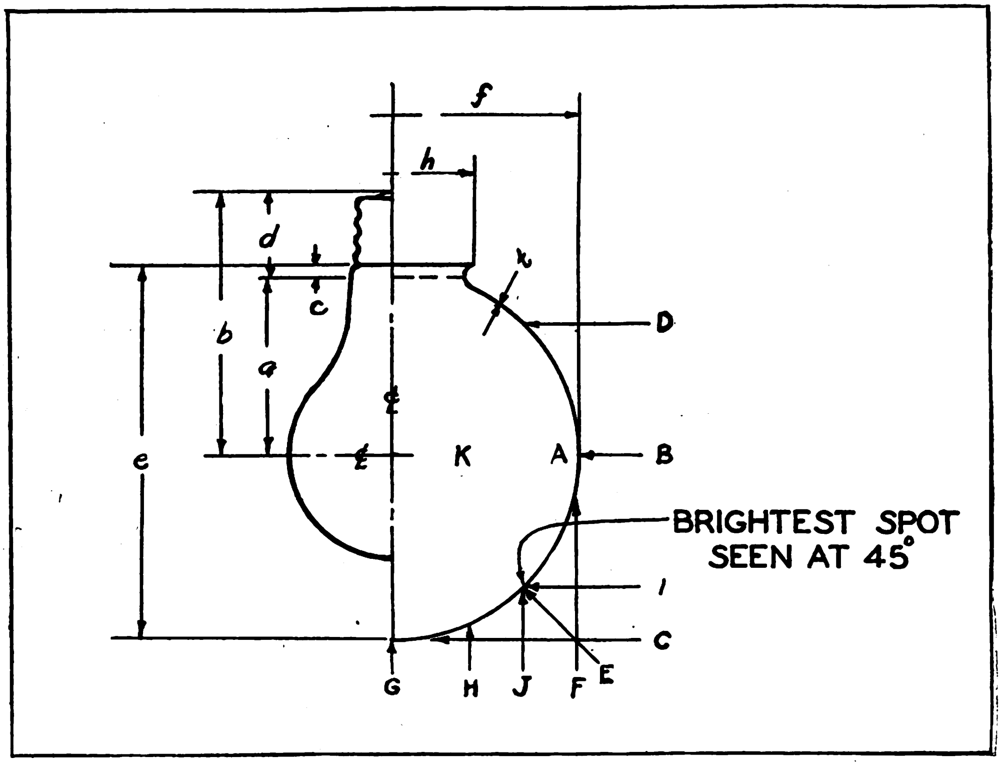


FIG. 1—SECTION DRAWING OF LUMINAIRE.

H—Remarks

1. The report shall include under the heading "Remarks" any notes not given elsewhere, which in the opinion of the testing laboratory would be pertinent in judging the globe, such as "filament visible," "spotted appearance," "exceptionally thin spots," etc.

Explanation of Specifications for Testing Diffusing Glassware and Remarks on Analysis of Tests

General

In selecting the proper inclosing globe for any lighting installation, much information can be obtained from photometric reports. A photometric report, however, means little unless it presents a clear and accurate statement of the conditions under which the test was made. Furthermore, this statement must be accurately interpreted.

To assist in the analysis of such photometric reports it has been felt necessary first to have tests made on the same basis and, second, to explain how the information contained in the report is to be interpreted.

In order to make sure that the test report can be considered on a par with others, it should first be ascertained if the report is distinctly marked, "Tested according to I. E. S. Standard Specifications." The testing laboratory which signs the report is then responsible for the conduct of the test according to these specifications. They draw no conclusions, but give information from which conclusions can be drawn. It has been thought best, upon careful consideration, to make the specifications fairly rigid and

LIGHTING GLASSWARE

Data Required

Test in compliance with I. E. S. specifications for testing commercial lighting glassware.

Selection

The selection of the six globes sent to the Laboratories was made by a Mr. ...., Engineer, representing the .... Company. The samples were selected at random from a group of twenty-five at the .... In compliance with the specifications twenty-five globes were weighed, from which six were selected representing the maximum, minimum and four of average weight. The selection was a fair sampling of the product from the standpoint of appearance. The sampling was 30 per cent of the globes available.

Globes. No. ...	Weight ounces	Light Output
1	48	87 per cent
2	56	86 per cent
3	56	85 per cent
4	56	86 per cent
5	56	85 per cent
6	64	84 per cent

Remarks

Exceptions—None.

FIG. 2—DATA SHEET FOR GLASSWARE.

[*To be shown on double sheet with Fig.* 3.]

REPORT No. ORDER No. PLATE No.

CANDLEPOWER DISTRIBUTION

Rendered to

No.Submitted - Six. Light output range 84-87, average 86 per cent.

	Watts	Volts	Bulb	Base
Lamp-	200	115	PS30,Clear	Medium

Service	Filament	Lumens
General	C-9	3240

Holder-None submitted. Surface covering globe opening, reflection factor 40 per cent.

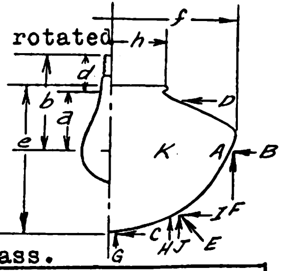
Procedure-Luminaire rotated

DIMENSIONS OF LUMINAIRE

a 3-1/2 in.
b 6
c
d 2-1/2
e 8
f 14
h 6

WEIGHT OF GLASS 56 oz.

White diffusing glass.



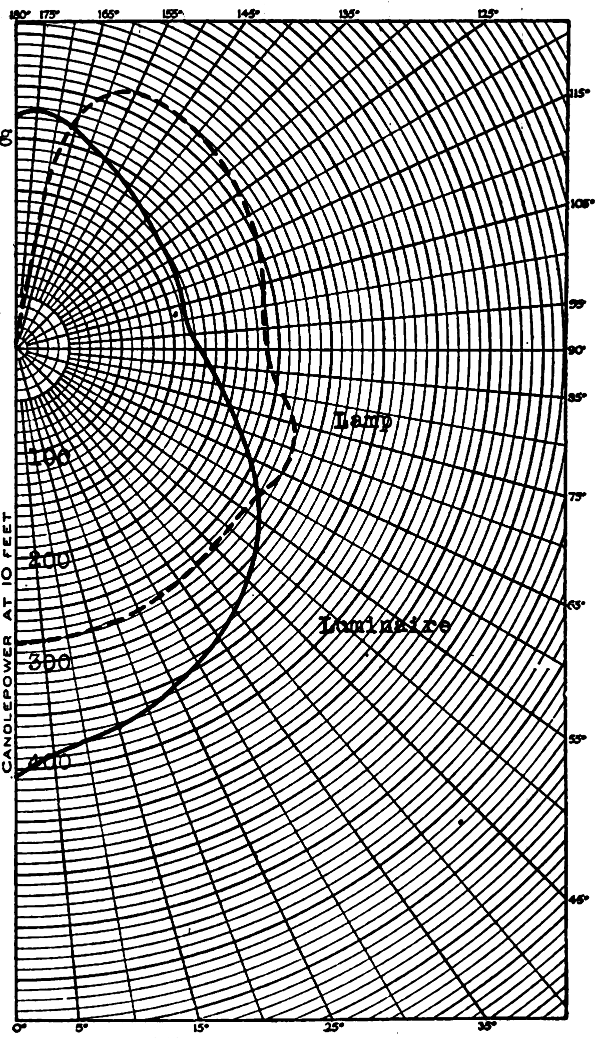
LUMINAIRE DISTRIBUTION DATA

Mean Vertical

MID-ZONE ANGLES	APPARENT CANDLEPOWER AT 10 FEET	ZONAL LUMENS	MID-ZONE ANGLES	APPARENT CANDLEPOWER AT 10 FEET	ZONAL LUMENS
180° ZEN.	220		90° HOR.	173	
175°	226	21	85°	185	202
165°	220	62	75°	208	220
155°	199	92	65°	245	244
145°	187	117	55°	279	250
135°	175	135	45°	312	241
125°	169	152	35°	339	213
115°	166	165	25°	356	165
105°	166	176	15°	374	106
95°	167	182	5°	387	37
			0° NADIR	407	

LIGHT FLUX VALUES

ZONE	LUMENS		PERCENT TOTAL LUMENS BARE LAMP	PERCENT LIGHT OUTPUT
	LAMP	LUMINAIRE		
0°-60°	846	1012	31	86
0°-90°	1675	1678	52	
90°-180°	1563	1102	34	
0°-180°	3238	2780	86	



LUMINAIRE BRIGHTNESS

MILLILAMBERTS AND CANDLEPOWER PER SQUARE INCH
THE ARROWS INDICATE THE LOCATION AND ANGLE OF VIEW

LOCATIONS	A	B	C	D	E	F	G	H	I	J	K
ML.	900	1020	1020	920	1420	570	1420	1180	1100	1180	940
CP. PER SQ. IN.	1.85	2.1	2.1	1.9	2.9	1.2	2.9	2.4	2.3	2.4	1.9

TESTED BY PLOTTED BY COMPUTED BY CHECKED BY ISSUED July 3, 1928.

APPROVED BY

FIG. 3—SAMPLE REPORT FOR GLASSWARE.
[*To be shown on double sheet with Fig. 2.*]

to allow no variation, except in the size and type of lamp to be used, and in the light-center position.

Every effort has been made to draft specifications which will be fair to both manufacturer and consumer.

Choice of Units for Testing

In the manufacture of single layer (homogeneous glass) or multi-layer (cased glass) inclosing globes, the pieces produced will vary to some extent in weight as well as in light output. This results from the fact that the manufacture of inclosing globes is still largely a manual process. We cite a case where ten 14-in. globes of one manufacture were purchased on the open market. These inclosing globes varied in weight over a 10-oz. range, while the total light output varied 8 to 12 per cent. Special globes can be made thin enough to have a high efficiency, and even in a heavy globe of homogeneous glass the weight might be so distributed that it would show a high efficiency when tested. The average globe, considered from the standpoint of performance, cannot be selected correctly by choosing a globe of the average weight of those produced.

Due to the physical characteristics of multi-layer glassware there is even stronger reason why weight cannot be the criterion for selection. A cased glass globe is formed by blowing together two or more gatherings of glass, one of clear and another of an opalescent or diffusing glass. The clear layer serves as a mechanical backing for the thin opal layer and is, therefore, necessarily thicker. The opal layer serves as a light diffusing medium and, for the sake of efficiency, is blown as thin as practicable. Two cased globes may be of the same weight and still may differ widely in output. This is due to the fact that the output of each largely depends upon the thickness of the opal layer, which, in one case, may be as much as twice as great as the other without the individual globes differing in total weights.

In view of these facts, it can be seen that merely to select a globe of average weight would not give us a fair sample, but weight does play some part. The method of selection given in the specifications is to have an impartial observer select twenty-five globes at random as they are passed by the factory inspector. These globes are then weighed and six are selected, including the heaviest, the lightest, and four, as nearly as possible, the average weight of twenty-five. If it is impossible to inspect as many as twenty-five globes, due to the fact that the run is smaller, then the inspector is authorized to select the samples from a smaller number, but in the report he is to state how many globes were inspected and what percentage of the total run was weighed. The information as to light output and brightness is obtained by the laboratory not from the globe of mean *weight* but from that of mean *output*. After all six samples have been tested, either in a sphere or by some equivalent method, the report, based on this method of selection, is generally agreed to be a fair indication as to the qualities of the product.

It has also been generally agreed that if the test is made on the 14-in. diameter globe, generally used with a 200 watt lamp, the results will fairly represent all sizes of that particular line. Globes of this size generally have an opening to fit a 6-in. fitter.

The report will show both the total light output and the weight of each of the six samples which, due to the method of selection, should give a fair picture of the variation of these two elements in the product as commercially marketed.

Candle Power Distribution and Lumen Output

In the manufacture of diffusing globes it is impossible to avoid some differences in the distribution of the glass which will cause a corresponding change in the candle-power distribution of the luminaire. It would, therefore, be ideal to take complete candle-power measurements on all six of the selected samples. We could then determine the average distribution by plotting in the report a curve representing the mean of the six individual curves. This would increase the cost of the test unreasonably and, for practical purposes, the result would be very little, if any, better than the curve which will be obtained from the globe giving the nearest to the average total output. These output measurements are made in a sphere or by some other integrating method which can be done more quickly and at much less cost.

In analyzing the distribution it should be borne in mind that the lumen output in the 0 deg.—60 deg. zone is most effective in putting light on the working plane, except in the case where the principal plane to be illuminated is vertical, in which case the most effective lumens are those in the zone 60 deg.—90 deg. The principal glare zone lies probably between 60 deg. and 85 deg., which is not shown specifically in the report. However, the lumens in this or any other zone can be obtained by adding those which occur in the 10 deg. zones included in the larger zone. The light emitted in the 90 deg.—180 deg. zone, of course, goes to the ceiling and upper part of the side walls from which a portion is reflected back to the working plane. The effectiveness of this portion naturally depends upon the reflection factor of the ceiling. Therefore, in comparing globes it is obviously not sufficient to compare the total output efficiency as given for the 0 deg.—180 deg. zone in per cent of the lumens of the bare lamp, but the distribution of the lumens must be analyzed with respect to the conditions under which the globe will be used.

In obtaining distribution curves it is customary to operate the test lamp at lower than its rated voltage in order to secure better control. However, the results are tabulated and plotted at the rated lumen output for the type of lamp used, either by calibrating the photometer to give these values or by correcting the results by well-established constants. A test made under these specifications will give a fair indication of the variation in total light output or efficiency for the type and make of the luminaire tested. The examination of a good many tests indicates that in general the variation will not be more than 5 per cent above or 7 per cent below the value shown in the test report.

Selection of the Test Lamp

The lamp should be a clear (inside frost for the 100 watt size) lamp selected to be as nearly as possible a perfect type of current manufacture, both in respect to mechanical construction and light output. It should be properly aged and calibrated by the laboratory. The size of lamp specified for each size of globe corresponds to good practice. It is not the intent of the committee to limit the size of lamp to be used with a given globe, but merely to standardize testing procedure. The ranges of globe sizes have been given so that as far as possible no globe will fall on the dividing line, but, even in that case, the wording of the table should be clear. If occasionally some manufacturer may feel it necessary to have his globe tested with a different size or different kind of lamp he may do so under these specifications by stating that fact plainly as an exception, so that there will be no likelihood of a comparison being made between such a test and a test made with the standard size and type of lamp.

Lamp Position and Cover for Globe Opening

Diffusing globes are submitted for test in two general classifications: Those sold by glass manufacturers on the open market for use with any type of fitter and those sold with a particular fitter. The glass manufacturer naturally wants his product to show up as well as possible and, therefore, it has been his general practice to have his globes tested with the openings covered by white blotting paper and with the light source at the position which will give the most nearly uniformly illuminated appearance to the globe. There has been no assurance that these conditions can be duplicated in practice. Some holders are finished on the inside with a reflecting material, but many are left in their natural state. Examination of quite a number shows that the average reflection factor lies between 30 and 40 per cent. The variation in output efficiency is only in the order of 6 per cent for a 6-in. fitter opening when the cover for the opening is varied from black velvet to white blotting paper. Therefore, it is felt to be a fair representation of practical conditions to cover the globe opening with a material having a matte surface, a neutral color and a reflection factor somewhere between 30 and 40 per cent.

There is no standardization among fixture manufacturers as to socket positions in their fitters. Variations have been found which change the cap-contact position of the lamp over a range of approximately two inches. The average of several fitters showed a cap-contact position of 2.08 in. (d in diagram). Therefore, two inches has been specified as the testing position for globes with 6-in. fitter openings, in the absence of definite recommendations from the manufacturer. For similar reasons the positions have been specified for other fitter sizes. It must be understood that with the present variation in fitter dimensions the actual cap-contact position of the lamp in the installation may vary an inch up or down from the specified test position unless care is used in selecting a fitter which will give this position.

It is recognized, however, that a globe of given shape will have its performance materially altered by moving the light center through this range. One test showed that a movement of one inch in the light-center position changed the total output 3 per cent. Other tests have shown changes from 2 to 10 per cent. The glass manufacturer should know and specify the light-center position, both for test and actual use, which will produce the best results with the particular globe shape in question. It is also to his interest to see that there are fitters on the market which will give this position. On the other hand, the engineer in the field in recommending an installation should make sure that the fitter he selects for use with a particular globe shape will give the light-center or cap-contact position recommended by the globe manufacturer. The glass manufacturer can certainly be depended upon to specify a light-center position which can be obtained in practice, as otherwise the report would be more or less worthless. Therefore, if the manufacturer finds no stock fitter on the market which will give the theoretically best position for the globe shape in question, he has four courses open to him, namely: (1) To have a special fitter made, or (2) to specify for test the best position given by a commercial fitter, or (3) to have the test made with the position specified as standard, which represents no particular fitter, but the average of those examined, or (4) to arbitrarily specify the theoretically best position and trust to public demand to have a fitter manufactured. It is to be hoped that all the glass manufacturers will adhere to either the first or the second course.

Perhaps the glass manufacturers and fixture manufacturers will find some working agreement leading toward standardization to the end that the best interests of both may be served.

If the globe and fitter are specially designed to fit only each other and are, therefore, sold as a complete unit, it is necessary that they be so tested in order to present a fair report of the performance. If a globe which obviously falls in this class is submitted without a fitter, it cannot be tested according to these specifications.

Brightness

Brightness readings are recognized to be quite important in the determination of relative glare. In designing a lighting installation, the engineer consciously or unconsciously determines what degree of glare can be permitted. It is impossible to say definitely whether or not certain brightnesses or certain magnitudes of candle-power in the direction of the eye will be glaring unless all of the conditions of use are known. Values of these factors which may not be glaring where there is only one unit in the room, mounted fairly high and located almost overhead, may be distinctly uncomfortable in a large room with a great many units exposed to view or where the ceiling is low or dark in color. Authorities differ as to the maximum brightness which is allowable and no very definite statements can be obtained, but it is obvious that a reduction of the candle-power in the direction of the eye or of the maximum brightness, or both, will tend to reduce glare and make the luminaire more comfortable to look at.

It is claimed by some engineers that for comfortable work in an office where artificial light is used all day long, and several units are in the field of view, the maximum brightness of the luminaire in the direction of the eye should not exceed two candle-power per square inch. In stores where the mounting height is greater and the application of the eye is not so constant or intensive, brightnesses as high as four or five candles-per-square-inch do not seem annoying under most conditions. It is to be hoped that in the future more quantitative work will be done on this subject so that more definite specifications can be given.

In the test report the brightness reading at the point "E" is intended to show the maximum brightness which would normally be encountered by the eye. However, in a large office with a ten or twelve foot ceiling the luminaires which cause the most annoyance will be seen at angles between 10 and 20 deg. below the horizontal. In other words, the candle-power in the direction of the eye which causes the most annoyance in this case will be that between 70 and 80 deg. from the nadir, as shown on the candle-power curve. Also the maximum brightness from this viewing position will be very close to that shown for the readings made in a horizontal direction on the lower portion of the globe.

The purpose of taking brightness readings on different portions of the globe and in different directions is to show the distribution of brightness and to determine to some extent the diffusing qualities of the globe. It will be noted that brightness readings at points "A" and "B," "C" and "G," and "F" and "B" are at right angles to each other. In each case one is normal to the luminaire looking toward the light source and the other is measured at nearly grazing incidence. Examination of a good many reports indicates that the ratio of brightness at grazing incidence to that at normal incidence shall be in the order of 0.65 or greater. It is obvious, also, that the brightness at points "K" and "B," "I" and "E," and "J" and "E" are read in directions which make an angle of 45 deg. with each other. Examination of a number of tests indicates that the ratio of brightness at 45 deg. to that at normal incidence at any point should be in the order of 0.8 or greater.

All the brightness readings, except "E," "I" and "J," are made with the globe rotating so as to give the average brightness around the globe. The readings at "E," "I" and "J" are made with the globe stationary, as it is specified that they are to be read on the brightest visible spot when the globe is viewed at approximately 45 deg. from the vertical.

Remarks

There are certain characteristics of globes which cannot be determined by brightness and candle-power readings and yet which are important in forming an opinion as to the fitness of a globe for any particular application. These points should be stated by the laboratory under the heading "Remarks." They should particularly call attention to a visible filament, a spotted appearance, or to excessively thin spots.

Specifications for Acceptance of Diffusing Glassware

One of the main purposes of these standard testing specifications is to provide a test so made that any purchaser may accept it as truly representing the product. It should, to a large extent, obviate the necessity of special tests and, therefore, should, in the long run be cheaper to the manufacturer. To cover this point it is suggested that the following paragraph might be included in specifications for the lighting equipment of buildings, when diffusing glassware is to be used.

> The contractor shall submit with his bid a properly certified test, made on the basis of the I. E. S. Standard Specifications, of the glassware which he proposes to use, with the understanding that the luminaires as delivered will comply with the physical and photometric characteristics as disclosed by the test report submitted.

As a further specification the standard fitter dimensions as adopted by the Illuminating Glassware Guild and the National Council of Lighting Fixture Manufacturers may be used, as given in the following tabulation:

Maximum diameter of neck (h in Fig. 1) in inches:

Nominal	*Basic*	*Minimum*	*Maximum*
4	3-31/32	3-13/16	4
6	5-31/32	5-13/16	6
8	7-31/32	7-13/16	8

Distance along axis from top to minimum diameter of neck in inches (c in Fig. 1):

Nominal fitter diameter in inches	*"c" in inches*
4	3/8 plus or minus 1/16
6	7/16 plus or minus 1/8
8	7/16 plus or minus 1/8

Incandescent Floodlight Testing Procedure

Introduction

The photometry of floodlights is inherently a difficult operation. Various laboratories and individuals each use different methods, dictated often by differences reflecting the viewpoint of the responsible individual. But even where the methods of test are in good agreement, there are liable to be wide variations in the interpretations of the results of the tests.

The following procedure specifies definite methods for testing floodlights and establishes a uniform procedure for the calculating and reporting of results. Since the methods given are designed to cover the entire field of floodlight testing, the instructions are complete and satisfactory for projectors giving unsymmetrical light distribution. In the case of a floodlight projector having a symmetrical beam, it is possible to simplify the method and the calculations as noted in the instructions. The nature of the test made according to the following method is strictly a laboratory operation. While variations from the outlined method are possible for quick intercomparative tests, these instructions are not concerned at the present time with these methods.

The instructions are divided as follows:

(1) Description of the floodlight.
(2) Description of the lamp.

(3) Procedure for making observations.
(4) Computation of results.
(5) Essential results to be reported.
(6) Necessary constants for computation.
(7) Sample report sheets.

(1) Description of the Floodlight

The floodlight chosen for test should be representative of manufacturer's regular product of the equipment desired to be tested.

Report data should give complete description of floodlight, including:

Manufacturer's Name
Type and Catalog Number
Reflector
    Description—shape.
    Material—Manufacturer's designation.
    Dimensions—Sketch of reflector section.
        Diameter and overall depth.
        Lamp and filament position.
    Cover Glass—Manufacturer's designation.
        Description—shape.
        Optical character of surface.
    Accessory Light Control Apparatus
    Focusing Mechanism
    Sketch of Complete Projector, sufficient for identification including reflector dimensions.

It is desirable to standardize the letters used for dimension identification of the reflector sketch, although this procedure has not been followed in the sample report submitted. It is recommended that letters be standardized as follows:

A—Light Center Length (the light center length of a lamp with a threaded base is the distance from the base contact to the center of the filament measured on the axis of the lamp).
B—Axial Length of Light Source (filament).
C—Width of Light Source (filament) measured across the axis, parallel to the plane of the lead wires.
D—Working Length (the working length is defined for convenience in measurement as the distance along the reflector axis from the center of the light source to the inside surface of the reflector or to plane of inside edge of rear opening).
E—Reflector Diameter.

(2) Description of the Lamp

Lamps chosen for test in equipment should be very carefully selected and of current design. The size of light source should be within 10 per cent of the manufacturer's design dimensions. Lamps should be aged sufficiently to stabilize candle-power before using as test lamps. A satisfactory aging process is to burn lamps for one hour at normal volts.

Report data should give the following lamp information:

Nominal Rating
    Service (Floodlight, spotlight, projection, general lighting service, etc.)
    Volts
    Watts
    Rated Initial Lumens
    Bulb Designation (PS-52, G-40, etc.)
    Base (mogul screw, medium screw, etc.)
    Light center length (distance from cap of base to center of light source)
    Filament Designation (C-5, C-13, C-7A, etc.)
    Light Source Dimensions (width and axial length in millimeters).

(3) Procedure for Making Observations

a. Calibration of Standard Lamp and Photometer

An acceptable lamp of the desired size and service should be aged and calibrated for current at rated lumen output, and also calibrated for intensity in a horizontal direction, as indicated by permanent markings (fiducial lines) placed on the bulb.

The calibration data of the lamp then consist of three items:

Rated light output in lumens,
Fiducial intensity in candle-power,
Input in amperes and volts.

It will be noted that having the fiducial intensity in candle-power and the rated output in lumens, the numerical ratio between the total bare lamp output in lumens and the intensity in the marked direction can be calculated. The fact that this numerical ratio is independent of the current or voltage at which the lamp is held is the basis of the following method for obtaining the projector illumination values. Of course, the lamp can be used as an absolute standard of intensity, but for the purpose of these tests it is better to use it as a combined standard and test lamp. The lamp is held at some definite current value instead of voltage value throughout the test, which further eliminates possible errors due to socket drop or faulty electrical connections.

The standard lamp is first used to calibrate the photometer with which the floodlight is to be tested. Since the intensity of the standard lamp in the marked direction is a fixed numerical ratio to the total output of the lamp in lumens, regardless of the current at which the lamp is held, it is possible to calibrate the photometer by light received from the bare lamp in the marked direction, as though the lamp was operated to give rated intensity. Since the lamp is held at the same current throughout the standardization and the test, projector illumination values will be determined which will be the same, as if the lamp was held at rated lumen output throughout test.

For this purpose any ammeter of good constancy and giving a large scale deflection for the current to be measured is satisfactory. The exact meter calibration need not be known. In general, it is best to hold the current about 5 per cent less than the calibration current in order to insure minimum change of light output from the lamp during the test. However, the selected current must be carefully maintained throughout the test. By calibrating the photometer directly against the test lamp, regardless of the exact candle-power at which the lamp is held, projector illumination values are obtained in terms of the standardization values of the lamp.

The standard lamp is placed at a measured distance D (in feet) from the photometer head, so that the illumination received by the photometer plate is that established by the fiducial lines on the bulb. The assumed illumination is then

$$E = \frac{I}{D^2} \text{ Foot-candles}$$

where I is the standardized fiducial intensity in candles. This value of E is used to find the scale constant of the photometer. When the scale reading is S, then

$$\text{Constant } C \times S = E \text{ foot-candles}$$

The standard lamp is then adjusted in the floodlight as previously described, connected with the same ammeter as used for the previous calibration and the test carried on at the selected current.

While the light output and beam intensities under these conditions will be, in general, less than the actual output in intensities of the lamp at normal rating, this method of calibrating the photometer exactly compensates for this difference, so that the photometer readings times Constant C are correct.

b. Adjustment of Lamp in Floodlight

In general, the focusing of the lamp in the projector is to be done at a distance of 100 feet or more from the observing screen, and should be done at the same distance at which the photometer readings are made. In order to have definite location of the light source (filament), lamps for base-up or base-down burning should be set in the floodlight with the lead wires away from the principal optical element. For lamps which burn in horizontal position, the lead wires should be placed uppermost.

The lamp should be adjusted in the floodlight to give the narrowest uniform and symmetrical beam. The determination of reference lines for the beam can be made visually when feasible. In many cases it will be necessary to determine the reference lines by establishing the vertical and horizontal limits of the beam. The intersecting lines halfway between these limits will constitute the reference lines.

c. Method of Testing

As a general rule, a floodlight beam is inclined to be uneven in intensity. Traces of filament images are nearly always visible, and unless care is taken in the photometric exploration, will cause the results to be either too high or too low, depending upon the extent to which the images fall upon the photometer test plate. If the floodlight beam is not symmetrical in outline, a general and complete exploration of the entire beam section may be necessary to determine its true formation.

The arrangement of test points that can most conveniently be made is a rectangular spacing of stations, so that they will in general resemble a checkerboard in spacing, but the edges of the explored field will have the general outline of the beam section, that is, circular or oblong.

The real axis of the beam, if the beam has sufficient symmetry to have an axis, can be located only after the test has been completed and the data plotted. It is, therefore, necessary to estimate the position of the axis by visual observations on the edges of the beam or by other means. This arbitrarily selected axis is used throughout the test.

As previously stated, floodlight beams usually show visible traces of filament images. If the photometric observation is made to cover too small an area, these filament images may cause erratic results which are difficult to reconcile with the rest of the data. For this reason an integrating device should be used which will integrate the ilumination over one square degree (20.94 in. x 20.94 in. for 100 ft. testing range).

This method of measuring candle-power values averages out minor variations in the one degree beam, and makes possible the obtaining of less erratic and, therefore, more readily duplicatable data.

The collecting device is set up 100 ft. or more from the floodlight. The method of taking observations is to traverse the beam with such spacings as to give approximately 100 reading stations uniformly spaced throughout the beam, and in addition, to obtain the candle-power values along eight equally spaced radial lines carried out to the extreme angular range of the stray light. The test, therefore, involves a series of stations spaced in a rectangular manner over the area of the beam, plus stations spaced on eight equally spaced radial lines.

[NOTE:—An exception to the above occurs when the beam is known to be symmetrical about a central axis, in which case four radial lines of exploration from the axis to the limit of stray light will suffice, or the alternative method of an integrating photometer which measures the light in concentric circular zones may be used. Reading stations in the beam are to be spaced approximately one-tenth of the beam spread.]

This method of taking readings insures complete information as to the beam characteristics, and also gives sufficient data to discuss the distribution of stray light from the floodlight. This method of testing requires that a suitable holder be used for the floodlight, so that the floodlight can be rotated to definite degrees in both the horizontal and vertical directions. A conveniently simple method is to mount the floodlight on a hinged platform which can be raised or lowered, or to use the floodlight trunnions, and set at predetermined degree positions. This platform is then mounted on a turntable with its center directly under the test unit. The turntable is provided with a scale and pointer, so that horizontal angles can be obtained.

A necessary practice before setting up the reflector and starting measurements is to make sure that all glass parts are thoroughly clean.

Since the illumination to be measured by the photometer is in many cases quite small, adequate precautions must be taken to eliminate errors due to stray light. It is desirable that the walls and ceiling and floor of the test room be black, and that screens be provided to cut off the light reflected from any of the building surfaces. At large angles of incidence of the light from the unit to the walls or floor of the room, even very dull surfaces have a comparatively high specular reflection.

As a suggested method, the exploration of the horizontal and vertical axis to the limits of the stray light should be made first, followed by horizontal traverses at the various vertical angles to include the limits of the beam, and then followed by the remaining radial angular traverses of the total lighted area. This method of exploration permits of checking back frequently at the zero setting of both the floodlight degree scales, which will eliminate the possibility of error due to changing candlepower of the lamp throughout the test.

The horizontal and vertical traverses can be made directly from the degree settings on the vertical and horizontal scales of the floodlight holder. In the case of the angular traverses, which will be in between the vertical and horizontal traverses, a table is given in the appendix for the correct degree settings, to take care of the fact that the settings for these angles cannot be read directly on the scales.

Since this method is laid out to cover floodlights of from narrow to wide beam divergences, it is important to determine before starting the test the degree spacing at which readings are to be made. Approximate degree limits for the beam should be determined. This can usually be done by visual inspection. The spacing for the stations is taken so that approximately 100 readings can be made throughout the beam. To simplify the calculation, spherical constants are given for equal spacing, vertical and horizontal, by spaces of 1, 1½, 2, 3, and 5 deg. By a proper selection of these steps any size of beam can be explored by about 100 equally spaced steps. Since the stray light outside the border of the beam does not vary, as a rule, very sharply, the readings along the axial traverses are to be made for all types of floodlights at 5 degree spacings.

(4) Computation of Results

The spherical area of the observing section of the photometer, which is one square degree, is 0.000305 when the radius of the spherical shell comprising the field of exploration is unity. The product of this factor times the square of the distance from the collecting device to the floodlight, times the foot-candle value is the average lumens in the one square degree area of the collecting device. The method of rotating the floodlight around a vertical axis, making equal angular steps in the principal horizontal plane, makes the actual spacing for the elevated or depressed beam somewhat less than the set values. Thus with the beam elevated 30 deg. and rotated 10 deg. in the horizontal plane, the actual vertical distance traversed by a point is somewhat less than 30 deg., but this may be corrected by using a proportionately reduced area for the computation of lumens at the 10-deg. angle. The reason for this can be appreciated when it is realized that the elevated and depressed great circles through the horizontal axis vary in spacing and converge toward the 90 deg. points of the horizontal scale setting. The tables given in the appendix of constants for the conversion of candles into lumens for 1, 1½, 2, 3 and 5 deg. spacings automatically take care of this correction.

For wide angle beams the spacings in degrees can usually be greater than one degree. Since this means measuring a one square degree area at intervals beyond the spacing of the square degree of the photometer, a factor must be used to correct for the fact that this reading represents a larger area than one square degree. If, for example, it is necessary to have the stations 2 deg. apart, the constants may be multiplied by 4, that is 2 times 2, or the curves may be plotted and the intermediate points for one degree spacings obtained from the curves. The first method is the preferable one.

The method of computing the results involves, first plotting the change of candle-power across each of the horizontal traverses in the beam and working out from these data the isocandle and the beam limit curves of the beam. The limits of the beam are to be taken as 10 per cent of the average of the ten highest candle-power values recorded in the prescribed exploration of the beam.

[NOTE:—Where a beam is of such symmetry as to permit of readings on only the two major axes, the limits of the beam shall be determined by 10 per cent of the highest reading.]

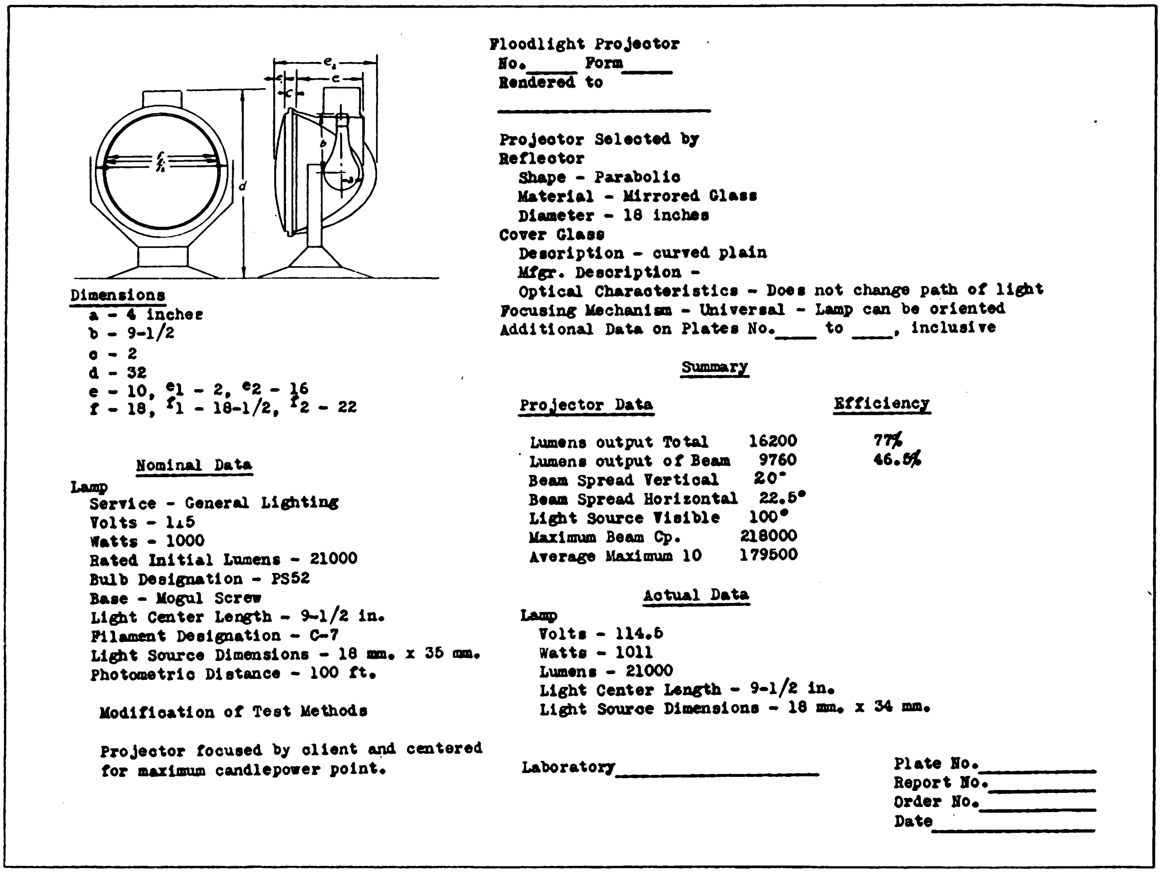
The computation of the lumens in the beam is made by summing the lumens of each individual test area, making suitable allowances in area and candle power value where a test area lies partially within the beam and partially in the stray light area.

An approximate computation of the stray light is comparatively simple when the beam is circular, but is a more difficult operation when the beam is of a spread or elliptical shape.

The computation of the stray light from a circular beam involves only the averaging of the photometer readings on the same degree setting for each of the angular traverses, and multiplying by a constant representing that particular zone area times the distance in feet squared. Of course, the zone areas involved will not include areas within the beam proper.

In the case of the elliptical beam, since the beam extends into the concentric zone areas, deduction must be made for the light already accounted for in the beam itself. A method sufficiently accurate for even extreme cases is to compute the average lumens in the annular zone area by averaging the photometer readings for the same degree settings of all of the radial traverses except those which are in the beam itself. The stray light based on the averages of the readings of the traverses outside of the beam is considered to extend at the same average value for the zone through the beam. An estimate is then made of the amount of stray light in the concentric zone, which is represented in the beam. This may be done by determining the ratio of beam area in the zone to the entire concentric zone, in terms of the average angle intercepted by the beam section of the zone.

A method adapted for ordinary beams of elliptical shape is to average the photometer readings for the same degree setting of the angular traverses as though the values within the beam were zeros. While


e₁
c
e
c
f₂
f₁
d
b
a

Dimensions
a - 4 inches
b - 9-1/2
c - 2
d - 32
e - 10, e_1 - 2, e_2 - 16
f - 18, f_1 - 18-1/2, f_2 - 22

Nominal Data

Lamp
Service - General Lighting
Volts - 115
Watts - 1000
Rated Initial Lumens - 21000
Bulb Designation - PS52
Base - Mogul Screw
Light Center Length - 9-1/2 in.
Filament Designation - C-7
Light Source Dimensions - 18 mm. x 35 mm.
Photometric Distance - 100 ft.

Modification of Test Methods

Projector focused by client and centered for maximum candlepower point.

Floodlight Projector
No._____ Form_____
Rendered to
____

Projector Selected by
Reflector
Shape - Parabolic
Material - Mirrored Glass
Diameter - 18 inches
Cover Glass
Description - curved plain
Mfgr. Description -
Optical Characteristics - Does not change path of light
Focusing Mechanism - Universal - Lamp can be oriented
Additional Data on Plates No.____ to ____, inclusive

Summary

Projector Data		Efficiency
Lumens output Total	16200	77%
Lumens output of Beam	9760	46.5%
Beam Spread Vertical	20°	
Beam Spread Horizontal	22.5°	
Light Source Visible	100°	
Maximum Beam Cp.	218000	
Average Maximum 10	179500	

Actual Data

Lamp
Volts - 114.5
Watts - 1011
Lumens - 21000
Light Center Length - 9-1/2 in.
Light Source Dimensions - 18 mm. x 34 mm.

Laboratory____________________

Plate No.__________
Report No.__________
Order No.__________
Date__________

FIG. 4—DATA SHEET FOR FLOODLIGHT.

this method makes correction values which are too small at the center of the beam and too large at the extremities, it will usually average out to give an approximately correct result.

The lumens obtained by either of the above methods for the concentric zones in the stray light area are added together and represent the stray light.

It must be remembered that the obtaining of exact values for quantity of stray light is a very difficult operation, due to the fact that the level of illumination is very low and that a considerable amount of light may be found in a comparatively narrow concentric band. To obtain this value with the same degree of accuracy as the beam lumens would necessitate in some cases a prohibitive number of readings over the entire lighted area. A table of constants for computing zonal lumens is given in the appendix for concentric zone areas of 5-deg. and 10-deg. widths.

The beam efficiency of the floodlight is computed using the ratio of beam lumens to the lumen output of the lamp. The overall efficiency of the floodlight is computed using the ratio of the total lumen output of the floodlight to the lumen output of the lamp.

(5) Results to Be Reported

The report of a test made according to this procedure should be marked, "Tested according to I. E. S. Standard Procedure."

Fig. 5-A, 5-B, 5-C and 5-D show the method of reporting results. It will be noted that the following results are shown:

(1) Complete description of floodlight.
(2) Complete description of lamp.
  (a) If other methods than those outlined in these instructions are used for standardizing lamp and photometer, reporting candle-power and lumen results for the floodlight should be based on rated lamp lumen output.
  (b) Lamp volts and watts should be reported for rated lumen output.
(3) The maximum beam candle-power as recorded in the prescribed beam exploration.
(4) The beam spread in degrees in both vertical and horizontal directions.
(5) Curves showing the horizontal and vertical candle-power distribution along the reference lines averaged about the axial line.
(6) The outline of the beam.
(7) Tabulation of candle-power for test stations.
(8) The beam efficiency of the floodlight.
(9) The overall efficiency.
(10) Distance at which photometer readings were made.
(11) Angle of cut-off of floodlight in horizontal or vertical plane or both, depending on the service for which the floodlight is designed.
(12) Note of any modification of the preceding instructions.

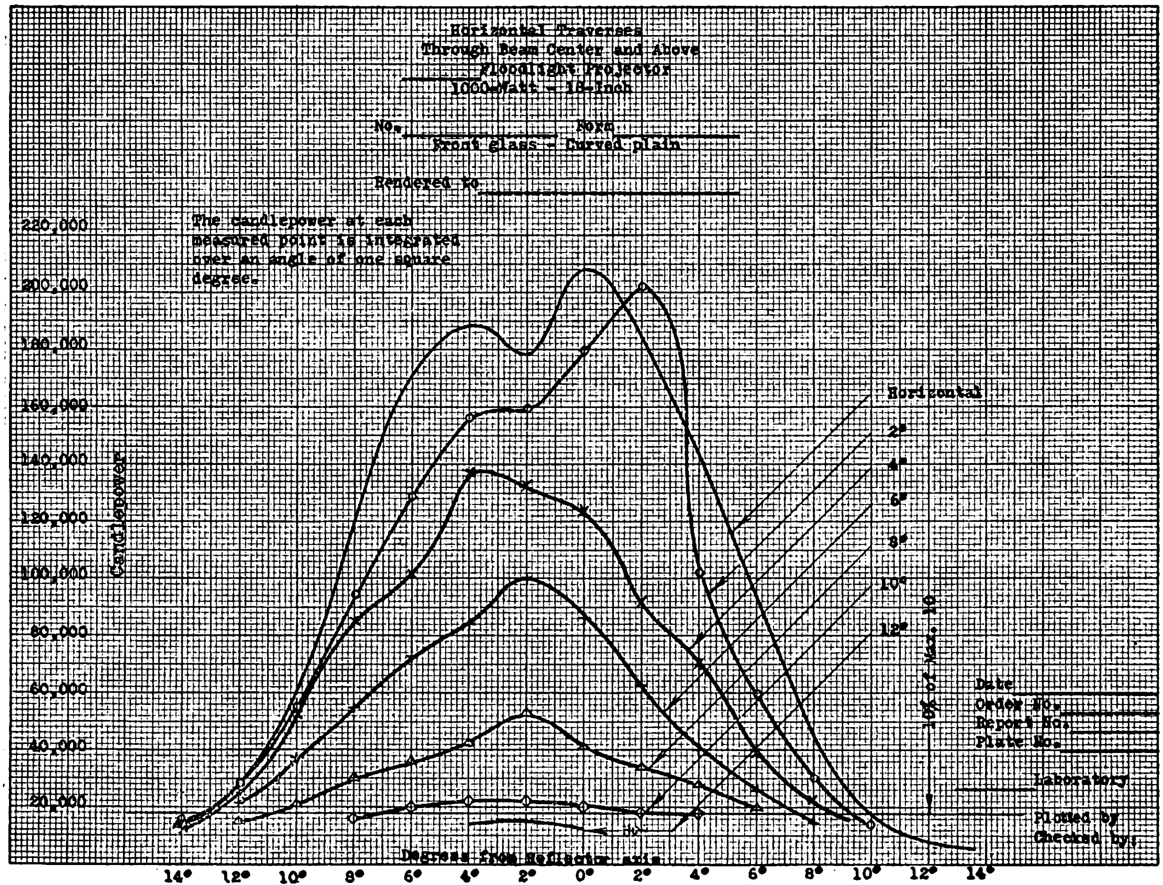


FIG. 5-A—SAMPLE REPORT FOR FLOODLIGHT—HORIZONTAL TRAVERSES THROUGH BEAM CENTER AND ABOVE PROJECTOR.

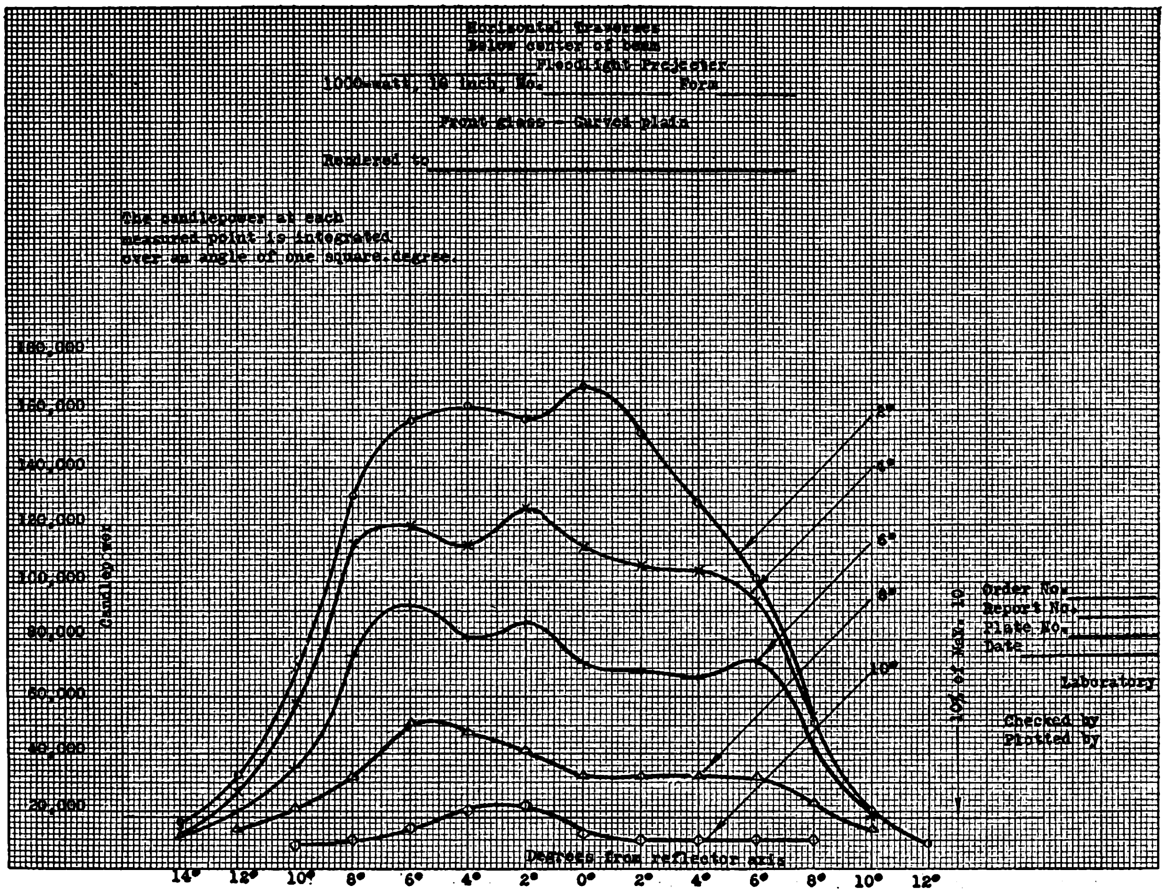
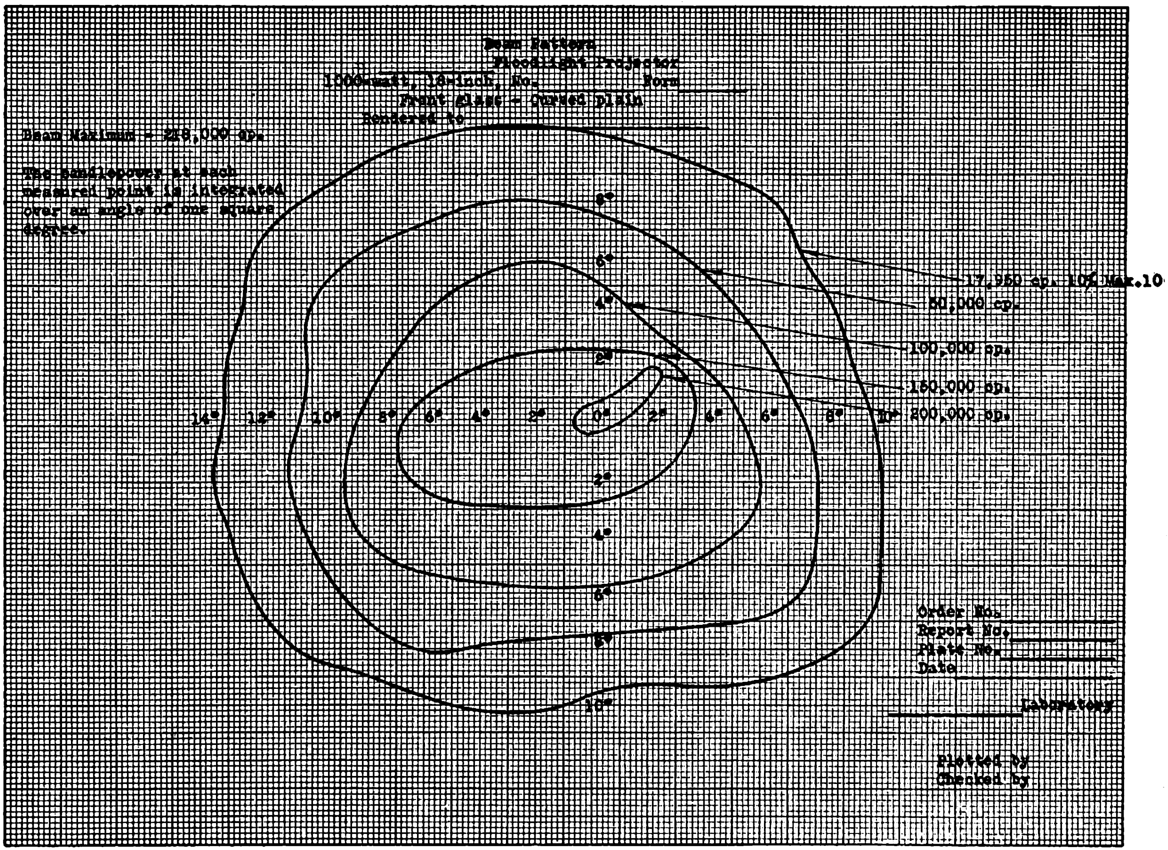


FIG. 5-B—SAMPLE REPORT FOR FLOODLIGHT—HORIZONTAL TRAVERSES BELOW CENTER OF BEAM



Beam Pattern
Floodlight Projector
1000-watt, 18-inch, No. Form
Front glass - Curved plain
Rendered to

Beam Maximum - 218,000 cp.

The candlepower at each measured point is integrated over an angle of one square degree.

Order No.
Report No.
Plate No.
Date

Laboratory

Plotted by
Checked by

FIG. 5-c—Sample Report for Floodlight—Beam Pattern.

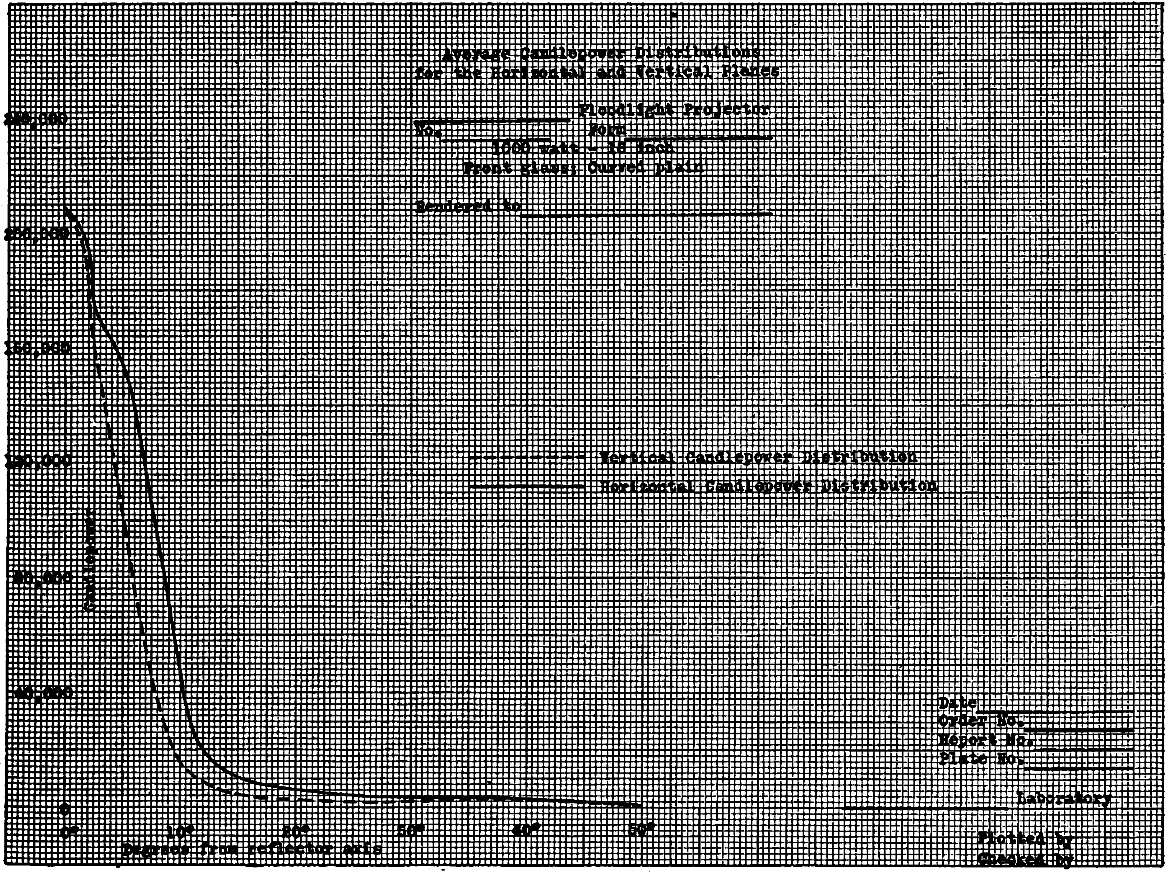


FIG. 5-D—SAMPLE REPORT FOR FLOODLIGHT—AVERAGE CANDLE-POWER DISTRIBUTION.

APPENDIX OF CONSTANTS

TABLE I

CONSTANTS FOR THE CONVERSION OF CANDLES INTO LUMENS
1 Degree Spacing (Square Degrees)

Horizontal Angle	K	Horizontal Angle	K	Horizontal Angle	K
0	0.000305	30	0.000264	60	0.000152
1	0.000305	31	0.000261	61	0.000148
2	0.000305	32	0.000259	62	0.000143
3	0.000304	33	0.000256	63	0.000138
4	0.000304	34	0.000253	64	0.000134
5	0.000304	35	0.000250	65	0.000129
6	0.000303	36	0.000247	66	0.000124
7	0.000303	37	0.000243	67	0.000119
8	0.000302	38	0.000240	68	0.000114
9	0.000301	39	0.000237	69	0.000109
10	0.000300	40	0.000234	70	0.000104
11	0.000299	41	0.000230	71	0.000099
12	0.000298	42	0.000226	72	0.000094
13	0.000297	43	0.000223	73	0.000089
14	0.000296	44	0.000219	74	0.000084
15	0.000294	45	0.000216	75	0.000079
16	0.000293	46	0.000212	76	0.000074
17	0.000292	47	0.000208	77	0.000069
18	0.000290	48	0.000204	78	0.000063
19	0.000288	49	0.000200	79	0.000058
20	0.000286	50	0.000196	80	0.000053
21	0.000285	51	0.000192	81	0.000048
22	0.000282	52	0.000188	82	0.000042
23	0.000281	53	0.000183	83	0.000037
24	0.000278	54	0.000179	84	0.000032
25	0.000276	55	0.000175	85	0.000027
26	0.000274	56	0.000170	86	0.000021
27	0.000272	57	0.000166	87	0.000016
28	0.000269	58	0.000161	88	0.000011
29	0.000267	59	0.000157	89	0.000005

TABLE II

CONSTANTS FOR THE CONVERSION OF CANDLES INTO LUMENS
1.5 Degree Spacing (Square Degrees)

Horizontal Angle	K	Horizontal Angle	K	Horizontal Angle	K
0.0	0.000686	30.0	0.000594	60.0	0.000343
1.5	0.000686	31.5	0.000585	61.5	0.000327
3.0	0.000685	33.0	0.000575	63.0	0.000311
4.5	0.000684	34.5	0.000565	64.5	0.000295
6.0	0.000682	36.0	0.000555	66.0	0.000279
7.5	0.000680	37.5	0.000544	67.5	0.000262
9.0	0.000678	39.0	0.000533	69.0	0.000245
10.5	0.000674	40.5	0.000522	70.5	0.000229
12.0	0.000671	42.0	0.000510	72.0	0.000211
13.5	0.000667	43.5	0.000497	73.5	0.000195
15.0	0.000662	45.0	0.000485	75.0	0.000177
16.5	0.000658	46.5	0.000472	76.5	0.000160
18.0	0.000652	48.0	0.000459	78.0	0.000143
19.5	0.000647	49.5	0.000446	79.5	0.000125
21.0	0.000640	51.0	0.000432	81.0	0.000107
22.5	0.000634	52.5	0.000418	82.5	0.000090
24.0	0.000627	54.0	0.000403	84.0	0.000072
25.5	0.000619	55.5	0.000389	85.5	0.000054
27.0	0.000611	57.0	0.000374	87.0	0.000036
28.5	0.000603	58.5	0.000358	88.5	0.000018

TABLE III

CONSTANTS FOR THE CONVERSION OF CANDLES INTO LUMENS
2 Degree Spacing (Square Degrees)

Horizontal Angle	K	Horizontal Angle	K	Horizontal Angle	K
0	0.00122	30	0.00106	60	0.00061
2	0.00122	32	0.00103	62	0.00057
4	0.00122	34	0.00101	64	0.00053
6	0.00121	36	0.00099	66	0.00050
8	0.00121	38	0.00096	68	0.00046
10	0.00120	40	0.00093	70	0.00042
12	0.00119	42	0.00091	72	0.00038
14	0.00118	44	0.00088	74	0.00034
16	0.00117	46	0.00085	76	0.00030
18	0.00116	48	0.00082	78	0.00025
20	0.00115	50	0.00078	80	0.00021
22	0.00113	52	0.00075	82	0.00017
24	0.00111	54	0.00072	84	0.00013
26	0.00110	56	0.00068	86	0.00009
28	0.00108	58	0.00065	88	0.00004

TABLE IV

CONSTANTS FOR THE CONVERSION OF CANDLES INTO LUMENS
3 Degree Spacing (Square Degrees)

Horizontal Angle	K	Horizontal Angle	K	Horizontal Angle	K
0	0.00274	30	0.00238	60	0.00137
3	0.00274	33	0.00230	63	0.00125
6	0.00273	36	0.00222	66	0.00112
9	0.00271	39	0.00213	69	0.00098
12	0.00268	42	0.00204	72	0.00085
15	0.00265	45	0.00194	75	0.00071
18	0.00261	48	0.00184	78	0.00057
21	0.00256	51	0.00173	81	0.00043
24	0.00251	54	0.00161	84	0.00029
27	0.00244	57	0.00150	87	0.00014

TABLE V

CONSTANTS FOR THE CONVERSION OF CANDLES INTO LUMENS
5 Degree Spacing (Square Degrees)

Horizontal Angle	K	Horizontal Angle	K	Horizontal Angle	K
0	0.00763	30	0.00661	60	0.00381
5	0.00760	35	0.00625	65	0.00322
10	0.00751	40	0.00584	70	0.00261
15	0.00736	45	0.00539	75	0.00198
20	0.00716	50	0.00490	80	0.00132
25	0.00691	55	0.00437	85	0.00066

TABLE VI

RELATION OF ANGLES (r) ON RADIAL LINES TO HORIZONTAL (h) AND VERTICAL (v) ANGLES

r	h	v
0°	0° 0′	0° 0′
5°	3° 32′	3° 32′
10°	7° 3′	7° 6′
15°	10° 33′	10° 44′
20°	14° 0′	14° 26′
25°	17° 23′	18° 15′
30°	20° 42′	22° 12′
35°	23° 56′	26° 20′
40°	27° 2′	30° 41′
45°	30° 0′	35° 16′
50°	32° 48′	40° 7′
55°	35° 24′	45° 17′
60°	37° 46′	50° 46′
65°	39° 51′	56° 36′
70°	41° 38′	62° 46′
75°	43° 5′	69° 15′
80°	44° 8′	76° 0′
85°	44° 47′	82° 57′
90°	45° 0′	90° 0′

TABLE VII

LUMEN CONSTANTS
Ten Degree (Annular) Zones

Candles at	Zone From	To	Lumen Constant
5°	0°	10°	0.095
15°	10°	20°	0.284
25°	20°	30°	0.463
35°	30°	40°	0.628
45°	40°	50°	0.774
55°	50°	60°	0.897
65°	60°	70°	0.993
75°	70°	80°	1.058
85°	80°	90°	1.091

TABLE VIII

LUMEN CONSTANTS
Five Degree (Annular) Zones

Candles at	Zone From	To	Lumen Constant
2° 30′	0°	5°	0.0239
7° 30′	5°	10°	0.0715
12° 30′	10°	15°	0.1186
17° 30′	15°	20°	0.1648
22° 30′	20°	25°	0.2098
27° 30′	25°	30°	0.2531
32° 30′	30°	35°	0.2945
37° 30′	35°	40°	0.3337
42° 30′	40°	45°	0.3703
47° 30′	45°	50°	0.4041
52° 30′	50°	55°	0.4349
57° 30′	55°	60°	0.4623
62° 30′	60°	65°	0.4862
67° 30′	65°	70°	0.5064
72° 30′	70°	75°	0.5228
77° 30′	75°	80°	0.5352
82° 30′	80°	85°	0.5435
87° 30′	85°	90°	0.5476

TABLE IX

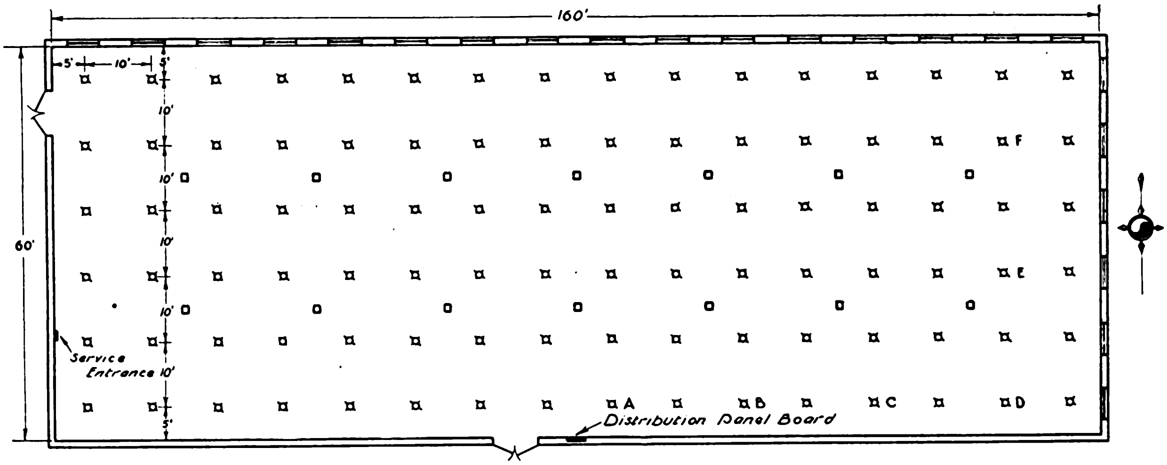
LUMEN CONSTANTS
Five Degree (Annular) Zones

Candles at	Zone From	To	Lumen Constant
0°	0°	2° 30′	0.0060
5°	2° 30′	7° 30′	0.0478
10°	7° 30′	12° 30′	0.0951
15°	12° 30′	17° 30′	0.1419
20°	17° 30′	22° 30′	0.1875
25°	22° 30′	27° 30′	0.2317
30°	27° 30′	32° 30′	0.2741
35°	32° 30′	37° 30′	0.3144
40°	37° 30′	42° 30′	0.3523
45°	42° 30′	47° 30′	0.3876
50°	47° 30′	52° 30′	0.4199
55°	52° 30′	57° 30′	0.4490
60°	57° 30′	62° 30′	0.4747
65°	62° 30′	67° 30′	0.4968
70°	67° 30′	72° 30′	0.5150
75°	72° 30′	77° 30′	0.5295
80°	77° 30′	82° 30′	0.5398
85°	82° 30′	87° 30′	0.5461
90°	87° 30′	90°	0.2741

REPORT OF ADEQUATE WIRING SUBCOMMITTEE

During the past few months this subcommittee has made a study of the subject of cost of adequate wiring for lighting circuits. It is very evident that the demand for higher illumination level is becoming more manifest each day; higher wattage lamps are replacing smaller lamps on circuits that already were overloaded; wiring is often installed that is insufficient to serve the present day load to say nothing of the possibilities of future needs.

In order to make a study of the actual costs and lighting results of wiring, a plan for a new building showing the construction details and the lighting layout was sent to electrical contractors in five different cities. The construction specifications for the building as sent to the contractors are included in the appendix to this report. Fig. 6 shows the plan view with the location of outlets, panel board, and service entrance. The contractors were asked to submit cost estimates on complete wiring for this building, assuming the six following different conditions, the first five of which were to be based on



LIGHTING LAYOUT
for
NEW BROWN ANNEX BLDG.

¤ Outlet to be wired according to attached specifications. All wires are to be placed in Conduit, concealed in the Flat Slab Concrete Construction. The finished ceiling height is 12 feet.

FIG. 6—LIGHTING LAYOUT.

good practice for wiring as shown by the specifications in the appendix.

1. Each of the 96 outlets to be equipped with 1-100 watt lamp.
2. Each of the 96 outlets to be equipped with 1-150 watt lamp.
3. Each of the 96 outlets to be equipped with 1-200 watt lamp.
4. Each of the 96 outlets to be equipped with 1-300 watt lamp.
5. Each of the 96 outlets to be equipped with 1-500 watt lamp.
6. Each of the 96 outlets to be equipped with 1-300 watt lamp, disregarding entirely the two volt maximum drop and all other definite specifications as given for the preceding conditions, except that conductors must be placed in iron pipe conduit concealed in concrete, and the work must at least meet the requirements of the National Electrical Code for Electric Wiring, as recommended by the National Fire Protection Association.

Eleven different cost estimates were returned from the five cities. The bids were submitted in the form shown in Table X, which not only gives the cost data but also the sizes of wire to be used for typical branch circuits. The cost estimates given in the table are the averages obtained from the eleven different bids submitted. The wire sizes for typical branch circuits are the largest sizes specified by a majority of the bidders. Table XI shows the cost per outlet and cost per watt for wiring. These data are also shown by curves in Fig. 7 and 8.

TABLE X

AVERAGE ESTIMATES SUBMITTED BY ELEVEN ELECTRICAL CONTRACTORS

	Wattage per Outlet	Outlets per Circuit	No. of Branch Circuits	Wire Sizes To Be Used							Cost to Owner for Complete Jobs*		
				Three-wire Feeder	Typical Branch Circuits Panel Board to Bays (see blueprint)								
					A	B	C	D	E	F	Material	Labor	Total
(1)	100	8	12	4	14	14	12	12	10	10	$367	$293	$660
(2)	150	8	12	2	12	12	12	12	10	10	405	313	718
(3)	200	4	24	1	14	14	14	12	10	10	455	375	830
(4)	300	4	24	00	12	12	10	10	10	10	545	409	954
(5)	500	3	32	250,000	12	12	10	10	8	8	704	505	1209
(6)	300	4	24	00	14	14	14	14	14	14	424	373	797

*What is labor rate per hour $1.50? About what per cent overhead and profit has been assumed in arriving at owner's cost 15 and 10?

TABLE XI

COSTS OF WIRING INSTALLATIONS FROM ESTIMATES GIVEN IN TABLE XI

Watts per Outlet	Complete Installation Cost	Material Cost per Outlet	Labor Cost per Outlet	Total Cost per Outlet	Cost per Watt
100	$660	$3.81	$3.04	$6.85	$0.068
150	718	4.22	3.26	7.48	0.050
200	830	4.75	3.90	8.65	0.043
300	954	5.68	4.25	9.93	0.033
500	1209	7.33	5.25	12.58	0.025

Lighting Trends Demand Better Lighting

The standards of lighting as evidenced by the present day lighting of buildings are, as a whole, very low. The number of lighting systems that can be classified as those providing illumination of modern standards are relatively few in comparison to the number of those which are below good practice. Furthermore, the saturation point on lighting is not even approached in the well illuminated interiors, and the best authorities today would hesitate to hazard an opinion as to when the demand for more and better lighting will cease. It is, therefore, obvious that the lighting trends are upward. Larger sizes and more lamps will be installed as time goes on. In view of this fact, serious consideration should be given to the proper wiring of buildings at the present time in order to minimize not only immediate losses which result from inadequate wiring, but also greater losses which will inevitably occur when it is desired to employ larger lamps.

In present lighting installations, the wattage is often as much as doubled without rewiring. From the wiring data submitted for this report, a typical example can be shown as to what happens when 300-watt lamps are substituted for 150-watt lamps on a circuit originally designed for 150-watts per outlet. In order to find the magnitude of the losses for this typical example, it will first be necessary to analyze the cost of lighting, assuming that the building is wired in accordance with good practice for a 300-watt installation (System 4, Table X), and compare the losses with those which would be obtained when the 300-watt lamps are installed on the 150-watt per outlet system (System 2). The wire sizes shown in Table X for the 300- and 150-watt lamps were used in the calculations. It was assumed that the lamps would be burned 1500 hours a year at an energy rate of 5 cents per kilowatt hour.

Analysis of System No. 4

Using the wire sizes No. 12 and No. 10 as recommended by the bidders, the lamps burn at normal voltage. Thus 100 per cent or normal life, wattage and light output are obtained. The annual energy cost amounts to

$$96 \text{ outlets} \times \frac{300}{1000} \text{ kw.} \times 1500 \times 5\text{c.} = \$2{,}160$$

The cost of lamps was figured at the net price obtained on a $600 consumer lamp contract. It was assumed that this size of lamp contract would be fulfilled since the building under consideration was defined as an annex to a larger building. The annual lamp cost for 300-watt lamps for this layout is

$$96 \times \$0.95 \times \frac{1500}{1000} = \$136.80$$

The loss due to current overcoming resistance (I^2R) in this case amounts to $28.46 annually as shown from Table XII. This cost, added to energy and lamp costs, brings the total annual operating cost to

$$\$2{,}160 + \$136.80 + \$28.46 = \$2{,}325.26$$

From this system of lighting the lumen hours of lights obtained is

$$96 \times 5300 \times 1500 = 763 \text{ million lumen hours}$$

When the lamps are operating at normal voltage—115 volts—the voltage drop averages 1.5 volts (Table XII). The voltage at the panel board is, therefore, 116.5 volts.

TABLE XII

Computations for Voltage Drop and I^2R Loss for System No. 4 300 Watts per Outlet—1200 Watts per Circuit—115 Volts I = 10.44 Amperes per Circuit I^2 — 109.

Typical Branch Circuits	Wire Size	Load Center Feet	Ohms R	I R Drop per Circuit Volts	I^2R Loss per Circuit Watts	No. of Branch Circuits	All Circuits	
							I R Drop Volts	I^2R Loss Watts
A	12	24	0.076	0.794	8.3	2	1.588	16.6
B	12	42	0.1334	1.392	14.52	4	5.68	58.08
C	10	62	0.124	1.296	13.5	6	7.776	81.0
D	10	82	0.164	1.712	17.9	6	10.272	107.4
E	10	86	0.172	1.795	18.75	4	7.180	75.0
F	10	95	0.190	1.985	20.7	2	3.970	41.4
					Totals..	....	36.354	379.48

Average voltage drop per circuit—1.5.

$$\text{Cost of Energy loss} = \frac{379.48}{1000} \times 1500 \text{ hrs.} \times 5¢ = \$28.46.$$

Analysis of System No. 2, Assuming 300 Watts Per Outlet

If the 300-watt, 115 volt lamps are operated on circuits designed for 150-watts per outlet, we find that the average voltage drop is 4 volts (Table XIII). Since the normal panel voltage is 116.5 volts, the lamps will be operating at 112.5 volts or 2.5 volts below their rated voltage. This also reduces the lamp wattage to 96.6 per cent of normal and the lumen output to 93 per cent of normal, while the life is increased 33⅓ per cent.

The annual energy cost amounts to

$$96 \text{ outlets} \times \frac{290}{1000} \text{kw.} \times 1500 \text{ hr.} \times 5\text{c.} = \$2{,}088.$$

The cost of lamps is

$$96 \times \$0.95 \times \frac{1500}{1333} = \$102.62$$

The I^2R loss from Table XIII is \$76.52.

The total annual operating cost for this system is

$$\$2{,}088 + \$102.62 + \$76.52 = \$2{,}270.74$$

From this system of lighting the lumen hours of light obtained is

$$96 \times 4930 \times 1500 = 710 \text{ million lumen hours}$$

From the foregoing analysis of Systems 4 and 2, it is found that for an annual saving in operating cost of \$2,325.26 — \$2,270.74, or \$55.52, there is a loss in light of 53 million lumen hours. Since the cost per million lumen hours from System 4 is \$2,325.26 ÷ 763 or \$3.05 then the cost of light lost in System 2 is

$$53 \times \$3.05 \text{ or } \$161.65$$

This amount minus \$55.52 gives a net loss of \$106.13 due to inadequate wiring.

TABLE XIII

Computations for Voltage Drop and I^2R Loss for System No. 2 When 300 Watt Lamps Are Installed. 2400 Watts per Circuit. I = 20.9 Amperes per Circuit. $I^2 = 436$.

Typical Branch Circuits	Wire Size	Load Center Feet	Ohms R	I R Drop per Circuit Volts	I^2R Loss per Circuit Watts	No. of Branch Circuits	All Circuits	
							I R Drop Volts	I^2R Loss Watts
A	12	49	0.155	3.24	67.6	2	6.48	135.2
B	12	58	0.184	3.84	80.2	2	7.68	160.4
C	12	68	0.216	4.52	94.2	2	9.04	188.4
D	12	78	0.247	5.16	107.5	2	10.32	215.0
E	10	87	0.174	3.64	76.0	2	7.28	152.0
F	10	97	0.194	4.05	84.6	2	8.10	169.2
					Totals...	....	48.90	1020.2

Average voltage drop per circuit—4.0.

Cost of energy loss $= \frac{1020.2}{1000} \times 1500$ hrs. $\times$ 5¢ = \$76.52.

From the installation cost estimates for Systems 2 and 4 as given in Table X, it is found that System 4 costs \$236 more than System 2. It is, therefore, seen that by an added initial investment in this case of \$236 for better wiring, an annual saving of \$106.13 in light is obtained during the time when the wattage might be doubled. Since this is a typical instance, it may be more useful to express these costs in terms of dollars per outlet. To wire so as to insure enough copper in the circuits for 300 watts per outlet to minimize losses, costs \$9.93, or approximately \$10 per outlet (from Table XI). The cost of wiring for only 150 watts per outlet is approximately \$7.50. The better wiring, therefore, will cost \$2.50 more per outlet, but will insure the system against an annual loss of \$1.10 per outlet. It is also a fact that, during the time when the initial installation of 150-watt lamps is used, light would be produced more economically from a wiring installation designed to accommodate the higher wattage lamps. It can, therefore, in general be concluded that an initial investment of a few extra dollars in the wiring system will pay an exceptionally high dividend when the standard of illumination is increased by installing higher wattage lamps.

Inadequate Wiring Results from Cut-Rate Jobs

There is a tendency on the part of some electrical contractors and builders to try to reduce costs to such an extent that not only are the requirements for the future disregarded, but also the present requirements are not met. An appreciation of what better lighting is and what it will do is growing very rapidly. Tenants are beginning to write their own lighting specifications in their leases before signing them. Just such an instance recently occurred which brought out emphatically the expense of inadequate wiring and the need for more careful consideration of wiring requirements. A tenant was considering the lease of a suite of offices in a modern building that had very recently been completed. The prospective tenant insisted that the lighting be of a high order. The building manager agreed to provide illumination in accordance with the tenant's specifications, and in order to comply with this agreement he was very much exasperated when he learned that the changes which he had to make because of inadequate wiring resulted in an expense of over \$2,000. The so-called "modern" building was probably modern in all other respects excepting wiring.

In making wiring specifications, many electrical contractors and builders consider the current carrying capacity of the wire as a criterion for wire sizes. The wire sizes so specified in the National Electrical Code are intended only to regulate the installation of electrical apparatus so that fire risks would be minimized. The Code should, therefore, only be considered as a guide to safe carrying capacity of wires, but not as a guide to the economical distribution of energy.

In many instances electrical contractors and builders use their local city code as a guide in laying out wiring jobs. These codes often specify only the maximum number of outlets on a circuit which often leads the contractor to standardize on one wire size which probably is entirely inadequate for the great majority of jobs. Such procedure gives no opportunity for consideration of the load that the circuits may be called upon to carry or the resulting losses which accrue through heat and voltage drop. The effect of cutting down materials to save costs is illustrated by again using the 300-watt installation as an example.

Referring to Table X, System 6, the average figures submitted for this installation by the eleven contractors are given. In this case, as noted before, all definite specifications were disregarded, it being necessary only to meet the requirements of the National Electrical Code for wiring.

From the computations already made on System 4, we found that the voltage at the panel board was 116.5 volts. When operating on the smaller wire sizes as specified in System 6, the average voltage drop is 3.5 volts (Table XIV). The lamps on this system are, therefore, burning at 113 volts. At this voltage, the wattage of the lamps is 97.5 per cent of normal and the lumen output is reduced to 94 per cent of normal. The life of the lamps is increased to 125.8 per cent.

The annual energy cost amounts to

$$96 \text{ outlets} \times \frac{292}{1000} \text{ kw.} \times 1500 \text{ hr.} \times 5\text{c.} = \$2{,}102.40$$

The cost of lamps is

$$96 \times \$0.95 \times \frac{1500}{1258} = \$108.74$$

The I^2R loss from Table XIV is $66.64. The total annual operating cost for this system is

$$\$2{,}102.40 + \$108.74 + \$66.64 = \$2{,}277.78$$

From this system of lighting the lumen hours of light obtained is

$$96 \times 4980 \times 1500 = 717 \text{ million lumen hours}$$

By comparing the foregoing analysis with that of System 4, we find that for an annual saving in operating cost of $2,325.26 — $2,277.78, or $47.48, there is a loss in light of 46 million lumen hours. Since the cost per million lumen hours from System 4 is $3.05, then the cost of light lost in System 6 is $140.30. This amount minus $47.48 gives a net loss of $92.82 because of inadequate wiring.

TABLE XIV

Computations for Voltage Drop and I^2R Loss for System No. 6 300 Watts per Outlet—1200 Watts per Circuit—115 Volts. I = 10.44 Amperes per Circuit. $I^2 = 109$.

Typical Branch Circuits	Wire Size	Load Center Feet	Ohms R	I R Drop per Circuit Volts	I^2R Loss per Circuit Watts	No. of Branch Circuits	All Circuits	
							I R Drop Volts	I^2R Loss Watts
A	14	24	0.1212	1.268	13.2	2	2.536	26.4
B	14	42	0.212	2.216	23.1	4	8.864	92.4
C	14	62	0.313	3.27	34.1	6	19.62	204.6
D	14	82	0.414	4.32	45.2	6	25.92	271.2
E	14	86	0.434	4.54	47.3	4	18.16	189.2
F	14	95	0.480	5.02	52.4	2	10.04	104.8
					Totals.	......	85.14	888.6

Average voltage drop per circuit—3.5.

$$\text{Cost of energy lost} = \frac{888.6}{1000} \times 1500 \text{ hrs.} \times 5¢ = \$66.64.$$

From the installation cost estimates for Systems 4 and 6, Table X, it is found that System 4 costs $157 more than System 6. It is evident, therefore, that by an added initial investment of $157 for proper wiring, an annual saving of $92.82 in light is obtained. In other words, for an added initial investment of $1.64 per outlet a return of $0.96 per outlet will be obtained each year.

Discussion of Data and Conclusions

(1) From the cost estimates given in Table XI it will be noted that the cost of wiring increases with the increase in wattage per outlet, as would be expected. It is interesting to note that the rise in cost per outlet for materials is quite regular as shown by the curve in Fig. 7. There is a sharper increase in labor cost between 150 and 200 watts per outlet which is probably due to the fact that the number of branch circuits for the 200-watt system are doubled. However, the cost of labor for installing wiring above 200 watts per outlet does not increase as rapidly as does the cost of material. This is apparent from a comparison of the slopes of the curves showing these costs (Fig. 7).

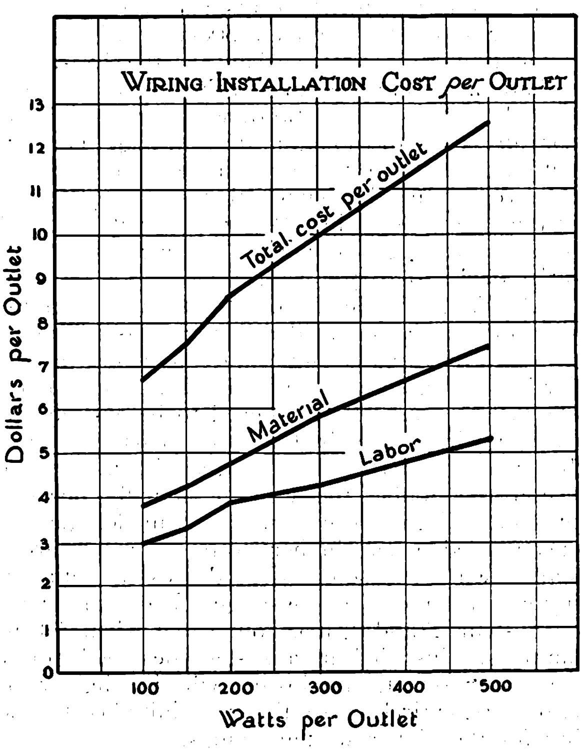


FIG. 7—WIRING INSTALLATION COST PER OUTLET.

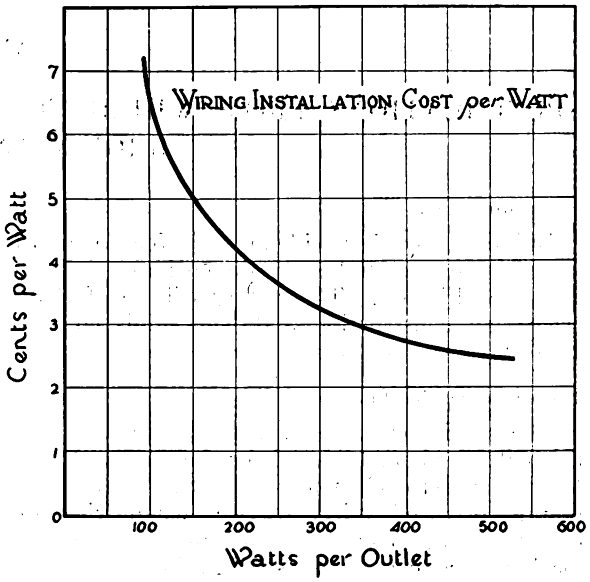


FIG. 8—WIRING INSTALLATION COST PER WATT.

From the curve in Fig. 8, it will be noted that the cost per watt greatly decreases as the wattage per outlet is increased. For example, to install 150 watts per outlet the cost is at the rate of 5 cents per watt, while to double this wattage per outlet reduces the rate to 3⅓ cents per watt. Thus the actual cost for the complete 300-watt wiring installation is only ⅓ greater than for the 150-watt installation. From the curve (Fig. 8) it can be observed that this same ratio of wiring costs holds true for any case of doubling the wattage per outlet within the 100 to 500-watt range. Also it can be observed from this curve that by increasing the wattage per outlet by 50 per cent within the 150 to 500-watt range the wiring cost increase is of the order of 15 to 18 per cent.

(2) With the levels of illumination increasing year by year as demanded for various interiors, it is today of primary importance to make provision for higher wattage than may be demanded for present installations. It is believed to be entirely practical in wiring new buildings to provide at least a 100 per cent safety factor, that is, making provision for double the wattage actually needed at present. If this provision is not made, the losses encountered when higher wattage lamps are installed will very soon offset the extra initial wiring cost for the higher wattage. From the analysis of Systems 2 and 4, it is found that when 300-watt lamps are installed in a system designed for 150 watts per outlet, the losses will, in slightly over two years, entirely offset the extra initial cost of wiring for the higher wattage lamps.

(3) There are many "overloaded" lighting systems in use today which are costly to the owner because he is often unknowingly paying for a considerable amount of light which he never receives. Many of the buildings with these overloaded lighting circuits can well afford to rewire immediately, as the money invested would pay a good dividend. It is, of course, true that in those buildings where the existing outlets are improperly placed or are not sufficient in number of insure uniform distribution of light throughout the room, a rewiring job is imperative.

It should be noted particularly that the cost of estimates given in Table X are for wiring a new building and are, no doubt, in general, somewhat lower than those for rewiring an old building. Where plaster has to be removed, concrete channelled, or similar work done to install wiring, the cost obviously is increased. Referring again to comparative cost analysis of Systems 2 and 4, it is seen that there is an annual saving of $106.15, or $1.11 per outlet for the 300-watt system. Even if this were the only benefit to be gained, it would readily justify a rewiring expense which might even be considerably greater than the $9.93 per outlet as estimated for a new building. However, the value of illumination is not limited to its intrinsic worth, but even greater, its value to good vision and attractiveness of the room. In a factory workroom or store this latter value alone may easily be such as to pay for the rewiring cost many times.

From every viewpoint, then, it is reasonable to conclude that where excessive voltage drop exists, the cost of rewiring is unquestionably justified.

(4) Referring again to the initial wiring installation for a new building, it cannot be over-emphasized that efforts to cut down wiring specifications which would otherwise insure against losses in light and energy in order to reduce costs, often produce just the reverse effect; instead of creating a saving, greater expense is eventually incurred. From the analysis of the cost data for Systems 4 and 6 in Table X, it is found that for the latter system, where the initial wiring cost was cut to a minimum, the cost of light lost in approximately 1½ years would equal the extra cost required for installing a good wiring installation.

APPENDIX

SPECIFICATIONS FROM WHICH TO MAKE COST ESTIMATE FOR WIRING NEW BROWN ANNEX BUILDING

1. Building Plan

Building is 60 feet wide and 160 feet long divided into 24 bays, each having dimensions of 20 x 20 feet (see Fig. 6). The ceiling will be of flat concrete slab construction and when finished will be 12 feet above the floor.

2. Electric Service Entrance

The service entrance will be on the west side of the building about 16 feet from the southwest corner. Electric Service Company will bring service to this point. A fused safety service switch with proper meter loop and equipment to comply with code and local service company's specifications must be installed at this entrance by electrical contractor.

3. Feeder Wires

A 3 wire single phase 115-230 volt feeder shall be installed from service entrance to distribution panel board. The distribution panel board will be placed at about the half way point along the south side of building, thus making the feeder wire approximately 100 feet long.

In computing size of feeder wire, assume a load for each of two unconnected branch circuits equal to the load carried by each of the connected circuits.

4. Distribution Panel Board

A dead front double door distribution panel board 115-230 volt shall be installed flush with wall at about the half way point along the south side of building. This panel shall have slate frame doors and trim. It shall have a 30 ampere single pole toggle switch and plug fuse for each branch circuit. In addition to the connected branch circuits as specified in the table, Paragraph 10, the panel board shall have two unconnected switches for future circuits. For computing size of feeder wire it will be assumed that these two unconnected switches will control circuits of the same capacity as the other connected circuits on the panel.

5. Branch Circuits

The location of outlets shall be as shown on Fig. 6, namely, on 10 x 10 foot spacings symmetrically placed in each of the 20 x 20 foot bays.

The number of outlets per circuit and number of branch circuits will depend upon the size of lamp installed as shown in the table, Paragraph 10.

6. Conduit

Full wall loricated pipe conduit concealed in the concrete must be used with 3C-O concrete boxes as manufactured by Adapti, Steel City. or equal as approved.

7. Wire

Single braid rubber covered wire shall be used for all circuits requiring No. 8 or smaller sizes.

8. Voltage Drop and Size of Conductors

All conductors must be of such size that under full load conditions the voltage drop between panel board and outlets will not exceed 2 volts. The voltage drop in main 3 wire feeder should not exceed 2 volts when all circuits, including the present two extras, are connected (see Paragraph 3).

9. Cost Estimates

A cost estimate for furnishing all material and installing job complete from service entrance to outlet boxes is required for building owner. This cost estimate is to be made, assuming 100 per cent load factor on all circuits for six conditions as follows:

(1) Assume each of the 96 outlets to be equipped with 1-100 watt lamp.

(2) Assume each of the 96 outlets to be equipped with 1-150 watt lamp.

(3) Assume each of the 96 outlets to be equipped with 1-200 watt lamp.

(4) Assume each of the 96 outlets to be equipped with 1-300 watt lamp.

(5) Assume each of the 96 outlets to be equipped with 1-500 watt lamp.

(6) Assume each of the 96 outlets to be equipped with 1-300 watt lamp and disregard entirely the two volt maximum drop, and all other definite specifications as given above in Paragraphs 3 to 8, inclusive, except that conductors must be placed in iron pipe conduit concealed in concrete and the work must at least meet the requirements of the National Electrical Code for Electric Wiring, as recommended by the National Fire Protection Association.

10. Submitting Cost Estimates

Submit cost figures by filling in blanks in following table. Also fill in blanks to show size of feeder wire and size of wire which will be installed, for typical branch circuits to bays as indicated on blueprint as A, B, C, D, E and F.

	Wattage per Outlet	Outlets per Circuit	No. of Branch Circuits	Wire Sizes To Be Used							Cost to Owner for Complete Jobs†		
				Three-wire Feeder*	Typical Branch Circuits Panel Board to Bays (see blueprint)								
					A	B	C	D	E	F	Material	Labor	Total
(1)	100	8	12										
(2)	150	8	12										
(3)	200	4	24										
(4)	300	4	24										
(5)	500	3	32										
(6)	300												

*In computing size of feeder wire allow capacity for the 2 unconnected circuits (see Note 3).

†What is labor rate per hour ———? About what per cent overhead and profit has been assumed in arriving at owner's cost ———?

HOME LIGHTING

PART I—PROMOTION OF HOME LIGHTING SERVICE

Introduction

The subcommittee on Lighting Service has endeavored to point out the potential domestic lighting market and show that this market can be developed by the establishment of a "Service" in Home Lighting. Also it has prepared an outline of the necessary qualifications of a Home Lighting Specialist, the functions of the Lighting Service Division and its value to the electric service company.

This report covers the following subjects:

1. The Potential Market
2. Organization of a Home Lighting Department
3. Activities
4. Equipment
5. Value to Other Departments.

Section I

THE POTENTIAL MARKET

Of the total revenue received by the electric light and power industry during 1928, approximately 35 per cent was derived from the sale of electricity for lighting purposes.

Of the 23,238,000 customers on record as of Dec. 31, 1928, 82 per cent, or 19,077,000, were domestic lighting customers.

An analysis conducted by the National Electric Light Association covering a two-year period (1926-28) showed an increase in domestic customers of 15.1 per cent, an increase in kilowatt-hour sales of 33.8 per cent, but an increase in sales per domestic customer of only 13.6 per cent. The big problem indicated is to increase the energy use per customer. There are more than 19,000,000 homes which are prospects for improved home lighting.

Revenues from Sales of Electric Service, 1928
(From N. E. L. A. Statistical Bulletin No. 3)

		% of Revenues from Consumers	Total
Domestic service (inc'ld'g non-irrigated farms)..	$555,944,000	30.9	29.1
Commercial; small light and power (retail)...	523,180,000	29.1	27.4
Commercial; large light and power (wholesale)	591,195,000	32.8	31.0
Street lighting	74,566,000	4.1	3.9
Street railways and electrified railroads	47,933,000	2.7	2.5
Miscellaneous	8,620,000	0.4	0.4
Total from ultimate consumers	1,801,438,000	100.0	94.3
Other electric enterprises	107,365,000	.....	5.7
Total gross revenues	$1,908,803,000	.....	100.0

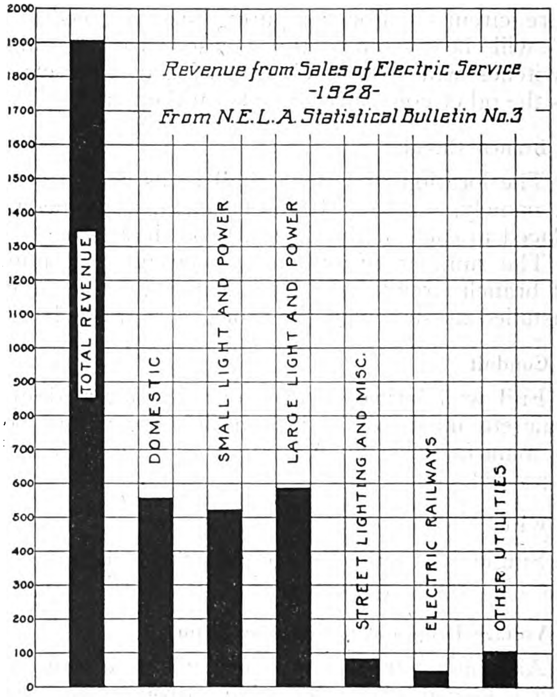


FIG. 1.

Survey and statistics indicate that lighting equipment in the home is far from the point of saturation, and that the home field offers wide possibilities.

According to a 1926 report of the Electricity in the Home Committee, N. E. L. A., the conservative ideal home shows the following wiring and lighting equipment which will supply reasonably convenient utilitarian lighting for the average home. It represents a condition for which the electrical industry should strive as a first milestone.

It is emphasized that these items must be considered not only in a given room, but for a home as a whole, and that they represent averages of several possible satisfactory layouts.

Using the average figure for domestic energy consumption in 1928, viz., 459 kw-hr. per year, the total energy consumed by residence customers totals 8,489,000,000 kw-hr. This load represents a revenue of $555,944,000 or 29 per cent of the total revenue received from all sources. This energy has been used by homes inadequately equipped electrically. If the homes of the country were brought up to the standard of the "conservative ideal" the energy consumption might be raised to 10,418,940,000 kw-hr. representing an annual revenue of $650,000,000. This would result from the increased use of home lighting alone.

In addition to the development work in the present wired homes and the homes being built each year there remain nearly 9,000,000 unwired homes, a

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Publication No. 289-119. Serial Report, Home Lighting Committee.

COMPARISON OF WIRING AND LIGHTING EQUIPMENT

AVERAGE WIRED AND "CONSERVATIVE IDEAL" HOMES

	Average Wired Home	"Conservative* Ideal" Home	Per Cent Saturation
Convenience outlets......	3.4	10.5	33
Ceiling fixtures .... (satisfactory)	6.1	11.5	53
Wall brackets .... (utilitarian)	2.5	8.0	31
Portable lamps	2.8	8.5	33
Connected load in watts..	954	1,845	51

*Some of the major items pertinent to this "conservative ideal" home are as follows:

Living Room

3 convenience outlets; 1 ceiling fixture; 6 portable lamps (including portables in sunroom, reception hall, dining room and various other places not otherwise listed); 540 watts.

Dining Room

1 convenience outlet; 1 ceiling fixture, 230 watts (1 or 2 small portables might be used here. If so, they would be included in the 6 portable lamps in the foregoing item).

Kitchen

1 convenience outlet; 1 ceiling fixture; 1 wall bracket; 200 watts.

Bedrooms

Average, 2.5 bedrooms per home; 2.5 convenience outlets; 2.5 ceiling fixtures; 5 wall brackets; 2.5 portable lamps; 475 watts.

Bathroom

1 convenience outlet; 2 wall brackets; 100 watts.

Hallway

1 convenience outlet; 1 ceiling fixture; 50 watts.

Basement

1 convenience outlet; 5 fixture outlets; 250 watts.

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portion of which are coming within reach of central station service every year.

Aside from the revenue which can be obtained in this field, electric service companies should not lose sight of the tremendous influence they can exert toward the conservation of eyesight and the bettering of living conditions by promoting good home lighting.

Therefore, it is recommended that central stations encourage the development of home lighting through the establishment of a Home Lighting Service Department.

The figures used in this report are quoted from and based upon figures secured from N. E. L. A. Headquarters—"Use of Domestic Service and Revenues Received Therefrom in the United States (N. E. L. A. Series)," the report of the 1926 N. E. L. A. Committee on Electricity in the Home and from the N. E. L. A. Statistical Bulletin No. 3, covering the year 1928.

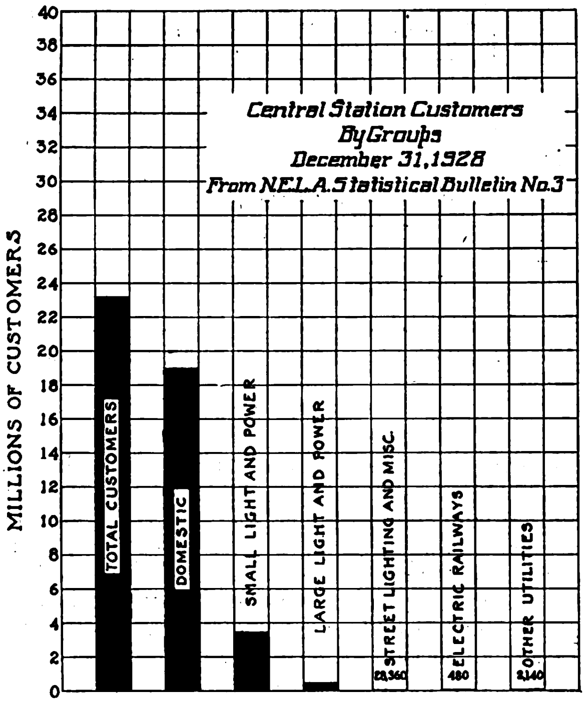

FIG. 2.

CONSUMERS (NUMBER) DEC. 31, 1928

(From N. E. L. A. Statistical Bulletin No. 3)

Domestic service (including non-irrigated farms)	19,077,000
Commercial service (small light and power)....	3,584,000
Commercial service (large light and power)....	546,000
Street lighting and miscellaneous, municipal.....	28,360
Electric railways and electrified railroads........	480
Total consumers..........................	23,236,000
Other electric enterprises	2,140
Grand total	23,238,000

Section II

ORGANIZATION OF HOME LIGHTING SERVICE

I—Place in Electric Service Company

It is assumed that the Home Lighting Service Department will be a part of the New Business or Commercial Division of the electric service company.

The work of the Home Lighting Specialist will fit into the organization of the New Business or Commercial Department as shown in Fig. 3.

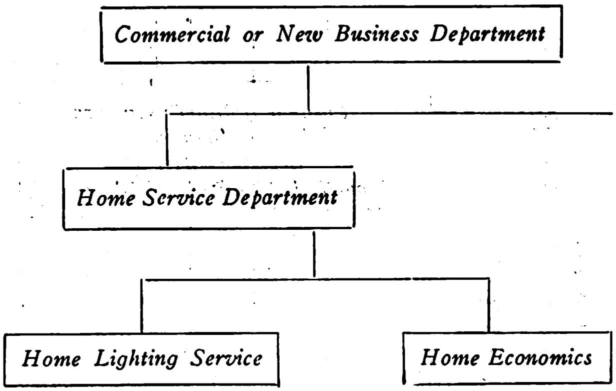

FIG. 3.

The various advisory services rendered by the company to homes should be coordinated in one department, usually designated as the Home Service Department. Home lighting service has become highly specialized, and some companies have developed women devoting their time exclusively to this work.

The Home Lighting Specialist may be a part of the Home Service Department, or in present practice, it may prove desirable to attach the Home Lighting Specialist to an already established Home Lighting Department.

II—Personnel

The number of trained women available for this type of work is limited.

The following qualifications may prove a guide in making a selection:

1. Good breeding, personality, dignity.
2. Background (previous training).
   - (a) A college education is preferable, but a high school education is necessary.
   - (b) Experience in interior decoration, and the use of color is necessary because home lighting and home decoration are closely related.
   - (c) Previous experience in teaching is valuable because teaching gives practice in coordinating ideas and in addressing groups.
   - (d) Experience in public speaking is valuable.
   - (e) Knowledge of fundamentals of home lighting is desirable.
   - (f) Active participation in club work provides valuable training.
3. Age.

   Women of mature judgment are better qualified for this work because—
   - (a) They have dignity and poise, qualities necessary in considering public relations.
   - (b) They have platform presence and inspire confidence in an audience.
   - (c) They inspire confidence in customers when making home lighting recommendations.
   - (d) They are seriously interested in business, thereby reducing turnover of employees.

III—Training of Specialists

It is essential that women inexperienced in lighting should be properly trained before coming into actual contact with the public. A satisfactory method of obtaining lighting information is through the Home Lighting schools conducted by manufacturers of incandescent lamps. Contacts made in these schools with others working in similar fields are invaluable. It is likewise desirable that the Home Lighting Specialist should attend these courses as often as possible in order to keep abreast of new developments.

Means of supplementing this instruction are the bulletins issued by the lamp manufacturers, the National Electric Light Association and the Illuminating Engineering Society. Attendance at conventions and local meetings of lighting societies, lectures and courses in decoration, membership in the Illuminating Engineering Society, and exhibitions of lighting and decoration are valuable aids in this work.

Section III

ACTIVITIES

Explanation of Chart

The good-will factor of business plays an important part in all Home Service work. There is great value in securing and maintaining the confidence and good-will of the people with whom contacts are made. These frequently seem to produce no immediate revenue for the company, but the ultimate value cannot be disregarded. Cooperation with architects, builders, etc., through voluntary service produces gratifying results.

The primary function of a Home Lighting Specialist is, by arousing the lighting consciousness of the residence customers, to improve home lighting conditions, thereby raising the residential load and increasing the revenue.

The Home Lighting Specialist will accomplish this in the following ways:

I—Promotion of Adequate Wiring and Lighting

Before large increases in consumption can be expected from either new or existing houses, it is essential that the wiring be brought up to modern standards. In the case of the new home this may be accomplished by working with the home owner, builder, architect and realtor. In new buildings the wiring is one of the last things to be installed, and is the item which is most often reduced in a spirit of false economy.

When modernizing an existing home, the house owner or lessee will be approached. Exhibitions of present approved wiring practice, of a permanent or portable character, are helpful, particularly demonstration homes correctly wired and lighted, which present to the customers a concrete example.

II—Arousing Lighting Consciousness

Lecture work in home lighting is desirable, as this is the most effective means of reaching any great

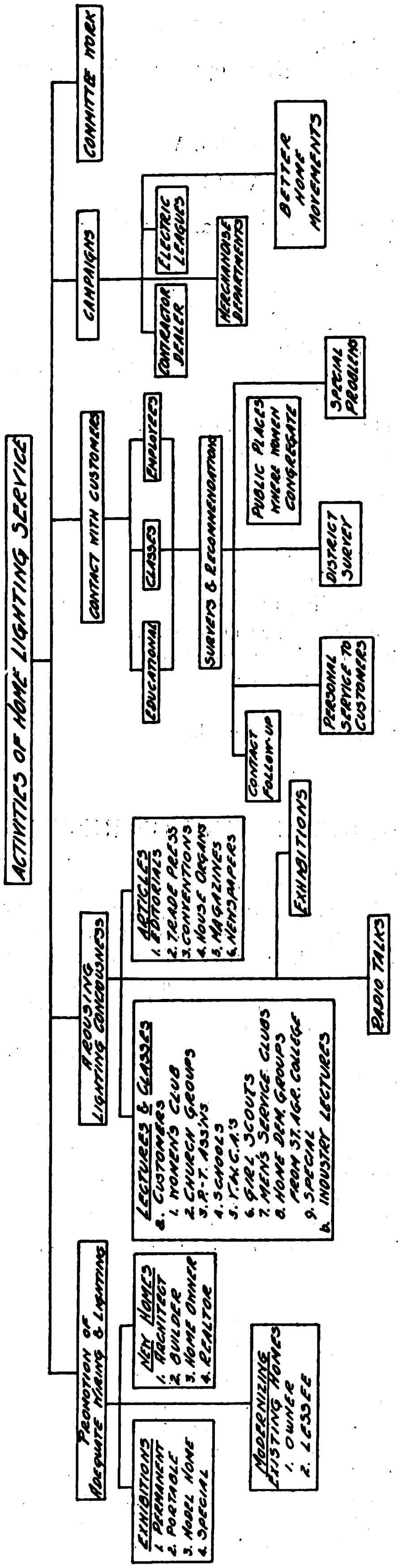
ACTIVITIES OF HOME LIGHTING SERVICE
COMMITTEE WORK
CAMPAIGNS
BETTER HOME MOVEMENTS
ELECTRIC LEAGUES
MERCHANDISE DEPARTMENTS
CONTRACTOR DEALER
CONTACT WITH CUSTOMERS
EMPLOYEES
CLASSES
EDUCATIONAL
SURVEYS & RECOMMENDATIONS
SPECIAL PROBLEMS
PUBLIC PLACES WHERE WOMEN CONGREGATE
DISTRICT SURVEY
PERSONAL SERVICE TO CUSTOMERS
CONTACT FOLLOW-UP
AROUSING LIGHTING CONSCIOUSNESS
EXHIBITIONS
ARTICLES
1. EDITORIALS
2. TRADE PRESS
3. CONVENTIONS
4. HOUSE ORGANS
5. MAGAZINES
6. NEWSPAPERS
RADIO TALKS
LECTURES & CLASSES
a. CUSTOMERS
1. WOMEN'S CLUB
2. CHURCH GROUPS
3. P.-T. ASS'NS
4. SCHOOLS
5. Y.W.C.A'S
6. GIRL SCOUTS
7. MEN'S SERVICE CLUBS
8. HOME DEM. GROUPS FROM ST. AGR. COLLEGE
9. SPECIAL
b. INDUSTRY LECTURES
PROMOTION OF ADEQUATE WIRING & LIGHTING
NEW HOMES
1. ARCHITECT
2. BUILDER
3. HOME OWNER
4. REALTOR
MODERNIZING EXISTING HOMES
1. OWNER
2. LESSEE
EXHIBITIONS
1. PERMANENT
2. PORTABLE
3. MODEL HOME
4. SPECIAL

FIG. 4.

number of customers collectively. Such lectures may be given before groups of customers such as women's clubs, church groups, parent-teachers' associations, schools, Young Women's Christian Associations, Girl Scouts and other organized groups of girls, men's service clubs, home demonstration groups under the State Agricultural College auspices and special groups. The Home Lighting Specialist should also take advantage of any opportunities to talk to those in the industry, at employee meetings, inter-company meetings, Illuminating Engineering Society and local N. E. L. A. meetings.

Instruction in making lamp shades is an effective means of focusing the attention of the customer on the lighting conditions in her home and arousing a desire to better these conditions.

Another excellent medium is the publication of articles on adequate wiring, home lighting and home decoration in the trade press, magazine, newspaper, house organ, editorial column and convention paper.

Radio talks and exhibitions are always helpful.

III—Contact with Customers

The Home Lighting Specialist will make contact with individual customers in a general way with the lectures, in a personal way with the lamp shade classes and through employees. Such contacts will result in requests on the part of customers for assistance in improving the lighting conditions in their homes. Where such requests are received, a careful survey of the existing conditions may be made and suitable recommendations insuring adequate lighting presented to the customer. In this work the Home Lighting Specialist will plan the lighting system for new homes, better conditions in existing homes, make convenience outlet surveys, incandescent lamp surveys and decoration surveys, including the selection of fixtures and portable lamps and will give customers advice on lamp and fixture buying. Therefore, it is necessary that the Home Lighting Specialist be in close touch with available lighting equipment in order that she may make practical recommendations.

By improving the lighting in public places, such as clubs, tea rooms, waiting rooms, etc., an example is set which women will follow in their homes.

It is essential that the potential customer market be analyzed in order to permit the intelligent planning of the work. A district survey would provide such an analysis.

The Home Lighting Specialist should be prepared to render assistance to customers having special problems such as the lighting of theatricals, pageants, fairs, parties, etc.

IV—Campaigns

The Home Lighting Specialist should give her support to campaigns designed to improve home lighting conditions. She should cooperate with the Merchandising Department in its efforts to sell better fixtures or portables and in Better Home Movements. She should also work with the Electrical League and contractor dealers where this seems desirable.

V—Committee Work

The Home Lighting Specialist should be encouraged to participate in committee work. This will provide valuable contacts for her and broaden her outlook.

Section IV

EQUIPMENT

The work of the Home Lighting Specialist should be promoted by providing for her a suitable background, and as much equipment as is possible, bearing in mind the changes which will occur, necessitating keeping up to date in all phases of the work.

A. Office Equipment

It is desirable that the Home Lighting Specialist be provided with a suitable space where she may introduce the home atmosphere and show home lighting effects, since she is dealing with women customers who react quickly to surroundings.

A library of books and magazines on home lighting and decoration is essential.

B. Educational Equipment

The Home Lighting Specialist should have informative literature on home lighting for customer distribution and a suitable announcement of her lecture service to send to women's clubs, church organizations, etc.

She will require portable equipment for lecture work and classes.

She should be given opportunities for personal development.

Section V

VALUE

The work of the Home Lighting Specialist will be of value to various departments of the company as follows:

1. New Business Department
   By stimulating the use of electricity through the increased use of convenience outlets, lamps of the proper wattage, portable lamps and fixtures and decorative lighting.
2. Merchandising Department
   By recommending the use of additional incandescent lamps and lighting equipment.
3. Publicity Department
   By affording publicity of the highest type through lectures and classes.
4. Public Relations Department
   By building up customer good will.
5. Home Economics Department
   By providing further contacts for the Home Economics Department.
6. Lighting Bureau
   By rounding out the work of the Bureau.

PART II—MERCHANDISING METHODS FOR THE RELIGHTING OF RESIDENCES

Introduction

A survey of the part which central stations played years ago in merchandising residential lighting fixtures reveals activity throughout the entire country during the time the wiring of old and new homes was a major issue. Among the merchandising offers prevalent at the time, it will be recalled that a combination set of fixtures for the main rooms of the home was most commonly offered along with the wiring installation.

In those early years the great step in satisfaction from no electric service to electric service became so obvious that sales records were undoubtedly made in all parts of the country. During the following years this work was aggressively carried on until now it is generally admitted that a very large part of the homes within reach of central station service are wired.

Since and during the earlier years of house wiring and fixturing great progress has been made in the art of lighting, until now we find that few of the fixtures previously sold render a service commensurate with present standards. Likewise, the standards of wiring have gradually risen to a point which render the wiring of these previously wired homes very inadequate when compared with present good practice.

As in many businesses a complete cycle of development has occurred since the earlier years of house wiring and fixture campaigns. We are now confronted with the problem of returning to these same homes with a story of modern inexpensive and controllable light. The opportunity exists, and it does not appear to be something the central stations can ignore if they are to continue to be as desirous of having their customers obtain the best of service from their product as they always have been.

The substitution of electricity for candles, kerosene and gas for general lighting has become so nearly universal that now it would be difficult to keep electricity from the homes within reach of present lines. This so-called "consciousness" indicates the value which the public now places upon electric service.

The Present Problem

Today the problem is not that of converting the customer from one of the inferior previously used illuminants, but rather a conversion from an unintelligent use to an intelligent use of the illuminants, which is now available and has been available for a considerable period of time. Obviously, selling the advantages of modern lighting presents a more difficult and complex commercial problem than that encountered in the earlier days of electrification. It is not unlikely that the apparent complexity of the present merchandising problem, that of relighting the homes of this country, has kept many of the central stations from entering this field. Other reasons for not entering this field do not properly enter this discussion.

Scattered activities here and there, with reports of failures or mediocre successes, have undoubtedly done much toward creating an unfavorable attitude toward the commercial possibilities of this field. On the other hand there have been a sufficient number of real successes to prove that the job can be done, and from these successful activities and also from those of the less successful, it is possible to gather together pertinent facts which greatly clarify the issues involved. The pioneers have paid the price for their knowledge, and thus it may be safely said that the selling of better lighting in the home has gone through much of the experimental stage. Relighting activities may be undertaken with assurance of success if these activities are properly handled.

The following present a study of methods and a summary of facts taken from the experiences of many central stations extending over a period of years.

Major Commercial Opportunities

The nation-wide Home Lighting Contest[1] revealed the following percentages of unquestionably obsolete lighting fixtures, drop cords, combination gas and electric fixtures, etc.:

	Obsolescence Per cent	Connected Load Watts
Living room	16	141
Dining room	18	125
Kitchen	65	74
Bedrooms	53	52
Bathroom	50	31
Hallways	25	...

In addition to the magnitude of the field indicated from these figures, extensive observations indicate that fully 50 per cent of remaining fixtures do not provide lighting according to present good practice.

Kitchen

From these facts and the actual experiences of a large number of central station companies, there is strong evidence to support the contention that the Kitchen Lighting Campaign should be the first to be conducted. The element of personal taste is less marked in selecting lighting equipment for this room than in the other rooms of the home thus far campaigned, hence one type of fixture is much more universally acceptable. Low price of fixture makes for less sales resistance. Longer hours of burning and a fixture employing one large lamp are guarantees of a definite reward. One type of fixture assures definitely improved and satisfactory lighting results. Only a moderate amount of training of the sales force in the subject of lighting is required.

Porch and House-Number Lighting

Recently the combination porch-light and illuminated house-number has been actively campaigned and with gratifying results. There are a number of points in connection with this campaign item, which make it nearly comparable with kitchen lighting as an initial activity. It is in the class of the lower-priced items. It is relatively free from the item of personal taste. There is practically none in use, and probably the most outstanding feature of practicability lies in the fact that the problem of installation can be exceedingly simple. The salesmen in the majority of cases make the installation by merely substituting the new unit for the old porch globe in the already installed ceiling-holder. Each installation is seen by a large number of people, and in this way it creates a certain amount of self-advertising. Due to the wattage of lamp used it does not appear to be comparable with the kitchen unit as a revenue builder; however, the illuminated number part of the unit should initiate more burning hours for an outlet which is generally quite insignificant.

Dining-Room

The dining-room has been considered the most desirable as the second room for a relighting activity, although a number of second activities have been built around the bedroom or living-room. In communities having a large industrial population there are excellent reasons for choosing the dining-room. In the homes of the industrial worker the dining-room is often used as a place for reading, studying and sewing. This is particularly true where there are children, for the dining-room is the only place in which there is a table of satisfactory size for school work and at which there is a lighting fixture. Good lighting for the conservation of the eyesight of children is a powerful sales argument. Finally, the competition with portable lamps is at a minimum in the dining-room. Lighting activities planned for the dining-room should incorporate lighting education for the sales force. The educational program should specifically develop a proper understanding of the facts pertaining to good lighting and the saving of the eyes of youngsters.

Bedroom

The bedroom also has been campaigned very successfully as a second-room activity. Satisfactory fixtures are usually obtainable costing less than satisfactory fixtures for either the living-room or dining-room, and the sales force need not be as thoroughly trained on the subject of lighting. Personal taste is usually more easily satisfied.

Living-Room

Although there are very good reasons for campaigning the living-room fixtures after the kitchen, very few companies have tried this for their second activity. All members of a family have a specific interest in this room, and when the budgeting of the family resources is considered, changes in furnishings are looked upon with more favor than in other rooms of the home. Pride of ownership is gratified, inasmuch as guests are entertained here. Usage of equipment permits decided increases in electrical consumption. The present disuse of ceiling fixtures which is becoming more customary is due in part to the unsuitability of equipment now installed. A better lighting education of the salesforce is needed for this activity than that which is required for some of the other activities.

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[1] Report of the Lighting Committee, Commercial National Section, 1924-25 Residence Lighting—Analysis of Home Lighting Contest Primers, M. Luckiesh, Subject Chairman.

Portable Lamps

Portable lamp campaigns have been conducted successfully by a large number of companies, although interest in this relighting item appears to be waning. Competition from many sources accounts in a large measure for this attitude. This item has a unique appeal to people living in rented homes, inasmuch as it can be transported readily. This factor is of considerable importance, for the number of rented homes probably constitutes one-half of the total. At present there is a marked scarcity of portable lamps possessing real lighting merit. Future developments incorporating improved lighting results from portable lamps should offer new opportunities for further development of the residence lighting field.

Laundry

The appeal for better lighting in the laundry is similar to that used in the kitchen. The utility light is a combination of porcelain enamel steel reflector and white glass inclosing globe, equipped with a closed-metal loop-suspension and extension cord which permits in many cases its use where desired without additional wiring. Due to its general usefulness it is not uncommon to find that the sale of one of these units leads to the sale of a second. The work-bench in the garage has drawn many of these units from the ironing or washing machine in the basement. After being inconvenienced in this way on a number of occasions, the housewife has insisted on having the second one purchased, so that she will not be further inconvenienced on laundry days. This unit, while not an unusual revenue producer, provides a means of creating an appreciation of better lighting in the mind of the householder.

Incandescent Lamp Sales

Extensive observations and surveys indicate that people in general do not have an extra supply of lamps on hand. As lamps burn out, empty sockets are created. Procrastination and habit go hand in hand in contributing toward this condition. If these sockets are filled and kept filled, it is not unreasonable to assume that revenue increases and increased customer satisfaction will follow. Furthermore, the introduction into the home of extra lamps of various sizes improves the likelihood of having on hand the right lamp for the socket. Assortment cartons of lamps should contain some of the higher wattage lamps (60-watt and 100-watt), inasmuch as there are a number of places in the average home where these sizes can be used advantageously. The carton lamp sales activity can specifically accomplish two things, namely, fill empty sockets and introduce the higher wattage household sizes of lamps. The achievement of both of these considerations would be a definite step toward adequate lighting in the home.

The carton sale of lamps can be effected through the employee group or through Boy Scout or high school groups. The particular points of merit which facilitate the handling of this activity versus the specific room activity are as follows: The sale price of the item is low, personal taste factor is eliminated, no outside help is necessary inasmuch as the problem of installation is eliminated and only a very limited lighting education is necessary.

Organization

Companies having new business or commercial departments and a regular force of house-to-house solicitors appear to be in a preferred position for successful activities. If, however, the department and solicitors have never sold lighting before, they must be thoroughly trained on lighting subjects before they are sent out. Power salesmen as a rule have not been successfully employed in house-to-house selling; but appliance salesmen, properly educated, have made good records.

Central stations without commercial departments or solicitors have employed temporary solicitors for relighting activities. In general this has proved to be an unsatisfactory undertaking. Solicitors hired temporarily cannot learn central station policies and the proper lighting story in a few days. These temporary salesmen are usually concerned with obtaining commissions, and they have often been found making extraordinary promises which they knew could not be fulfilled.

Employee Cooperation

Many central stations have featured their relighting activities to their employees shortly before the general public announcement. Special price concessions have been made to the employees at this time in order that definite action might follow quickly. This method is of value in getting some actual installations in use and is also of great value in educating employees.

The enthusiastic support of the entire employee group is of great importance, and a definite means of creating it should accompany each activity. Practically how far into the organization this can go depends upon local circumstances. Many trial installations of fixtures have been ordered removed from the homes of friends of central station employees because some employee, a friend of the family in question, either did not know about the activity, or was only lukewarm when questioned concerning the specific fixture. Strange as it may seem, practically all central station employees are looked upon as authorities on things electrical by their circle of friends and acquaintances. The word of mouth advertising which can filter through from employees to their families, friends and then on to the friends of these friends becomes a very big influence in the aggregate. The size of this formidable group warrants that their interest and enthusiasm be fortified by employee enthusiasm.

In some cases central stations have paid commissions to employees bringing in orders for fixtures. Commissions have also been paid to employees bringing in "leads" where sales could be easily made. This offer instills enthusiastic support for the movement and also offers an opportunity for creating a favorable impression for the activity among the employee group.

The enthusiasm of the regular solicitors must not be jeopardized by employees canvassing their territories. The plan used must provide for cooperation between the employee-group and the solicitor-group.

The interest and enthusiasm of the employee-group has been very effectively created through the medium of a sales activity centered about a "home convenience carton" assortment of Mazda lamps. All departments of the company, including meter reading, sales, engineering, line, office, purchasing, etc., have made excellent records in this type of activity. Quotas based on the sale of one carton to each six residence meters have been exceeded in a large number of activities. Single individuals have sold practically 700 cartons of lamps during a single activity. At twenty-five cents per carton, the usual commission, this activity netted these individuals $175. In addition prizes are usually offered.

Plans of Operation

It will be found advantageous to place the guidance and supervision of the lighting activity in the hands of one person. Those companies having a number of communities isolated from the main headquarters can operate the identical activity at the same time with one individual in charge of each of the isolated communities. The managers in each of the separate communities follow the same plan as that set at headquarters, and are made individually responsible for the results in their respective territories.

The manager in general charge must, of course, select the equipment to be sold, establish prices, determine payment schedules, trial installations, salesmen's territories and commissions, determine installation policy, follow-up promptness of installations, establish quotas, advertising, and provide the educational program for the salesmen. Meetings at the beginning of each day are invaluable for the checking of installation orders, for instilling enthusiasm and for the trading of experiences between the salesmen themselves.

The equipment to be sold must do what the story and advertising claims for it. Obsolescence, novelty of appearance, specifications, etc., taken singly are not strong enough in themselves to create sales. Eye conservation appears to create the greatest urge to buy.

Time payments permit of a great number of sales which could not otherwise be made. Payments extending over a period of nine to twelve months have been used in practically all cases, and the amounts are added to the regular electric service billing.

Trial Installations

Trial installations seem to be indispensable. A number of men who have been actively in charge of successful campaigns claim that a relighting activity should not be conducted unless trial installations are incorporated in the plan. The experiences from all fields of lighting confirm the idea that demonstrations of lighting are needed if the message of better lighting is to be conveyed. The trial installation is a means of providing a lighting demonstration, and in this case is even more valuable because it is conducted on the prospective customer's premises. It has been found that a trial installation of sufficient duration (30 days, for example) affords the prospective customer full opportunity to have lived with the equipment. It is not uncommon to find that people at the end of the trial installation have become fully accustomed and quite oblivious to the improved lighting. While every reasonable effort is made to retain the installation in case of cancellation, it is not at all unusual to find that a fulfilled order for removal at the end of thirty days brings the customer back to a full realization of the superior lighting which has been enjoyed. The contrast has often created an immediate voluntary reorder of the fixture or the sale of a fixture at some later date. The likelihood of this occurring is obviously reduced as the time of trial installation is reduced. The least amount of time that may be used has not been reduced to exact figures, inasmuch as this factor has not been subject to extensive research.

In planning the activity it must be remembered that surveys indicate that about one-half of the people are living in rented homes. These people will often consider the activity unsuited to their conditions. Fixtures have been sold to renters by extending the trial installation to these people the same as to the people owning their homes. Furthermore, the central station agrees to rehang the new fixture in the event that the purchaser moves within one year. The old fixture is wrapped for storage. These latter two offers are to be made at no additional cost to the customer. Some sales have been made without this offer, but the offer is considered a very important sales aid.

Survey Method

One method, requiring the surveying of the wiring and lighting of the home called on, possesses merit which deserves attention. Survey cards with spaces for the number and kinds of fixtures, portable lamps, lamp bulbs and convenience-outlets in each of the principal rooms of the home are carried by the solicitors. This affords an opportunity for the solicitor or the lighting department to make complete recommendations for the relighting of the home. Aside from this, these cards, when filled, afford an excellent reference for determining the most profitable future activities to be undertaken. It must be borne in mind that this method reduces the number of calls which the solicitor can make. For this reason adjustment in the salesmen's compensation has been made for the information obtained.

Salesmen's territories, quotas, commissions and bonuses should be established in advance and should be adhered to strictly. Variations in quotas between different groups of the sales organizations are often found necessary in the original plan due to variations in livelihood and density of population in the respective territories. While the possible number of calls a day per salesman may vary, it has not been unreasonable to assume that fifteen calls can be made. These are to be made from a properly selected list with credit standing assured. With a thirty-day activity planned, each salesman should report on from approximately 300 to 400 customers. From past experiences with well-organized activities directed to well selected lists, it is not unusual to find from 25 to 35 per cent of the customers called on were sold. Knowing the number of salesmen actively participating in the activity, it is possible for the manager to not only establish quotas, but also to have some idea of the size of the order to place with the manufacturer supplying the lighting equipment.

Compensation

The sales force is usually dependent on commissions for income, although a small salary in addition is not uncommon. Whatever the commission, although it is higher than that on regular appliance sales, it should be based on an adequate income for good work and should be as nearly comparable as possible per month with that obtained from activities on other merchandise sold. If this is not done, there will be an unsatisfactory reaction against the activity and future lighting activities. Some central stations have compensated their salesmen for both the sale of the unit and the amount of the added wattage as well. This appears both commendable and reasonable when the revenue from just an additional 25-watt lamp in an active socket is considered. On analysis this modest addition can increase the gross revenue $2.50 per year per customer.

An added incentive has been created in some activities by the offering of prizes. However, in general it is not wise to offer a grand prize for the most units sold, as it usually narrows the possible prizewinners down to a few men. Rewards for the attainment of individual quotas have proved to be effective. Prizes for the best showing over different periods during the campaign keep competition alive. This latter arrangement is particularly suitable for the first and last part of the campaign.

One method of simplifying the billing and recording of accepted lighting fixtures which has been on trial is to have the trial order agreement which is signed by the prospective customer read in essence as follows: If, at the end of thirty days, the customer has not requested the removal of fixture, it is understood that the customer is satisfied and that he desires to keep the fixture. A certain sum is to be added to the electric service bill until the total quoted sum has been paid. On the other hand, orders for removal under the thirty-day trial period are to be executed promptly by the central station company and without charge to the customer.

Fixture Hanging

It is very important that installations of all orders be made as soon as possible, preferably within 24 hours after the order is taken. Lack of coordination at this point has proved to be fatal to a number of activities.

The installers of equipment like the employee-group can do tremendous harm as well as work for definite good. Usually contractor-dealers have been called on to supply fixture hangers. Their competence for satisfactory installations is highly desirable. Therefore it is essential that they, and every individual associated with the activity, must know what is being offered, what its desirable points are, what increase in the electric service bill may be encountered, if any, and he must be behind the activity. While this may be somewhat difficult to obtain, from the fixture-hanger group, every effort should be made to obtain it, and, furthermore, checks should be made to maintain it. Negative attitude on the part of the fixture hanger accounts for many cancellations.

The payment for fixture hanging should be liberal enough to make it attractive to the contractor-dealer. The paying of a like amount for the original installation and the removal of the same fixture is to be avoided. Obviously this encourages the fixture-hanger to work for removals. An arrangement of paying more than the usual price for the original installation, with the understanding that no pay for removals will be made, eliminates the previously mentioned danger. Even paying double the usual price for hanging, which would also allow for removal of all fixtures should it be necessary, may be more advisable than the fee split into two parts.

Advertising

Newspaper space which the central station usually has under annual contract should be used to feature all of the important features of the campaign. Teaser advertisements preceding the campaign are to be followed by regular, clean-cut, simple advertising based on the appeal which is most effective in creating interest and an urge to buy. Of course, all of the appropriate appeals should be incorporated where possible, but these should be subordinated to the main issue. At present the best framework upon which to build the advertising is that of being "kind to the eyes," or the conserving of vision. The results obtained from this appeal, and the experiences of the solicitors have been continually adding support to the contention that this appeal possesses merit greater than another appeal taken alone. One group has declared that new fixtures are needed because, artistically, the fixtures in use are out of date; a few have argued that specification fixtures will turn the trick; some have advocated that lighting effect is the thing; and others feel that the story of reducing the burdens in the home is sufficiently convincing. Each of these attacks has been featured more or less to the exclusion of the others, and in practically every case only partial success has resulted. Procrastination on the part of the buyer has to be overcome, and none of these issues taken alone, or even several of them used together, seems to create the urge to act immediately. We cannot think of the home without thinking of children. Their eyes are immature in growth and in function and, therefore, they are readily susceptible to injury and malformation. Near-sightedness, eyestrain, nervousness and other disorders often result from inadequate and improper lighting. These and other similar arguments pertaining to better seeing and to conservation of vision, properly presented, urge immediate action on the part of the householder.

Convincing results have been obtained from certain recent home-relighting activities, of limited duration, based on the eye-conservation appeal.

Company A	5,884	lighting fixtures
Company B	2,546	lighting fixtures
Company C	3,498	lighting fixtures

Obviously a well-planned activity incorporated all of the other arguments.

Newspaper advertising has proved its ability to create interest and sales for relighting in almost every case. A recent test case of its effectiveness in a small community is of interest. The newspaper advertising was run for eight weeks, and at the same time two solicitors were put out in the territory. At first little or no interest could be sensed by the solicitors, and the sales which were made were largely due to their direct efforts. As the program of advertising progressed, the solicitors began to find that the people knew more and more about the relighting story and were more interested. The sales increases from these two solicitors, doubling as it did between the first and eighth week, illustrates the effectiveness of newspaper advertising. Of course, allowance must be made for the accumulated experience of the solicitors between the first and eighth week.

Show-Windows and Stores

Show-window displays and store displays should feature the equipment being sold, its advantages, trial installations, prices, payment plan, etc. Inside of the store demonstration booths should be erected in which the story and the lighting effect may be demonstrated by the store sales force, or even by one person assigned to it. Before and after contrasts are particularly effective in emphasizing improved lighting.

Where there is dealer cooperation on the activity, the cooperating group should be urged to make similar window displays. In many cases the central station has furnished the fixtures for these trims.

Educational Program

Specially trained people appearing before women's clubs to tell the story of better lighting enables the central station to get a more detailed and lasting impression of the importance of lighting before the public than the door-to-door sales force can unaided. A series of such meetings should be conducted before the specific time of the activity both for educational reasons and for the prospect list which can be built from them.

Lamp Shade Classes

Lamp shade classes are unique in creating lighting consciousness. These classes create many new sockets and provide means of obtaining excellent prospect lists. As a builder of good public relations they possess unusual merit.

Lighting School

The education of the sales force requires time and should be included in the general plan.

The educational program or sales school for lighting should immediately precede the activity with no intervening time spent on other merchandise. A typical educational program for the sales force follows.

First Day

Talks by several of the executives to convey the importance of the activity to the sales force.

The present status of wiring and lighting in the average home in your territory.

Luncheon

Better lighting a factor in improved customer relations.

Home lighting recipes.

Eyesight conservation.

Evening of the First Day

General employee meeting.

Inspirational talks on lighting and the campaign which is to follow the next week.

Second Day

How to appraise residence lighting fixtures.

The merits of the fixture which you are going to introduce to the public.

Experiences of other companies in selling better lighting.

Luncheon

The sales plan and quotas.

The advertising program.

Sales aids.

Playlet: "Turning to the Light" to be enacted by employees.

Evening—Banquet

While longer schools have been conducted, they have usually been held previous to two lighting activities; i.e., for commercial lighting and residential lighting. This program is intended primarily to educate; however, it is also the time for the manager of the activity to build up a spirit of enthusiasm for the undertaking.

Lamp Recipes

When the development of residential lighting began, standardization appeared hopeless owing to the variable personal taste. However, with the unfolding of fundamental requirements of convenient and adequate utilitarian lighting, it was found that personal taste is not involved in the principles of lighting recipes, and that it has wide latitude in utilizing them. In other words, the fundamental lighting recipes are the same in a cottage as in a mansion.

Taste has wide range in the choice of proper equipment. Light-users must be taught that good lighting principles are more or less fixed, although they allow a wide latitude of choice and arrangement. Lighting recipes afford a direct means to an end. They have been available for quite a few years, and by no means have they outlived their usefulness. In fact, they are such necessary and very important aids in the development of residential lighting that constant effort is being made to simplify and to extend them.

Lamp recipes—specific lamps for specific purposes—are evolving from the lighting recipes. Where one of these becomes established, confusion disappears and residential lighting makes a permanent advance. For example, one central station operating kitchen-unit campaigns for the last five years has and is selling the 150-watt Mazda daylight lamp for this purpose. During this time this lamp has been termed the "kitchen-unit lamp," and is now recognized as such. By establishing this lamp recipe, a recent survey of the homes on this utility's lines reveals that practically three out of four kitchens having modern lighting are using this lamp instead of the more generally recommended 100-watt inside-frosted lamp. This illustration of the efficacy of the idea is of particular interest when further analyzed. Neither the fact that the 150-watt Mazda daylight lamp at presents costs nearly three times as much as the 100-watt regular lamp, nor the difference of 50 watts, which during a year increases the consumer's bill perhaps 15 per cent, prevented the acceptance of this lamp recipe.

Other lamp recipes in the home can also be stated in terms of utilitarian requirements. As we approach the predominently esthetic application of lighting in the home, the lighting recipes—and, therefore, the lamp recipes—become less standardizable. Finally we have a large field of predominantly esthetic lighting in which personal taste and ideas have full sway.

Many specialized businesses base their development upon the service to be obtained from the product. Lighting recipes and lamp recipes afford the lighting interests a practical means of developing the residential lighting business. This foundation can be built most readily upon utilitarian requirements which these recipes supply. Esthetic aspects need not cause any worry—they will be taken care of in other ways for the time being. Even these as they become more understood and more generally used will evolve to the form of lighting recipes.

Contractor-Dealer Co-operation

As it is imperative to have cooperation from all electrical interests, the contractor-dealer should be included in the plan of activity. Liberal offers for sales, handling of time payments and all reasonable concessions should be made. This has been done repeatedly in all parts of the country, and more active participation on the part of this group is anticipated.

Repeating Relighting Activities

Many central stations entered the field of relighting residences via the kitchen unit, and having conducted one campaign have never re-entered the field. The reasons advanced for the discontinuance of relighting activities generally come down to either of the two following reasons: The activity was not successful and creates poor customer relationships, or the activity was very successful and the job is done. There is plenty of evidence to refute both contentions. For example, one company has repeated the kitchen activity periodically each year until now they have sold over 20,000 units. During the last three years in their sixth, seventh and eighth activities, they have averaged 2000 units per year. Even though relighting in the other rooms of the home has occupied their attention ever since their second campaign, the kitchen unit has never been forsaken. Even now they still have some 40,000 customers that have not been sold. From this it is obvious that a single activity does not conclude the job. By having a specified time on the calendar of each year for relighting, all details of the plan can be established well in advance. This is of real importance, as last minute arrangements leave many openings for trouble both on the inside of the organization and on the outside.

DOMESTIC OIL BURNERS

Scope

The Oil Burner Subcommittee of the General Merchandising Committee was organized in the National Electric Light Association administrative year 1927-28 to make a study in conjunction with a committee of the Oil Heating Institute; "to produce a report covering load factor characteristics, revenue producing value, service requirements, etc., of the oil burners; to conduct engineering and performance tests on different types of burners and to suggest methods of possible cooperation between the oil burner manufacturers and the power companies."

This report is published in the following administrative year by the Merchandise Sales Committee, Commercial National Section, and it is desired to give due credit to the General Merchandising Committee, 1927-28, and its Oil Burner Subcommittee.

The first work undertaken was a survey of all existing information on the subjects listed within the scope of the Committee. The purpose of this survey was to obtain records of what had been done in all phases of the industry, to coordinate the engineering tests which had been previously made; to determine the various methods of merchandising and sales financing either in use or proposed, and to obtain the opinions of various representative men of the industry concerning the general subject.

Sources of Information

The sources from which the information contained in this report was drawn were: American Oil Burner Association, American Petroleum Institute, individual oil heater manufacturers, oil companies (both producers and distributers), heating and ventilating engineers, members of Oil and Gas Section of American Society of Mechanical Engineers, electrical engineers and manufacturers interested in motors and ignition and also in radio interference, a manufacturer of blower fans for hot air furnaces, manufacturers of hot air furnaces, boiler manufacturers, Underwriters' Laboratories and Agencies, National Fire Protection Association, and electric light and power companies.

The cities which were covered by questionnaire letters requesting information, personal visits and published reports include: Atlanta, Ga., Boston, Mass., Chicago, Ill., Cleveland, Ohio, Detroit, Mich., Kansas City, Mo., Louisville, Ky., Minneapolis, Minn., Newark, N. J., New Orleans, La., New York, N. Y., Philadelphia, Pa., Pittsburgh, Pa., Portland, Ore., Salt Lake City, Utah, San Francisco, Cal., and St. Louis, Mo. In addition to the foregoing list, questionnaires were sent to manufacturers located throughout the country.

The data obtained cover in excess of 700 actual burner installations and represent information on the daily, monthly and seasonal electrical load characteristics.

DESCRIPTIVE

Number and Distribution of Domestic Oil Burners

Distribution of Burners

The total number of domestic oil burners in service up to Jan. 1, 1928, is estimated by a representative of the American Oil Burner Association as 304,200. This estimate is based on the "National Survey of Fuel Oil Distribution, 1927," by E. B. Swanson, a joint report of the U. S. Bureau of Mines and the American Petroleum Institute.

The number of burners installed in 1926, according to a survey made in February, 1927, and described in P. E. Fansler's book, "House Heating with Oil Fuel," was 76,964. The American Oil Burner Association estimates that approximately 95,000 were sold during 1926.

Mr. Fansler's total for 1927 was estimated as 15 per cent less than his total for 1926, or approximately 65,400. The estimate by a representative of the American Oil Burner Association for this same year was 85,000. The number of burners sold by twenty-nine companies covered in this report was found to be approximately 64,000.

This value was obtained from the replies to the N. E. L. A. questionnaire direct to the manufacturers. The total number sold by twenty-six of these same manufacturers, also taken from the replies to the questionnaires, was found to be 273,000. The replies to the questionnaire in so far as they applied to number of burners are given in Table I.

Distribution

There is no record available which gives the actual distribution of the various burners. A good idea of the relative distribution may be obtained, however, by comparing the number of dealers in the various parts of the country. The distribution of dealers has been estimated by a representative of the American Oil Burner Association as follows:

1. New England, metropolitan New York and northern New Jersey	33%
2. Pennsylvania, Ohio, southern New Jersey, Delaware, Maryland, Kentucky, Illinois (belt along the Mississippi Valley)	35%
3. West Coast	15%
4. Middle West	17%
	100%

Publication No. 289-8, Serial Report, Merchandise Sales Committee.

TABLE I

NUMBER OF BURNERS SOLD

Name of Burners	1927	Total
A. B. C.	1,700	10,000
Baker	1,500	8,000
Ballard, Jr.	900	1,800
Bettendorf	200	200
Caloroil	616	2,607
Chalmers	100	500
Combustion	1,723	9,494
Commonwealth	300	498
Electrol	3,500–4,000	17–18,000
Fluid Heat	200	319
Gulf	1,700	2,500
Hardinge	2,000–3,000	*9,000
Hart	2,000	11,000
Johnson	5,150	47,500
*Kleen Heat	2,400	*28,000
Lammert & Mann	1,000	3,000
Marr	600	5,000
McIlvaine	200	600
Nokol-Aetna	6,000	45,000
Nu-Way	1,500	5,000
Oil-O-Matic	15,000	60–70,000
*Petro	1,000	3,100
Quiet May	3,912	10,000
Ray	*4,100	45,000
Rickard	150	200
Silent Automatic	5,000	13,000
Super Oil Heator	2,000	5–6,000
Sword	650	2,200
Timken-Detroit-Socony	2,750	9,000
Torridheat	518	2,000
Wayne	1,000	3,000

*Figures from estimates of *Fuel Oil & Temperature Journal.*

Types of Boilers and Furnaces

The boilers and furnaces used in domestic heating may all be included under three main classifications: Hot water, steam and hot air. The number of types of boilers and furnaces which come under these three main classifications is very large. The classification including hot water boilers is probably the most specific of the three main classifications, as all hot water installations are based on the A. S. M. E. Boiler Construction Code, a standard code which has been in use since 1912. This code also covers steam boilers, but there are several types of boilers, such as the vapor, low, medium and the high pressure types. In both steam and hot water systems there are, of course, the usual differences due to individual design and also to the gradual improvements of any particular design, but there are, however, many features which are common to the class. In the case of hot air furnaces this is not generally the case. Until very recently there has been no standard code covering the design of domestic furnaces. In many installations the local dealer has designed and assembled the type of furnace which, in his estimation, best fitted the case. While the interior, the metal castings and metal frames may be made by a national manufacturer, it would be hard to recognize some of these castings installed in furnaces designed by the local heating man. This condition is, however, now correcting itself as there has been recently adopted a code which covers the design of domestic furnaces and is intended to be used as a supplement to the "Standard Code for Warm Air Furnaces" which covers the installation.

Types of Oil Burners

Classification of Burners—Natural Draft Type

There are many ways of classifying oil burners, but the two methods which are the most common differentiate as to whether the oil is vaporized or atomized and whether the draft is mechanical or natural (atmospheric). The natural draft burners are practically all based on the same general principles. The flow of oil to the burner is adjusted by means of a valve, usually of the needle type, and is fed into the combustion chamber, where it is vaporized by the application of heat. The air necessary for combustion is drawn into the chamber by the suction created by the natural draft of the chimney and the rising of the heated gases after combustion. In the majority of atmospheric burners it is necessary to control the amount of heat and to ignite the oil manually, but safety devices may be obtained which will shut off the supply of oil after combustion has ceased. In general it is necessary to manually reset these devices after they have once operated. Any attempt to force the atmospheric type of burner beyond its limited capacity, without some special means for providing excess air, meets with results that are unsatisfactory. Incomplete combustion, which is indicated by smoke, soot and low efficiency, is a natural consequence.

In some instances the straight atmospheric type is modified by the provision of a blower for mechanically inducing a draft to be used when it is necessary to force combustion. The principles of combustion remain the same, the blower merely provides the necessary air to burn more oil and thus force the heating system. It would be just as inefficient to operate the blower with a limited amount of oil as it would be to provide an excess of oil without the necessary air for complete combustion.

Mechanical Draft Type

The mechanical draft classification is the most important; it includes three specific types of drafts: (1) the draft caused by an independent fan or blower, similar to the one used in connection with the atmospheric type of burner; (2) the draft caused by air furnished by the burner in excess of that needed for atomization, but necessary for complete combustion; (3) the draft caused by the burner itself in the process of atomization. There has been an effort to have this third type of draft included among the main classifications as a mechanically induced draft.

Types of Control

The four types of control which are quite common may be classified as follows:

1. Manual Control—This provides for manual heat control, ignition and extinguishment; it may, however, include safety devices which require manual resetting after operation.
2. Semi-Automatic Control—This includes either a room temperature control (some form of thermostat) or some form of pressure control. The burner is usually manually ignited and extinguished.

3. Full-Automatic Control—This includes some form of automatic temperature or pressure control and also provides for automatic ignition and extinguishment.
4. There is also available a refinement of the full-automatic control provided by a master control clock, which will automatically start the burner at predetermined times if heat is necessary, and also stop the burner regardless of temperature. This master control clock is not usually supplied with the original full automatic equipment.

Types of Ignition

The different types of ignition used in connection with mechanical draft burners may be broadly classified as gas pilot, electrical arc, combination gas-electric and manual. The manually operated types constitute a relatively small amount of the total. There are two types of gas pilots, the constant flame and the expanding flame; both are located in the combustion chamber and are designed to burn continuously when the burner is in operation. In the constant type the flame is uniform throughout operation; in the expanding type the flame is small when the burner is not operating and enlarges during the period of operation. The electrically ignited types may be classified as temporary and continuous. The temporary type operates a few seconds, starting just before the oil is injected into the burner and continues until ignition has taken place. The continuous type starts just before the oil enters the combustion chamber and continues until the burner is extinguished and the oil supply shut off. In the combination gas-electric ignition an electric spark ignites a gas burner, the gas flame in turn ignites the oil. This method eliminates the necessity of a continuous gas flame. There is a marked difference in opinion concerning the advantages and disadvantages of the gas, gas-electric and electric types of ignition.

Types of Oil Fuels

The grades of oil which are generally used in domestic burners are now referred to as "Furnace Oil-Light" or "Oil No. 1"; "Furnace Oil-Medium" or "Oil No. 2"; "Furnace Oil-Heavy" or "Oil No. 3"; "Fuel Oil-Light" or "Oil No. 4." "Fuel Oil-Medium" or "Oil No. 5", and "Fuel Oil-Heavy" or "Oil No. 6" are not as yet in common use in the domestic field, although there is a tendency toward consideration of the heavier oils by the designers of the various burners. (The numbers used in connection with the types of oil refer to the number given the oil in the specifications recently adopted by the American Oil Burner Association, and which are now used by the Underwriters' Laboratories in their standard listing.) The new specifications are given in detail in Appendix A of this Report.

Until recently the gravity of the oil has been the chief consideration in the selection of oil fuel, the different types being classified as "Furnace Oil" 36-40 deg. Baumé, "Light Fuel Oil" 28-32 deg. Baumé and "Diesel Oil" 25-27 deg. Baumé. The need for further definite classification first appeared in the so-called "Diesel Oil Classification" where viscosities were specified varying from 45 to 75 seconds (Saybolt Universal at 100 deg. fahr.) for the different burners.

The groups into which the new specifications divide with respect to specific gravity, as listed by Underwriters' Laboratories, are included in Table II.

TABLE II

GRADES OF OIL

New	Old
Oil No. 1	36-40° Baumé
Oil No. 2	32-36° Baumé
Oil No. 3	28-32° Baumé and Special 25° Baumé Pacific Coast Diesel Oil
Oil No. 4	24-26° Baumé
Oil No. 5	18-20° Baumé or U. S. Gov't Bunker Fuel Oil "B"
Oil No. 6	10-18° Baumé or U. S. Gov't Bunker Fuel Oil "C"

The relation of the specific gravity to the heat content of the oil has been compiled by H. F. Tapp of the American Oil Burner Association and is plotted in Fig. 1. for various grades of oil.

The fact that the requirements for the different burners vary from Oil No. 1 to Oil No. 4 does not mean that the burner designed for Oil No. 1 will burn oil No. 4 with equal satisfaction. Since all tests to determine the hazard involved in the use of particular burners are based on a particular grade of oil, consideration should be given to the oil furnished to a burner. The oil for which each burner is listed may be found in the Underwriters' Laboratories current list of Inspected Oil Burners, a copy of which may be obtained from Underwriters' Laboratories, 207 East Ohio Street, Chicago, Ill.

Types of Oil Tanks

The size of tanks used in domestic installations was found to vary from 275 to 2000 gal. The smaller sizes are usually delivered to the installation completely assembled, while the larger sizes are sometimes built up and electrically welded on the premises.

The capacity of the largest exposed tank allowed within a building at present by the "Regulations of the National Board of Fire Underwriters for the Construction and Installation of Oil Burning Equipments and for the Storage and Use of Oil Fuels in Connection Therewith," is 275 gal. The use of this tank makes the whole installation easy to install or remove, and, therefore, makes a desirable installation for the tenant as well as the home owner. The larger tanks are sometimes buried in the yard and other times under the cement floor of the cellar. When buried in the yard the assembled tank is generally used; when buried under the cellar floor the use of the built up tank is more common. The larger tanks are generally advocated by oil companies as they reduce the possibility of emergency calls due to lack of oil. They also allow the delivery of a full tank-truck load and reduce the possibility of overfilling and its attendant evils. However, in thickly

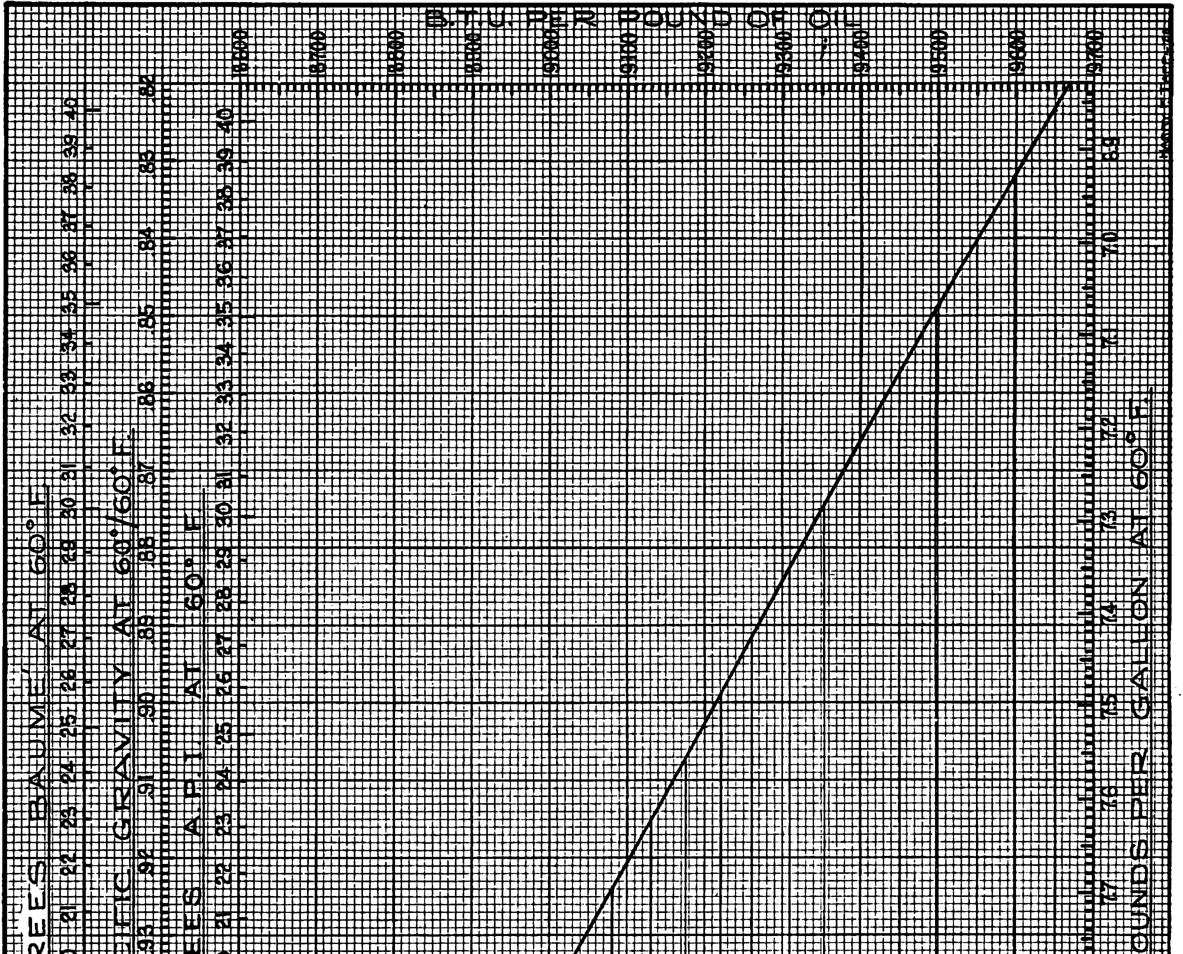

FIG. 1—SPECIFIC GRAVITY—HEAT CONTENT.

settled communities oil companies are establishing regular delivery service which makes the inside tank entirely satisfactory. The actual size of the tank should depend largely upon local conditions and ordinances.

Sizes and Types of Individual Motors

The motors used in the various types of oil burners vary in size from 1/20 to 10 h.p., this range includes the smallest motor used for domestic heating and the larger ones used for industrial heating. It has been estimated that 95 per cent of the domestic motors do not exceed ¼ h.p. Various surveys made in the past two or three years indicate that ¼ h.p. is the average size. The data collected in this survey indicate that the general average will be somewhat smaller for the past year. Current practice as indicated by the replies to the Committee's questionnaire to manufacturers is given in Table III.

TABLE III

MOTOR TYPES AND SIZES

Name of Burner	Name of Motor	Type	Size, H.p.	Speed, R.p.m.
Aetna	Holtzer-Cabot	Repulsion induction	⅙-½	1,750
	Westinghouse	Repulsion induction	2	1,750
A. B. C	A. B. C.	Universal	1/12	12,000
Arrow	Robbins & Myers	Repulsion induction	¼	3,500
Ballard Junior	Westinghouse	A. R. S	¼	1,725
Bettendorf	Emerson	Repulsion induction	¼	1,150
			⅓	1
			¾	1,750
Caloroil	Century	Split phase	¼	1,750
		Repulsion induction	½	1,750
		Repulsion induction	2	1,750
		Repulsion induction	3	1,750
Chalmers	Janette	Repulsion induction	⅙	3,600
			¼	1,800
			⅓	......
Combustion	Standard makes	Repulsion induction Poly phase	¼-3	1,150
Commonwealth Engineering	(2) G. E	Split phase	⅙	3,600
		Poly phase	1/20	10,300
Electrol	G. E			
	Century	Split phase	....	1,750
	Ohio Electric	Repulsion induction	⅙	1,150
	Emerson			
Fluid Heat	G. E	R. S. A	¼	1,725
Gulf	G. E.	Repulsion induction	¼	1,750
Hardinge	Century	Repulsion induction	¼-½	1,750
	Star			
Hard Model D-1	Emerson Wagner	Repulsion induction	⅙	1,725
Hard Model D-2	Emerson Wagner	Repulsion induction	¼	1,725
Hard Model D-3	Emerson Wagner	Repulsion induction	½	1,725
Johnson	Westinghouse	Split phase	1/12	3,450
		Repulsion induction	¼-2	3,450
Kleen Heet—Series 800	Century	Repulsion induction	⅙	1,750
Lammert & Mann	Baldor G. E		....	1,200-1,750
Marr Model E-g	Century	Repulsion induction	¼-1	1,725
Model H	G. E	Split phase	1/20	1,725
May Type A	G. E	Split phase	⅛	1,750
Type B	Century	Repulsion induction	¼	1,750
Type C	Century	Repulsion induction	½	1,750
McIlvaine		Split phase	1/20	750
Nokol-Rotary	Ohio	Split phase	1/12	1,750
Nokol-Standard	Janette, Westinghouse	Split phase	1/10-¼	3,500
Nu-Way	Emerson	Split phase	1/20-⅛	1,800
		Repulsion induction	⅙-⅓-¾	1,200
Oil-O-Matic	Baldor	Repulsion induction	¼	1,200
Petro L D-0			⅛	3,600
Petro L D-1			⅙	3,600
Petro L D-2			½	3,600
Petro L D-3			1	1,800
Ray	Westinghouse	Repulsion induction	⅛-10	3,450
Rickard	Janette	Repulsion induction	⅙	1,750
Silent Automatic	Ohio	Split phase	1/12	1,750
Super	Leland	Repulsion induction	⅙	1,140
			¼	1,725
Roto Flame	Janette Special		1/20	3,400
Timken Detroit Model 20	Robbins & Myers	Split phase	⅙	1,750
Sword & Kimber	G. E		⅙	1,750
Torridheet	Emerson		....	1,750
Wayne	G. E	Repulsion induction	⅙-¼-½	1,725

Practical Considerations in the Application of Oil Heat to Hot Water, Steam and Hot Air Boilers and Furnaces

One of the primary difficulties which is confronted in existing heating plants is that the installed radiation (the size or number of radiators or registers) is not, in many cases, sufficient to heat the house when the temperature of the radiators or hot air registers are at normal values. The radiator must, therefore, be overheated or the hot air excessively warm in order to furnish the necessary heat. The boiler or furnace may also have to be forced in order to furnish the necessary temperature at the radiator or register. When a boiler or furnace is forced beyond its capacity there is reduction in efficiency. The design of many boilers or furnaces makes them unsuitable for oil heating, and in some instances it is undesirable to install a burner in such an installation. There are also instances where particular types of burners are especially suitable for certain types of installations. This is exemplified by those companies who handle more than one make of burner in order to obtain better efficiency from the existing installations.

In the case of steam or hot water it is sometimes possible to increase the boiler capacity beyond its capacity as a coal burner by the intense application of the oil burner flame in the available area. This has sometimes led to the assumption that in any unsatisfactory heating plant an oil heater will correct the difficulty. This is not always the case. A careful survey should be made of the existing installation and the amount of radiation should be checked with standard practice in each case.

The application of oil heat to hot air systems is a problem in itself, and many additional factors not important in steam and water problems, must be considered to obtain good efficiency. Hot air furnaces will not stand an indefinite amount of heat without some provision to insure a very rapid circulation of the air. If the burner is improperly installed in the ashpit, unsatisfactory results are probable. This is due to the fact that the burner will heat the cold air intake and thus prevent the free passage of cold air to the furnace. This may be overcome, however, by the use of suitable baffles in the furnace or by the insertion of a forced air fan in the cold air supply. Great care should be taken to prevent the overheating of the furnace, for if it has become overheated there is always more or less leakage through the combustion chamber to the hot air supply. This also applies to the installation of a burner in an old furnace in which case the furnace should be overhauled if there is any question of its ever having been overheated. The 1928 Handbook of Domestic Oil Heating shows the proper method of installing a burner in a warm air furnace.

Present Status of the Development of Oil Burners

For several years the Underwriters' Laboratories of Chicago (an institution established and maintained by the National Board of Fire Underwriters for the purpose of rating the fire, accident and casualty hazards of various devices) have made a study of the hazards involved in the domestic oil burner, and they now regularly certify types submitted to them. The procedure followed by the laboratories contemplates that a burner will be sent to them for examination and test, and if the device is found to be satisfactory or if the hazard involved has been reduced to a satisfactory degree, a permit to attach the laboratories approval label to the devices will be issued to the manufacturer. Within the last year and a half the cases where, with the exception of a few technicalities, heaters did not comply with the existing requirements the first time they were submitted, have been the exception rather than the general rule. Another index of the state of development of the heaters is evidenced by the fact that of more than one hundred commercial makes of burners, only eight have been removed from the list in the last year and these eight were removed on account of discontinuance of manufacture. In order to remain on the approved list it is necessary for the manufacturer to maintain his standards of production so that the finished product is at least as good as the sample submitted to the laboratories.

The test requirements of the laboratories have now been definitely established so that all burners are given an equal test. These requirements include the operation of the burner, in accord with the published instructions and with the recommended grade of oil, for a period of from four to five weeks. The Underwriters' Laboratories have issued a very interesting booklet showing the actual test installations of various burners and also describing the testing and proper installation of domestic oil burners for safety. This booklet may be obtained direct from the Underwriters' Laboratories, 207 East Ohio Street, Chicago, Ill.

The National Board of Fire Underwriters published in 1925 the "Regulations for the Construction and Installation of Oil Burning Equipments and for the Storage and Use of Oil Fuels in Connection Therewith."* This booklet gives the rules which should be adhered to in order to prevent any undue hazard being caused by the burner or its equipment. A complete list of inspected oil burners may be obtained from Underwriters' Laboratories, 207 East Ohio Street, Chicago, Ill.

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* These regulations are now being revised and the 1928 edition will be issued shortly.

TEST METHODS AND RESULTS

Electrical Characteristics

In obtaining data for the daily, monthly and yearly load curves, recording meters and standard watt-hour meters were used. In one instance an index of yearly load curve was obtained from differences in consumption of specific residences for corresponding periods of nine months before and after the installation of the burner.

In making this survey the current required for starting the motors was not considered, as a joint committee of interested parties, including the National Electric Light Association, had already reached substantial agreement covering this subject. The new specifications were published in the *Electrical World* and are reproduced herein as Appendix D.

The Degree Day Method

It is a fact that the amount of coal, oil, gas or electricity required to heat a given house is dependent on the temperature maintained within the house and that existing outside. Since the amount of oil delivered to the burner is generally fixed, the interval of operation would largely depend on the relative temperatures; in other words, if the outside temperature is lower, more heat will be required and the burner would therefore operate a greater proportion of the time. The electrical consumption of a burner is practically constant, and since the number of operating hours depends on the temperature, it follows that this consumption would be a function of the temperature. On this basis the electrical consumption was checked against the heat required in a large number of installations, and it was found that it was in all cases practically proportional to the heat required. The unit of heat which was used in this comparison is known as the "degree day," and is exactly what the name implies, *i.e.,* 1 deg. for a period of 24 hours, or one day.

The temperature at which artificial heat is required was taken at 65 deg., in accord with the recent finding of the American Gas Association, which stated that if the heat supply was not automatic, the average person in the United States would manually operate some heater at this temperature. Having established the temperature of 65 deg. fahr. as a standard basis, the number of degree days required in any month was found by subtracting the average mean temperature for any month from 65 deg. if it does not exceed this value, and multiplying the remainder by the number of days in a month. For example, in Denver, Colo., the average mean temperature for the month of January, 1927, was 35.2 deg. fahr., subtracting this value from 65 we have 29.8 deg. and multiplying this by 31 (the number of days in a month) we have 923.8 deg. days for January. This degree-day method makes it possible to compare the heat required in a given installation when located in any part of the country in which accurate temperature records have been kept. It is therefore apparent that tests made in any locality, which include a detailed description of the exposure, construction, condition of the house, condition of heating plant, installed radiation, required radiation, radiation of boiler or furnace and a general description of the various factors which influence the radiation required, may be readily applied to any other locality with absolute assurance of comparable results.

General Results

The interval of operation of the burner is dependent on the setting of the thermostat, the construction and exposure of the house, and in some cases where the radiation is either greater or less than that required, this also is an important factor. The best condition from the standpoint of general efficiency occurs when the burner operates approximately twenty minutes on and twenty minutes off during the heating hours in the severest weather. The variation in temperature under these conditions should never exceed plus or minus 2 deg. fahr. Burners are often set to operate at 50 deg. fahr. from 11 P. M. to 6 A. M., although in some instances uniform heat is maintained during day and night.

The average load drawn by typical burners during operating periods was found to vary from 100 to 350 watts. The peak load in general occurs between 6 and 8 in the morning and tends to flatten out during the day. The total consumption varies with the geographical location of the installation and, other things being equal, is dependent on the temperature maintained within and that existing without.

The average monthly and yearly consumption in kilowatt-hours, as obtained by the methods described previously under electrical characteristics in Detroit, Kansas City, Minneapolis, Philadelphia and New York are given in Table IV. The table also

TABLE IV

KW-HR. CONSUMPTION

Location	Number of Burners	Average Monthly Consumption Kw-hr.	Average Yearly Consumption Kw-hr.
Detroit	205 (1927)	....	258
Philadelphia	301 (1927)	....	424
Kansas City	21 (1925)	....	194
Kansas City	20 (1926)	....	177
Minneapolis	35	43.*	386
New York	....	41.1	329**
General	....	57.1	456†

*The kw-hr. consumption of these burners was determined by subtracting the total energy used for a period of nine months previous to the installation of the oil burner from the total energy used for the same period subsequent to the installation of the burner. This method, would have a tendency to give values somewhat in excess of that actually used, as it is possible that these same installations have added some other appliances during the period.

**The total yearly consumption is based on an eight months heating period. The average consumption was obtained from monthly bills.

†This value was calculated from data furnished by a representative of the Oil Burner Association and is based on a heating period of eight months.

includes the estimated average monthly consumption for the country at large compiled from data furnished by a representative of the American Oil Burner Association.

Individual Test Results

Detroit

In Detroit, integrating watt-hour meters were installed on 55 oil burners. The results of a year's operation were published in an article by H. A. Snow in the *Electrical World* Jan. 21, 1928.

Fig. 2 is the daily load curve of 1000 oil burners based on the average of the 55 burners tested. It will be observed that the peak of this curve occurs between the hours of 6 and 8.

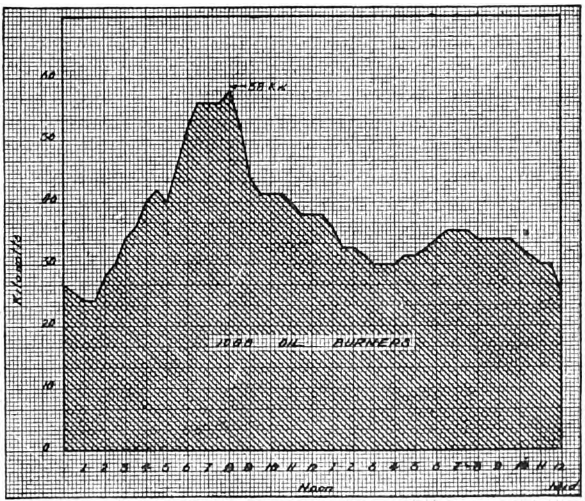

FIG. 2—DAILY LOAD CURVE 1000 OIL BURNERS—DETROIT.

Fig. 3 shows the yearly distribution of the load for an average oil burner based on the results of the tests made on the 55. The annual load factor for a single oil burner was found by Mr. Snow to be 17.1 per cent and the load factor for a large group was found to be 25.4 per cent. The increase being due to the intermeshing of the demands of the individual machines.

Fig. 4 shows the number of degree days required for each month and the percentage of coal, oil and gas which should be consumed for any given month in 1927. This figure was based on the degree day method assuming a temperature of 65 deg. fahr.

In Fig. 5 the solid curve is the number of degree days plotted against the months. The dash curve is the kilowatt-hour consumption for the 55 burners test plotted against the months.

Buffalo

Test work was conducted from March 28 to April 16 on two burners located in Buffalo. The kilowatt-hour consumption for each day during this period is plotted for the two different burners in Fig. 6. Fig. 7 is the degree day curve for the corresponding period. The values in Fig. 6 were obtained by means of a recording watt-hr. meter. The values used in computing the degree days in Fig. 7 were obtained from recording thermometers. Fig. 8 is the degree day distribution for the city of Buffalo in 1927. It also gives the percentage fuel distribution for the entire year. Applying the fuel distribution (as given in Fig. 8) to the kilowatt-hour consumption during the test period, the yearly kilowatt-hour consumption for these two installations has been derived and is plotted in Fig. 9. It will be noted that in these two installations the consumption of one burner is approximately twice the other. The values used in curve 2 of Fig. 6 are approximately double those used in curve 1. Curve 2 in Fig. 6 follows the curve in Fig. 7 a little closer than curve 1, and in examining the charts from the recording meters it was found that burner 2 operated at shorter intervals than burner 1. In some instances burner 2 operated as many as five times while burner 1 was operating continuously. In checking the description of the two installations it was found that installation No. 2 was exposed on four sides and the house was of stucco, while installation No. 1 was exposed only on the front and rear, there being houses on both sides, and was of a frame shingle construction.

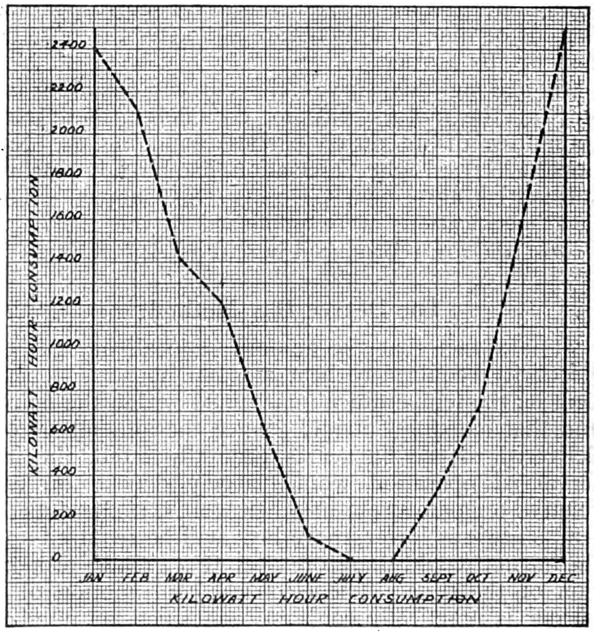

FIG. 3—YEARLY LOAD CURVE AVERAGE BURNER—DETROIT.

The size of the burner is apparently correct in each instance. The house exposed on four sides

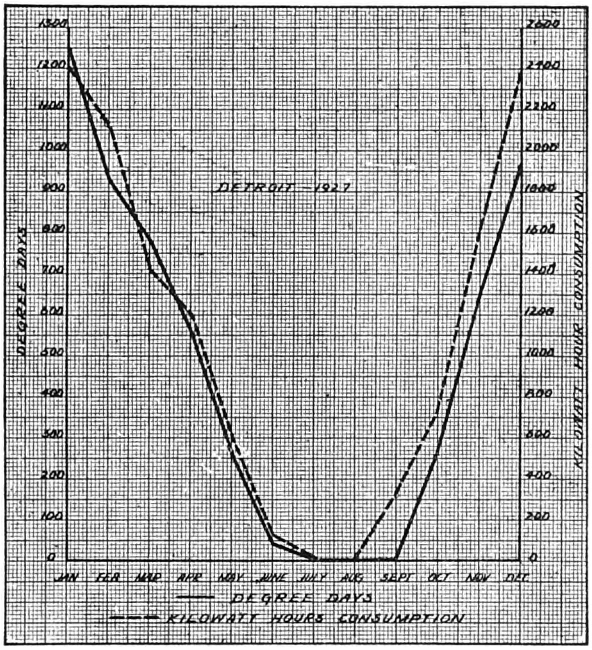

FIG. 5—Actual Versus Computed Kw-Hr. Distribution—Detroit, 1927.

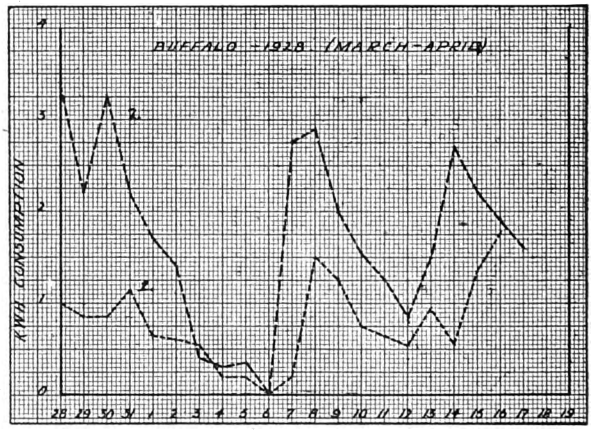

FIG. 6—Kw-Hr. Consumption Test Installation—Buffalo.

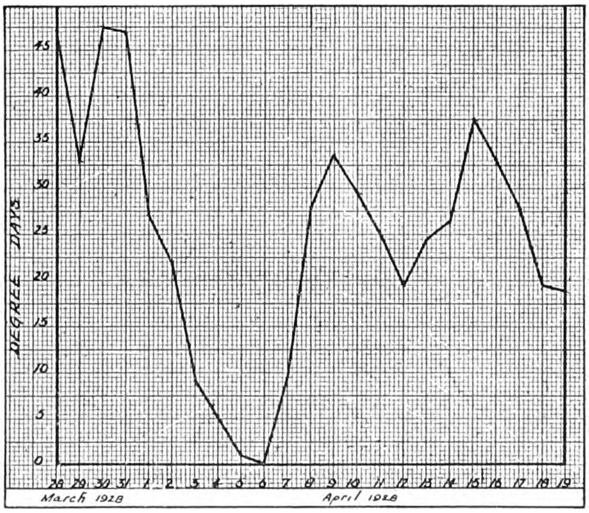

FIG. 7—Degree Day Curve at Time of Test—Buffalo.

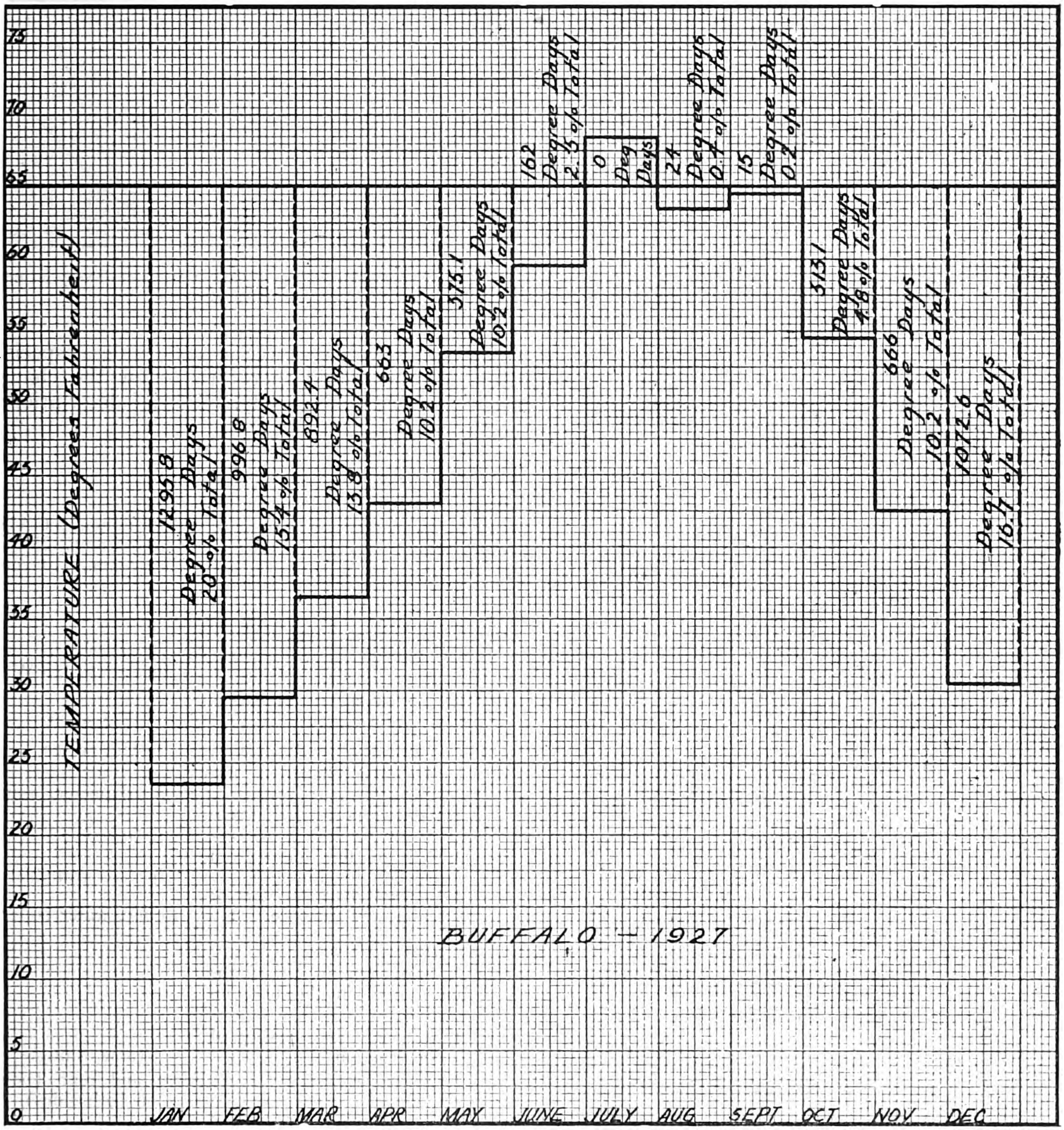

FIG. 8—DEGREE DAY—PERCENTAGE KW-HR. DISTRIBUTION—BUFFALO, 1927.

TABLE V

RESULTS OF PHILADELPHIA TESTS

From 10 A.M.	To 10 A.M.	Operating House			Oil				Electricity, Kw-hr.					Gas					Temperature, °F.	
					Total Gals.		Gallons		Total Kw-hr.			Kw-hr.		Total Cu. Ft.		Cu. Ft Gas				
		Per Period	Per Day	Total Test	Per Period	Per Test	Per Day	Per Oper. Hr.	Per Period	Per Test	Per Day	Per Oper. Hr.	Per Gal. Oil	Per Period	Per Test	Per Day	Per Oper. Hr.	Per Gal. Oil	Average Outside	Average Inside
2-3-26	2-5	30.25	15.1	30.25	38.0	38.0	19.0	1.255	8.0	8.0	4.0	0.265	0.211	230	230	115	7.6	6.06	28	74.3
5	9	41.03	10.25	71.28	52.75	90.75	13.2	1.285	14.0	22.0	3.5	0.342	0.266	452	682	113	11.0	8.58	30	75.2
9	10	13.56	13.56	84.84	11.75	102.5	11.75	0.866	3.0	25.0	3.0	0.222	0.256	114	796	114	8.4	9.70	25	74.3
10	12	30.05	15.02	114.89	39.25	141.75	19.6	1.305	10.0	35.0	5.0	0.333	0.255	224	1020	112	7.5	5.70	23	75.2
12	16	40.18	10.05	155.07	50.0	191.75	12.5	1.245	12.0	47.0	3.0	0.299	0.240	444	1464	111	11.0	8.90	33	77.0
16	20	40.45	10.1	195.52	49.0	240.75	12.25	1.212	8.8	55.8	2.2	0.218	0.180	452	1916	113	11.2	9.20	34	77.0
20	26	56.55	9.4	252.01	67.0	307.75	11.2	1.185	13.4	69.2	2.25	0.237	0.200	666	2582	111	11.8	9.95	36	77.0
26	3-3	56.5	11.3	308.51	85.75	393.5	17.1	1.975	14.0	83.2	2.80	0.322	0.164	550	3132	110	9.75	6.40	29	76.1
3	12	106.3	11.8	414.81	123.25	516.75	13.7	1.160	25.0	108.2	2.78	0.235	0.200	1002	4134	111	9.45	8.10	33	75.2
12	25	97.25	7.44	512.06	161.5	678.25	12.25	1.640	24.3	132.5	1.87	0.250	0.153	1442	5576	111	14.8	8.9	38	77.0
Total 50 days		....	10.25	512.06	......	678.25	13.55	1.325	......	132.5	2.65	0.259	0.1955	......	5576	111	10.9	8.22	30.9	75.83

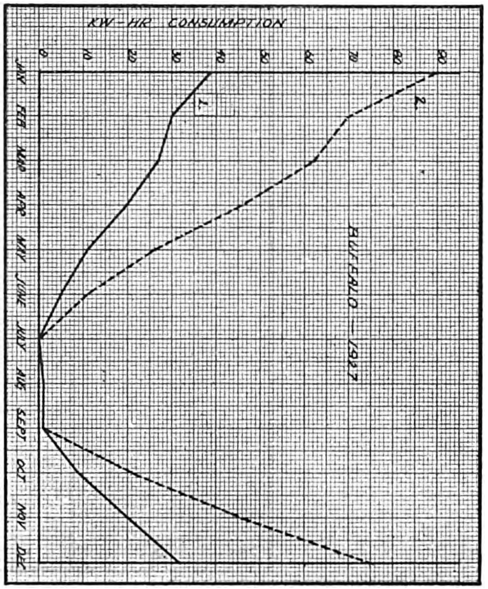

FIG. 9—COMPUTED YEARLY CONSUMPTION TEST BURNERS—BUFFALO.

would naturally dissipate heat faster unless especially insulated, and would therefore follow the changes in temperature more closely. A brief description of the two installations follows:

INSTALLATION No. 1

1. *Motor*

(a) Mfrs. name and type.....	Westinghouse OAH
(b) Rating	⅛ h.p., 2.6 amp., 25 cycle, 1140 r.p.m., 110 volt

2. *Heating System*

(a) Maker's name, type and serial number	American Radiator, Arco Ideal, No. 425-W
(b) Rating in sq. ft. of radiation surface	1575 sq. ft.
(c) Hot air, steam or hot water.	Hot water
1. Size and shape of fire box	25 in. diameter, round
2. Relative position of burner in fire box	Center, level of grate
3. Path of flue gas (from fire box to chimney) ...	Up, see pamphlet
4. General characteristics of boiler and furnace	Round, water boiler

3. *Description of House*

(a) A brief description of the house used in the test, including:	
1. Materials and quality of construction	Frame, shingle
2. General exposure	Front and rear (houses on both sides)
3. Approximate per cent of outside watts occupied by doors and windows	17.3 per cent
4. Approximate total cu. ft. heated	16,000 cu. ft.

INSTALLATION No. 2

1. *Motor*

(a) Mfrs. name and type	Special R S A
(b) Rating	¼ h.p., 4 amp., 350 watt, 25 cycle, 1500 r.p.m., 110 volt

2. *Heating System*
   (a) Maker's name, type and serial number .... Heggie-Simplex Boiler Co., Size No. 303, Serial No. 4598
   (b) Rating in sq. ft. of radiation surface .... 1050 sq. ft. of steam
   (c) Hot air, steam or hot water. Steam (vapor type)
      1. Size and shape of fire box .... 42 in. x 30 in. x 22 in.
      2. Relative position of burner in fire box .... rear-bottom

3. *Description of House*
   (a) A brief description of the house used in the test, including:
      1. Materials and quality of construction .... Stucco
      2. General exposure .... Four sides, no nearby houses
      3. Approximate per cent of outside walls occupied by doors and windows...... 16.5 per cent
      4. Approximate total cu. ft. heated .... 24,600 cu. ft.

Philadelphia

Table V gives the results of a 50 day test on one burner located in Philadelphia. This test was made under the direction of the Philadelphia Electric Co. in 1926, the results being published in the July 3, 1926, issue of the *Electrical World*. The detailed description of the test, including methods, results and costs may be found in Appendix B of this report.

Fig. 10 gives the degree days and also the per cent of the total fuel for each month for Philadelphia, based on the degree day method.

Fig. 11 gives the kilowatt-hour distribution for a normal year. It is based on a total consumption of 424 kw-hr., which was obtained from the records of the Philadelphia Electric Co. The distribution was obtained by means of the degree day method.

Kansas City

Table VI gives the kilowatt-hour consumption for twenty oil burner installations in Kansas City and also includes the number of rooms in each installation. This table is the result of a survey made by C. F. Foley, vice-president of the Kansas City Light & Power Company, and published in the April 24, 1926, issue of the *Electrical World*. The values in this table are plotted as the dash curve in Fig. 12. The solid curve in this figure is the degree day curve which was plotted from the values obtained in Fig. 13. The dash curve does not follow the solid curve exactly but is of the same general shape. This is probably due to the fact that the normal temperature was used in the calculations instead of the actual temperature for the year 1925.

St. Louis

Fig. 14, 15 and 16 show the average steam required for days in October, December and March. These curves were published in the June 3, 1926, issue of the *Electrical World* by Warren L. Berry of the Union Electric Light & Power Company, St. Louis, under the caption "Analyzing Steam Heat Requirements." We have shown previously that the kilowatt-hour consumption is proportional to the amount of heat required. These curves, therefore, represent the distribution of the kilowatt-hour as well as the steam consumption. The installations covered by these curves are mostly hotels and office buildings. It will be noted that the peak occurs between the hours of 7:30 and 9:30 in October, 7:30 and 9 in December and 7:30 and 9 in March. This peak is somewhat later than that shown by Mr. Snow in Detroit, but is exactly what would be expected. The domestic peak would naturally occur somewhat earlier than the more or less industrial peak. The curves, however, give a general indication of the distribution to be expected.

Fig. 17 to 28 inclusive contain the degree day

TABLE VI

CONSUMPTION BY MONTHS FOR TWENTY OIL-BURNER INSTALLATIONS IN KANSAS CITY, MO.

Installation......	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total Consumption
January..........	20	24	36	40	38	38	22	50	26	38	42	46	60	80	64	36	52	62	58	56	888
February.........	20	22	30	26	28	32	14	38	22	42	28	40	34	70	46	40	42	44	46	46	710
March...........	16	24	32	20	22	24	22	30	16	20	20	20	32	54	34	32	30	34	34	34	550
April............	8	16	32	12	16	18	0	24	10	14	8	22	16	34	24	18	28	28	20	24	372
May.............	2	4	4	4	8	8	0	10	6	4	0	8	8	14	12	2	12	14	8	10	138
June............	0	0	0	2	4	2	0	4	4	2	0	6	2	30	6	0	6	8	4	8	88
July............	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
August..........	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2
September.......	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	2	2	0	10
October.........	2	0	0	2	4	6	0	8	0	1	0	2	8	2	2	0	2	6	6	4	55
November.......	4	4	18	6	8	8	4	6	4	4	12	8	10	8	12	2	4	12	26	6	166
December.......	20	12	30	26	20	18	12	30	12	16	46	38	32	52	32	26	22	34	58	26	562
Annual consumption, kw-hr....	92	106	182	138	148	160	74	200	100	141	156	190	202	344	234	156	198	244	262	214	3,541
Number of rooms.	4	5	5	...	6	6	7	7	8	8	8	8	8	8	9	10	12	12	12	15	......

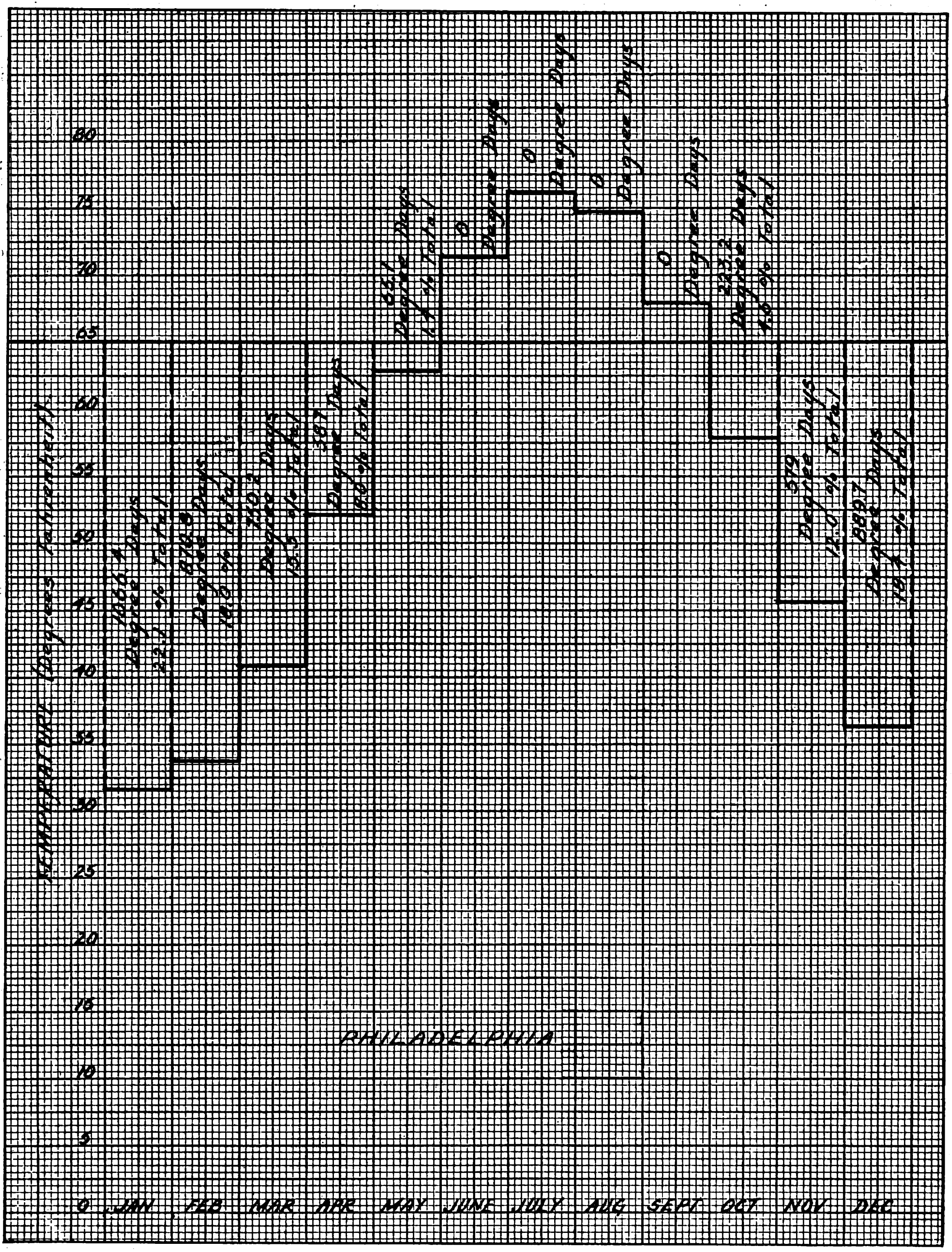

FIG. 10—DEGREE DAY—PERCENTAGE KW-HR. DISTRIBUTION—PHILADELPHIA.

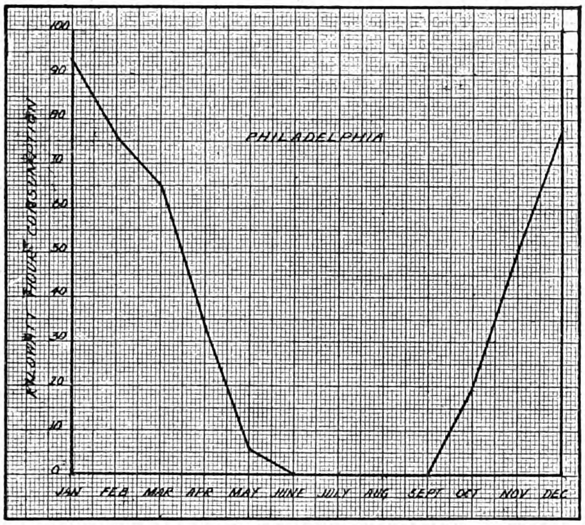

FIG. 11—KW-HR. DISTRIBUTION AVERAGE BURNER—PHILADELPHIA.

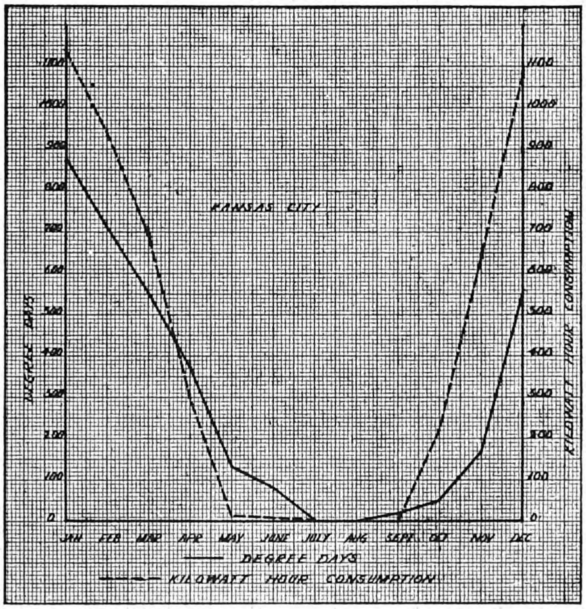

FIG. 12—ACTUAL VERSUS COMPUTED KW-HR. CONSUMPTION—KANSAS CITY.

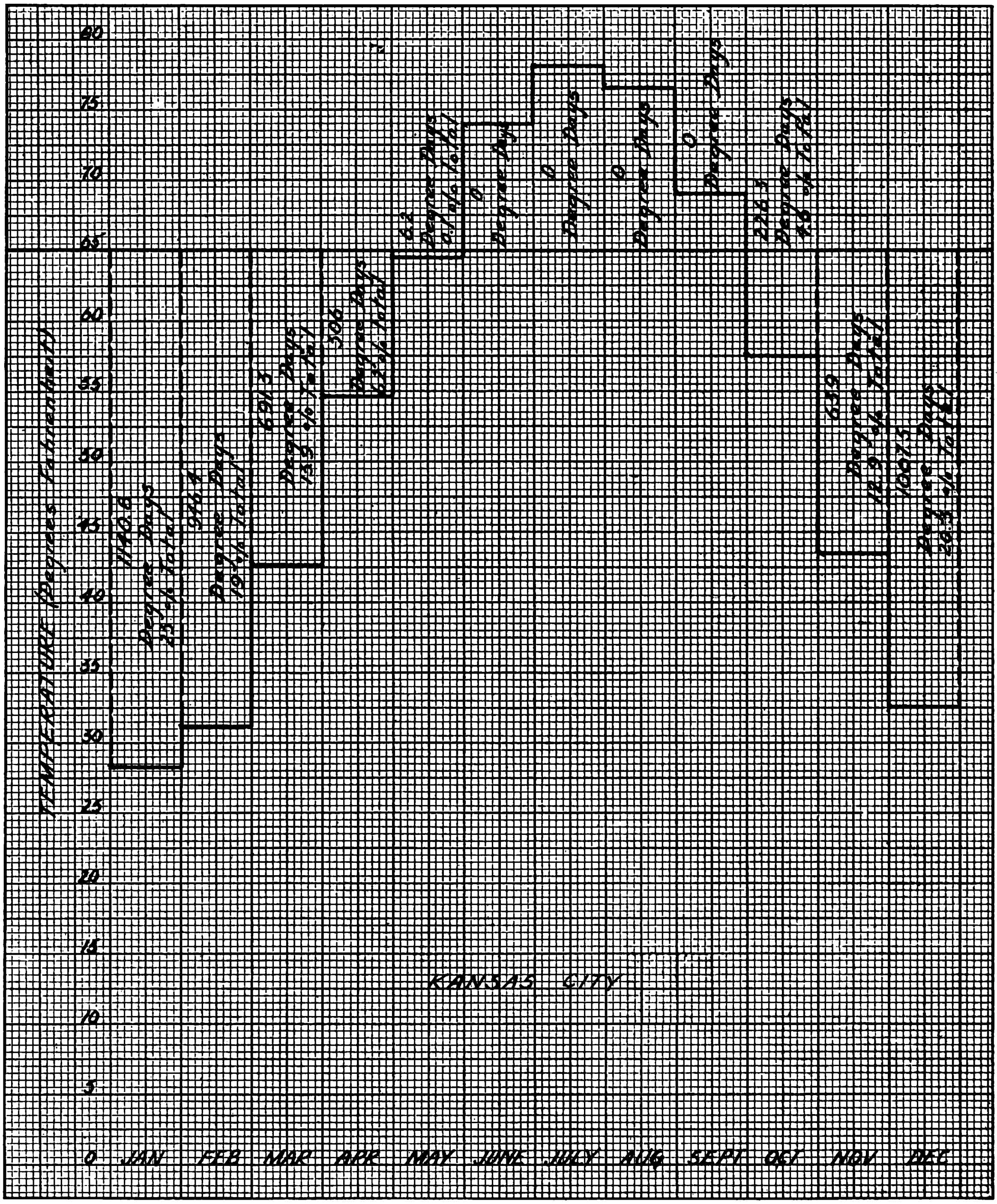

FIG. 13—DEGREE DAY—PERCENTAGE KW-HR. DISTRIBUTION—KANSAS CITY.

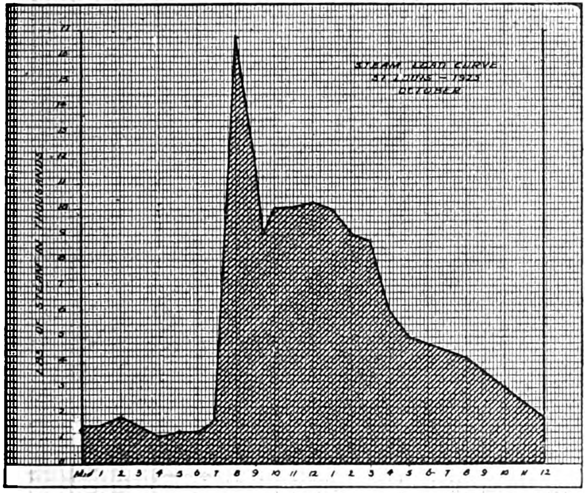

FIG. 14—STEAM LOAD CURVE, ST. LOUIS, OCTOBER, 1925.

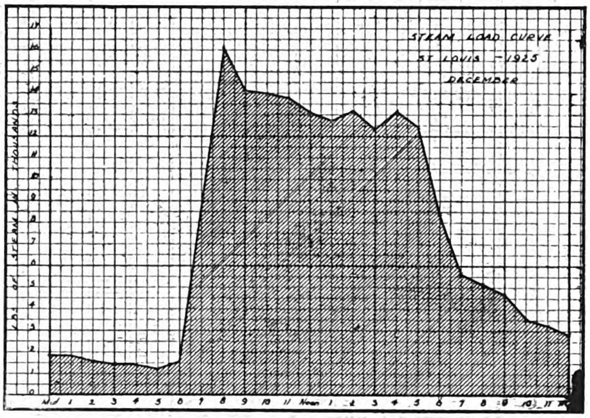

FIG. 15—STEAM LOAD CURVE, ST. LOUIS, DECEMBER, 1925.

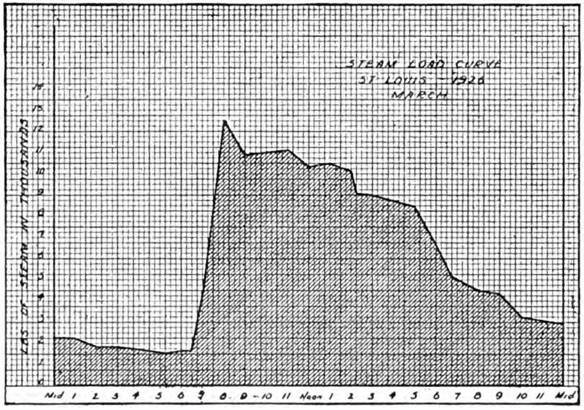

FIG. 16—STEAM LOAD CURVE, ST. LOUIS, MARCH, 1926

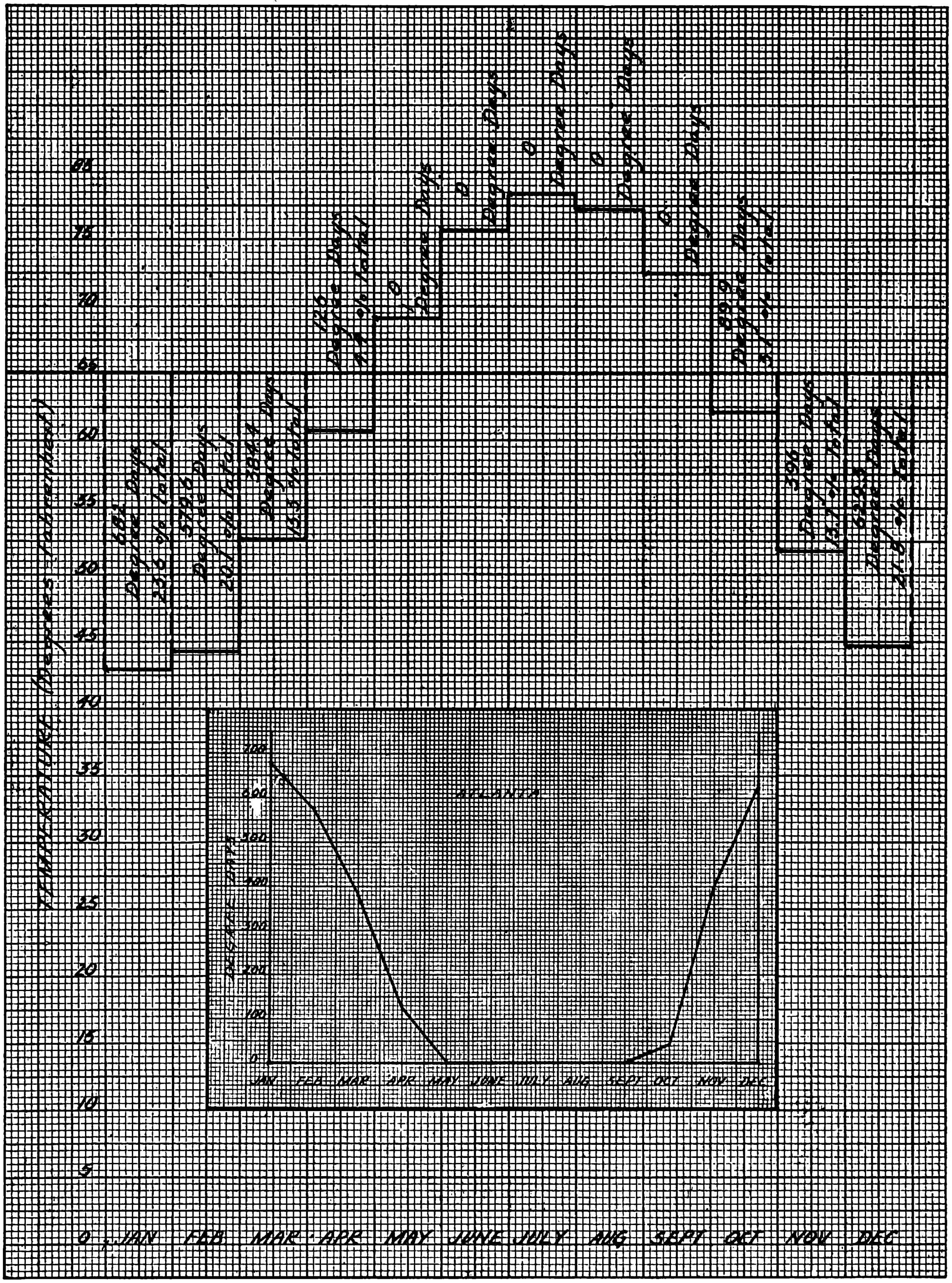

FIG. 17—DEGREE DAY—KW-HR. DISTRIBUTION—ATLANTA.

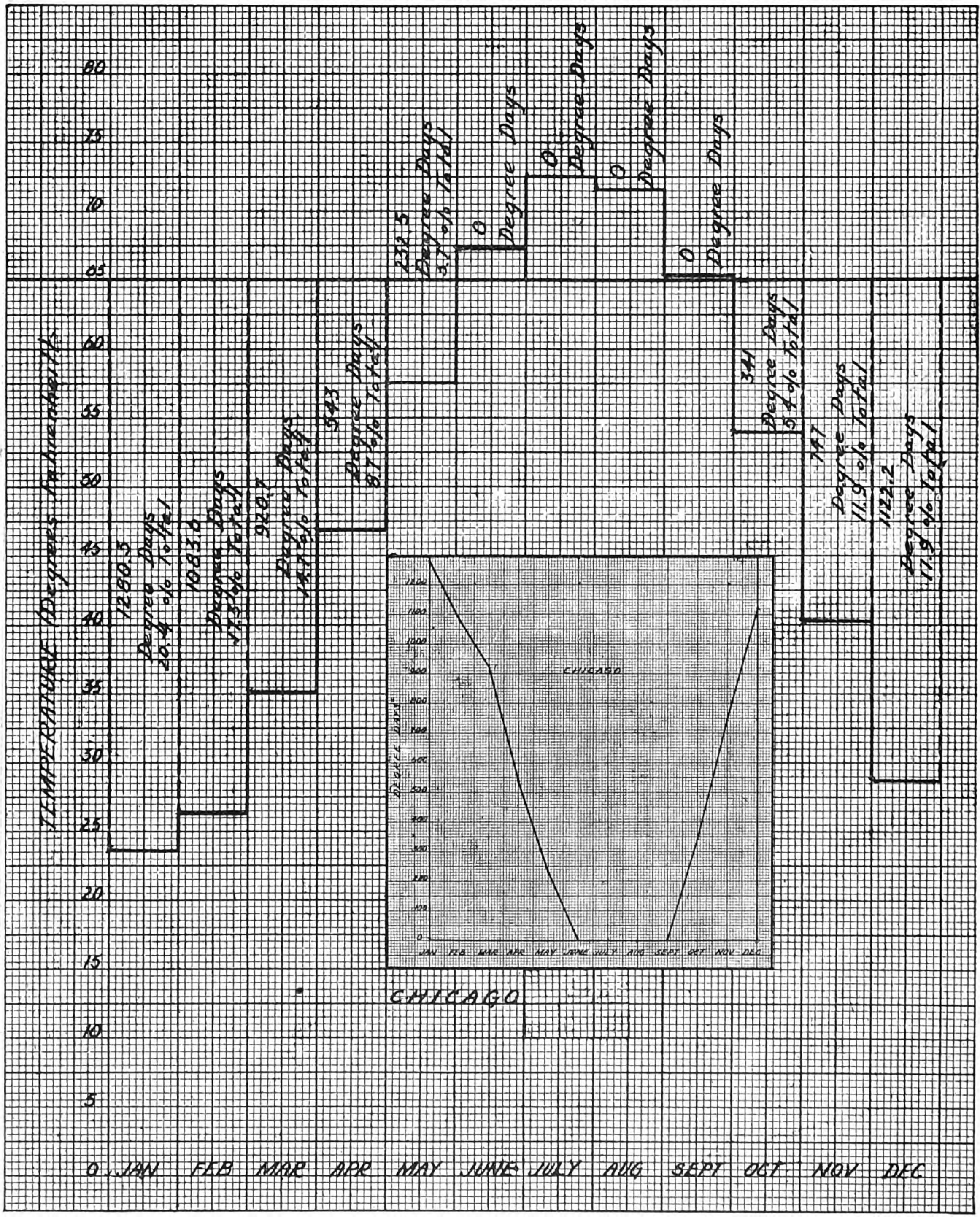

FIG. 19—DEGREE DAY—KW-HR. DISTRIBUTION—CHICAGO.

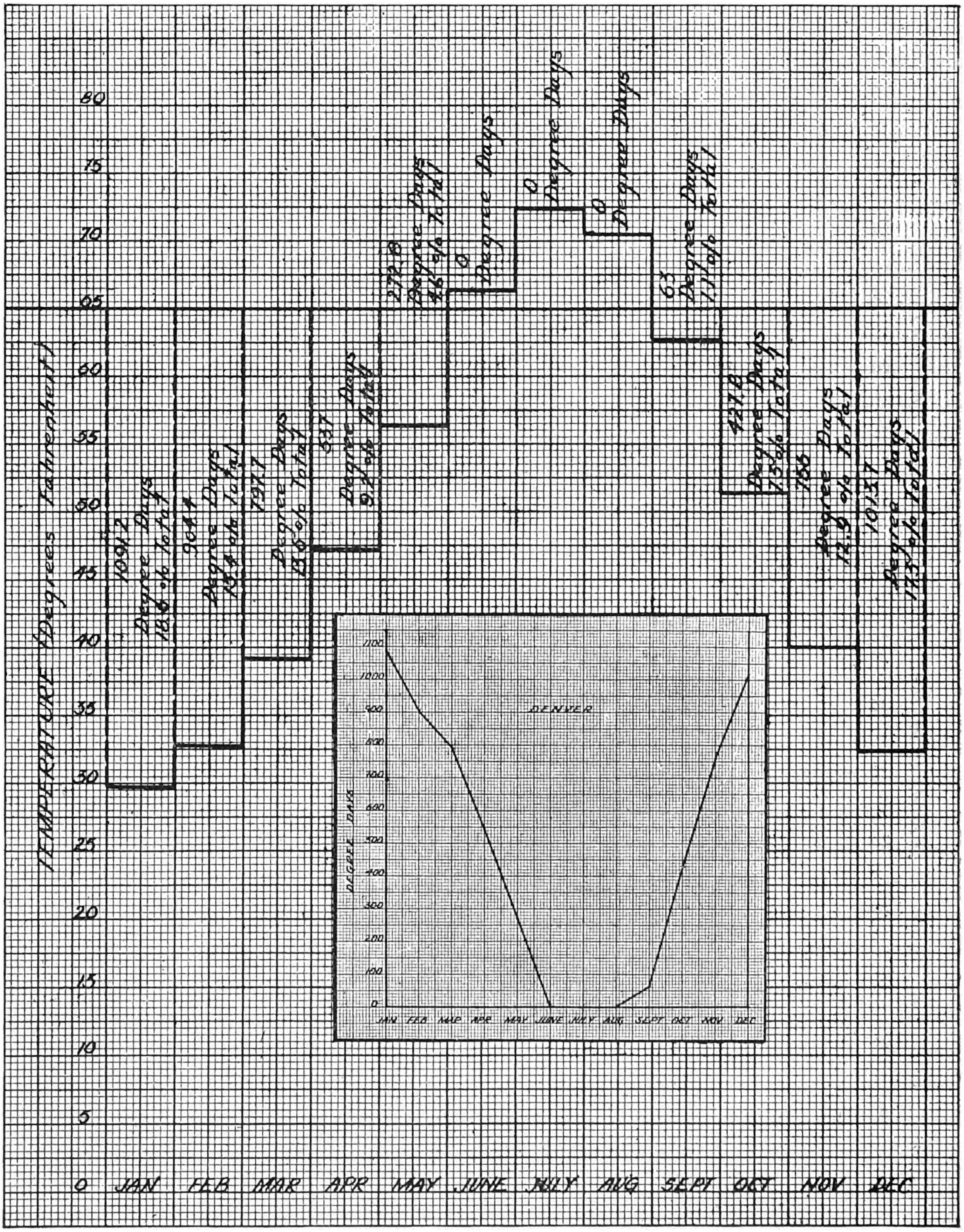

FIG. 21—DEGREE DAY—KW-HR. DISTRIBUTION—DENVER.

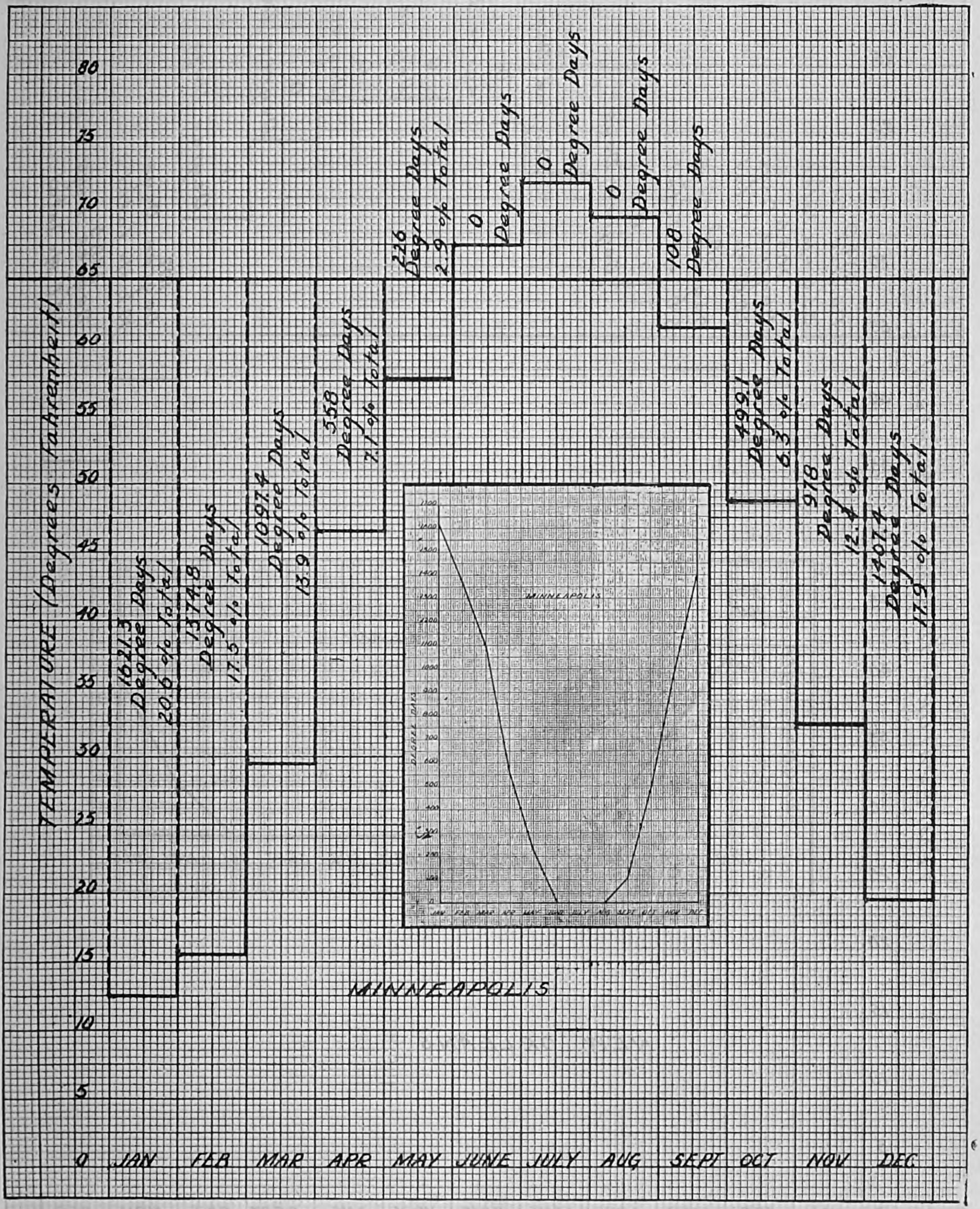

FIG. 22—DEGREE DAY—KW-HR. DISTRIBUTION—MINNEAPOLIS.

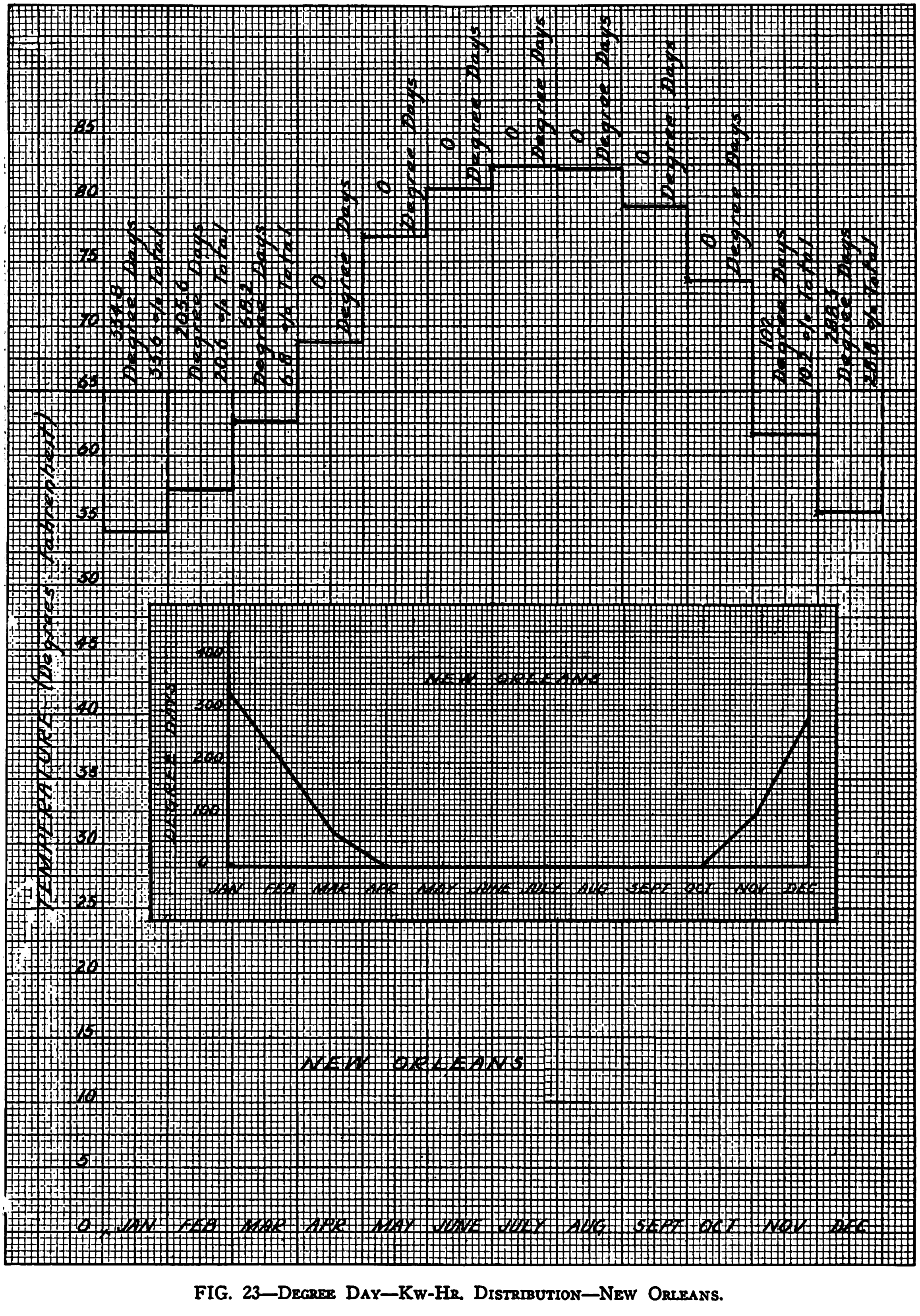

FIG. 23—Degree Day—Kw-Hr. Distribution—New Orleans.

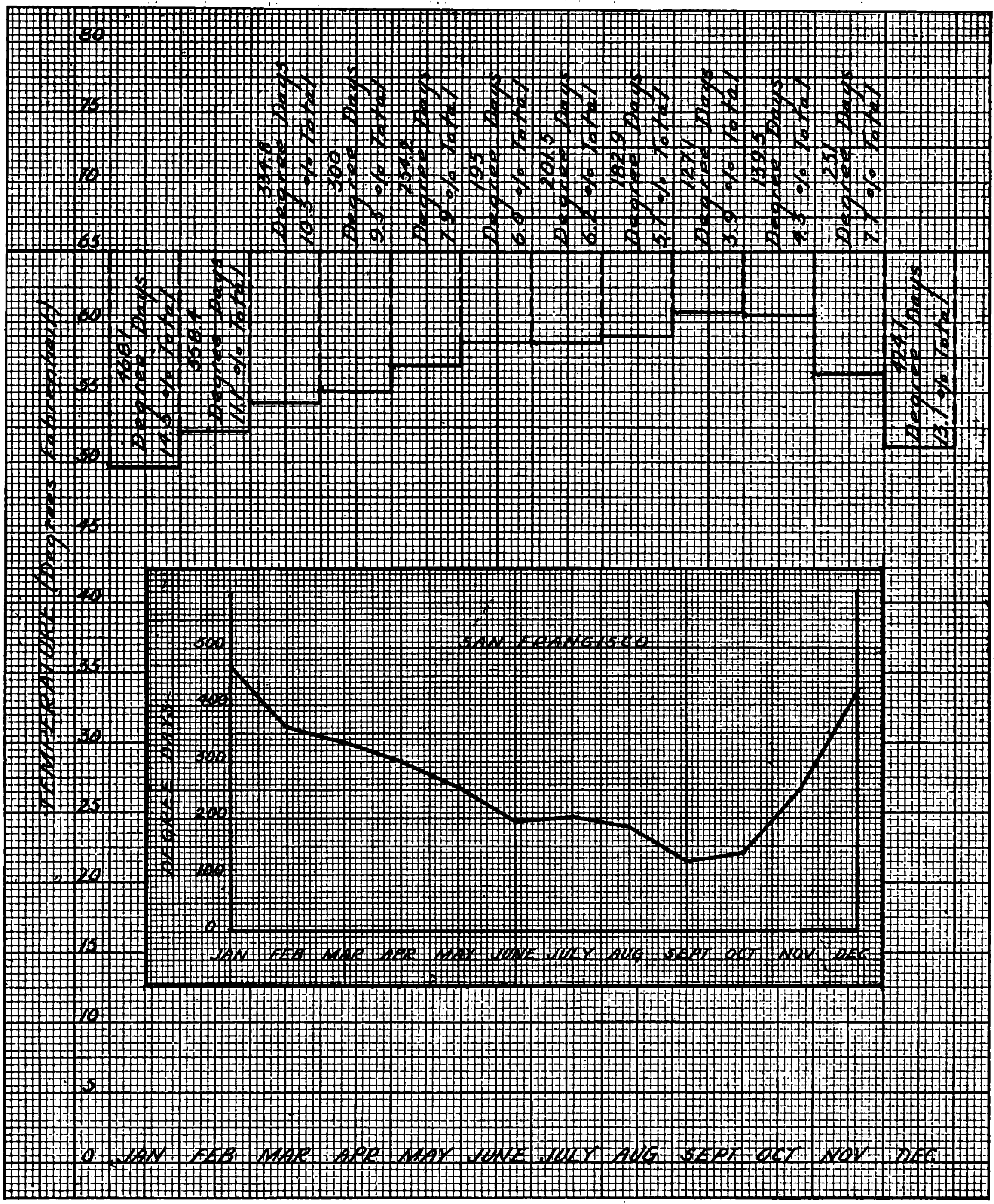

FIG. 25—DEGREE DAY—KW-HR. DISTRIBUTION—SAN FRANCISCO.

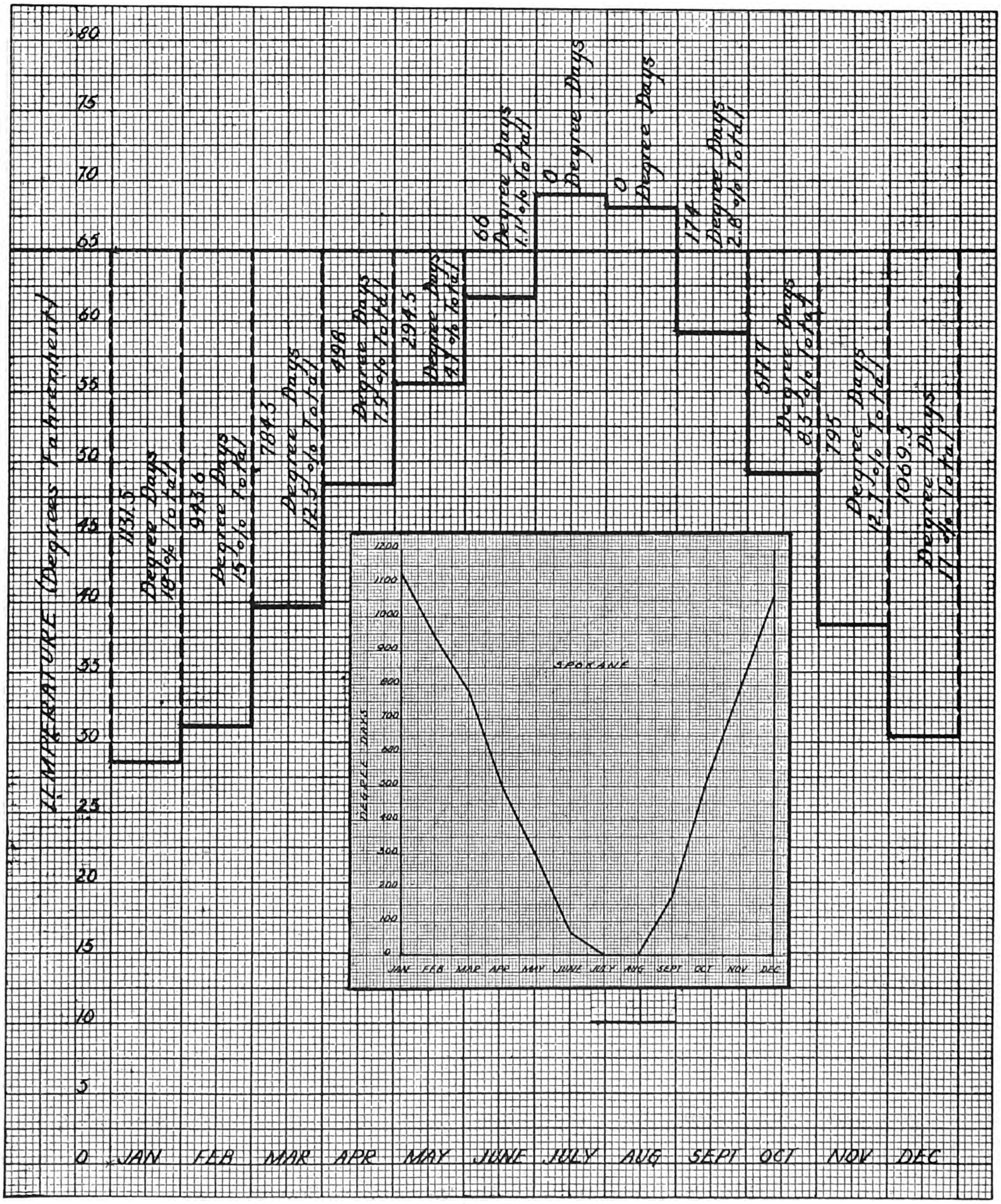

FIG. 27—DEGREE DAY—KW-HR. DISTRIBUTION—SPOKANE.

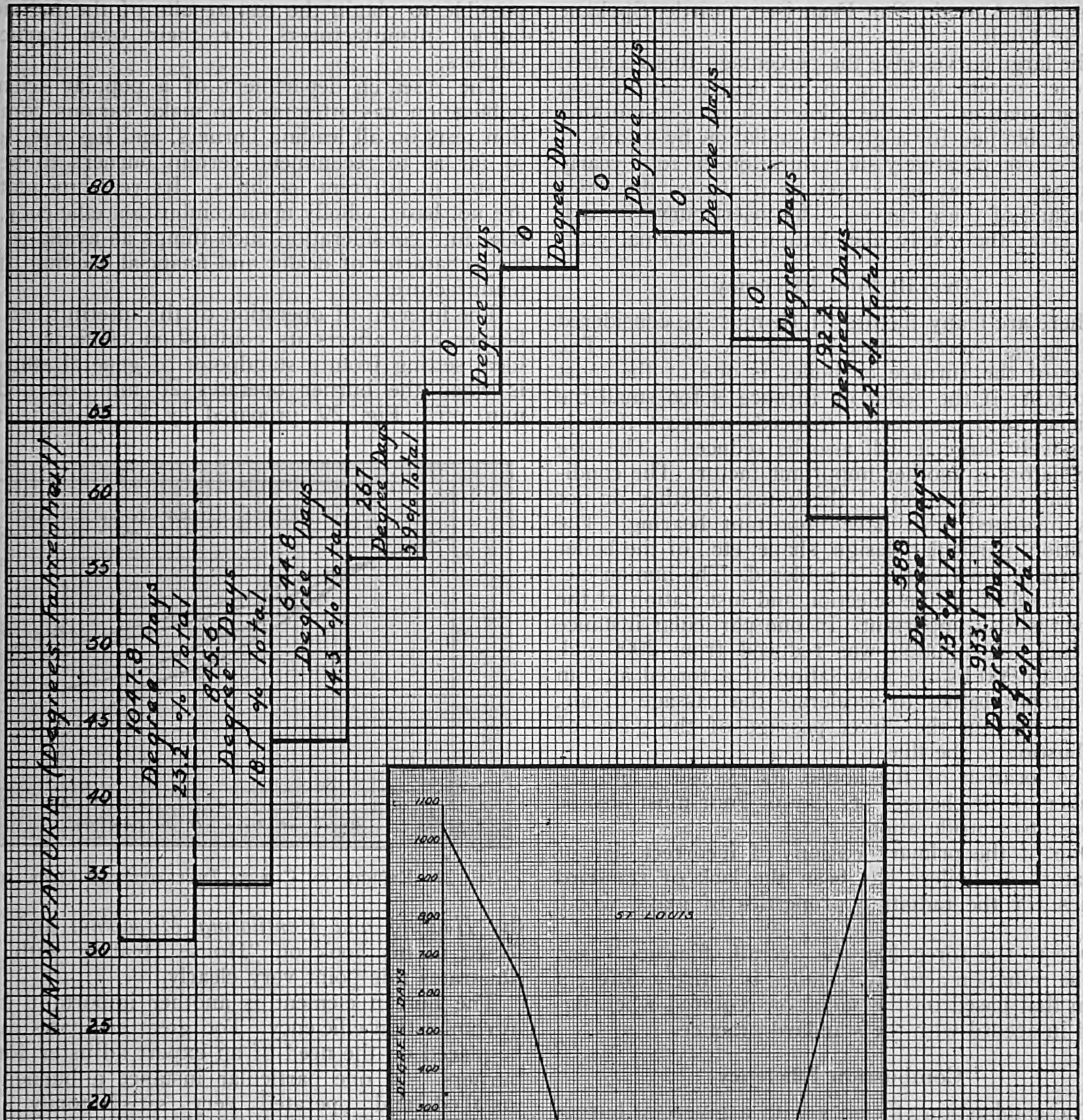

FIG. 28—DEGREE DAY—KW-HR. DISTRIBUTION—ST. LOUIS.

curves of the following cities: Atlanta, Boston, Chicago, Cincinnati, Denver, Minneapolis, New Orleans, San Antonio, San Francisco, Seattle, Spokane and St. Louis.

The large curves give the percentage fuel required for each month based upon the degree day method of computation. If the kilowatt-hour consumption can be obtained for a given installation by means of a test of comparatively short duration the total yearly consumption may be computed in any of the cities by means of these curves. The insert curve in each case gives the yearly distribution in a normal year.

Overall Fuel Efficiency

There are many factors which must be considered in judging overall efficiency of the system. The rating of the furnace or boiler is one of the most important; if the boiler or furnace is too small the efficiency will be greatly reduced, whereas if it is excessively large it will also be reduced. The size of radiators is another important factor. The condition and construction of the house, whether or not it is insulated, also have important bearing. The condition, particular design, shape, etc., of the boiler or furnace must also be considered. The human element involved in the selection and installation of the burner is also important. In one particular instance the fuel consumption was reduced from 2000 gal. a year to 900 by the installation of a forced air fan and proper baffles to accelerate the passage of air, and to prevent the direct passage of the gases of combustion to the flue.

The location of the house, its exposure and the number of air changes per day or hour must also be taken into consideration.

One of the primary reasons of incorrect size of radiators or boilers has been the lack of standard values for the radiating properties of glass, wood, etc.

Due to the foregoing, the overall efficiency based on the radiation actually installed is entirely different from that based on the radiation required when figured in accord with the standard practice.

Combustion Efficiency

The combustion efficiency with a given oil burner depends on the particular boiler or furnace in which it is installed. Boiler and oil burner manufacturers have both made many tests to determine the most efficient combinations of burners and boilers. The results of tests made by a boiler manufacturer show that the efficiencies of the first ten burners when correctly installed in suitable boilers will not vary over 5 per cent. The tests have been carried to a point where it is now safe to assume that the efficiencies for the majority of the listed burners will not vary more than 15 per cent. These figures have been reviewed by representatives of the oil companies, and of the oil burner manufacturers, and it was agreed by all that the maximum variation was within 15 per cent. The tests made by the boiler manufacturers are probably the most unbiased, as they have no particular interest in any burner. The tests made by the oil burner manufacturers would naturally be more or less biased, even if an attempt was made to treat the subject in a fair way. It is possible to obtain the test results of the individual burner manufacturers for their own particular burners.

The research department of a popular scientific publication has attempted to make various combustion tests on all leading burners, and has even gone so far as to recommend certain burners to people located in different localities. Its recommendations are not based wholly upon combustion efficiency, but take into consideration such things as available service, character of dealer and financial backing of the manufacturer.

The interval of operation of the intermittent type burner also affects its combustion efficiency. The ideal setting from a standpoint of general efficiency is when the burner operates 20 min. on and 20 min. off. Fig. 29, prepared by P. E. Fansler of the *Heating and Ventilating Magazine*, and published in his book on "House Heating with Oil" illustrates this point very clearly.

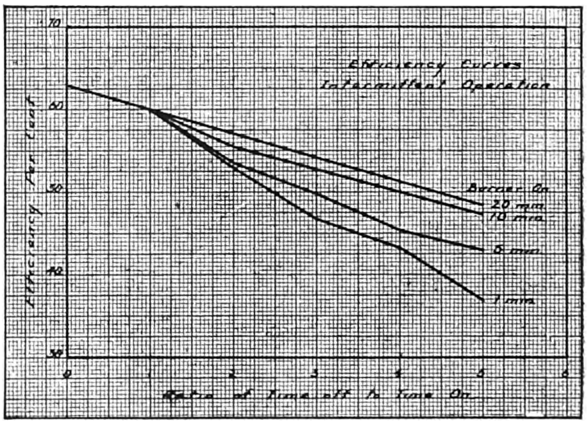

FIG. 29—EFFICIENCY CURVES INTERMITTENT OPERATION.

The human element is another important factor in combustion efficiency. Too great emphasis cannot be placed on the need of an expert adjuster for the burners. In one particular instance a burner was installed and operated very satisfactorily. The owner of the house (a mechanical engineer) became curious in regard to the CO_2 content of the flue gas. He therefore had one of the engineers from his plant make an orsat test and obtained a reading of 5. On the basis of this test he called the oil burner dealer, and while the engineer was there various adjustments were made in the burner and the orsat test reading for CO_2 was increased to 10. If this particular owner had not become curious he would have continued to pay an appreciable amount for heat going up the chimney in flue gas.

Combustion versus Overall Fuel Efficiency

As has been previously pointed out, the maximum variance in combustion efficiency with different burners is not in excess of 15 per cent. The overall fuel efficiency varies as much as 300 per cent. The figures obtained from data on 265 burners located in Louisville show that the gallons per degree day per thousand feet of steam radiation vary from 0.4 to 1.25 with an average of 0.7. The maximum effect of the 15 per cent difference in combustion efficiency as compared with the 300 per cent difference in overall fuel efficiency would be 5 per cent. The difference between the efficiency of the first 10 burners as compared to the difference in overall efficiency would be approximately 1.66 per cent. It is, therefore, apparent that under existing conditions the difference in the combustion efficiency is a negligible factor as compared to the overall efficiency. Therefore, any laboratory tests made in connection with the combustion efficiency of the burners would be of comparatively little importance.

Inasmuch as the greatest use of oil burners is in existing installations, it would seem that the efficiency should be considered when based on the installed radiation. If the oil burner is to be installed in a new house with proper radiation, or in a house in which the existing installation has been changed to meet present requirements, the installed radiation and the required radiation will, of course, be the same.

This is an important question in that the practice followed in the installation of gas heaters takes into consideration the required radiation, and in the majority of cases requires that the radiation be at least equivalent to the required radiation. This practice gives the gas installations a better efficiency, and even though it may reduce the actual number of sales, it reduces the number of high bill complaints thereby building up customer good-will. Before an oil burner installation is undertaken, careful consideration should be given to the suitability of the heating system as a whole.

FACTORS WHICH SHOULD BE CONSIDERED IN COMPARING COAL, OIL, GAS AND ELECTRIC HEATERS

The common practice of judging the cost of house heating by the amount paid for oil, coal, gas or electricity leads in many instances to erroneous results, as there are other costs which often equal or exceed the cost of the fuel.

The cost of house heating may be divided into the fixed charges and the operating charges. The fixed charges include depreciation, interest on investment, heating plant insurance and taxes. The operating charges include cost of upkeep on equipment and installation; labor or service charge and fuel charge.

In order to compute the fixed charges the cost of the installation as well as the average life of the component parts must be known. The life and cost of the heating system, with the exception of boiler or furnace and special equipment required for the particular fuel, is independent of the kind of fuel. In a comparison of the costs of heating, the fixed charges which depend on the type of fuel used include the cost of the boiler, and the cost of any other additional equipment which will be required for use in connection with the particular fuel. A survey made three years ago indicated that the average life of the domestic oil burner was ten years, while the average life of a coal boiler was twenty-five years. Since that time improvements and refinements have been made in the construction of the oil burner and the average life has undoubtedly been increased.

The operating charges, with the exception of the fuel costs are more difficult to obtain. An accurate basis for computing upkeep will only be available after records have been kept for long periods of time. In the same survey which is mentioned in the preceding paragraph instances were encountered where the upkeep was in excess of 10 per cent of the cost of the oil burner, while in the case of the coal burning equipment it was found to be 0.5 per cent of the cost of the installation. The refinements and improvements in the oil burner will, of course, lower this figure, but the nature of the two systems makes it unlikely that the upkeep for the oil installation will ever approach the figure for the hand fired coal installation. (The coal installations considered in this paragraph were all hand fired.) The labor or service charges, which include the tending of the furnace, the removal of ashes, etc., are often neglected as the home owner or some member of the family often performs this task. Even though the duties are performed by the owner, the time which it requires might be spent in remunerative work or recreation, and a certain charge is, therefore, justified.

The features which should be considered in addition to cost in dollars and cents include: Cleanliness, convenience and reliability. The average home owner is interested in obtaining clean, uniform heat at all times at a reasonable cost. In the cases of oil and coal the competition is between automatic control and a furnace man, either electric or human. The reliability of the human furnace man is, in some instances, highly questionable, and his ability to maintain a uniform temperature is even more questionable. In some communities it is also practically impossible to obtain the necessary labor for firing the coal and removing the ashes. There are automatic devices which utilize the smaller sizes of anthracite coal. They are provided with a container which is filled once a day. Once this container is filled, the machine does the rest, delivering the ashes to a second container ready for removal. It has the advantage that uniform heat is maintained with a minimum of attention; however, the coal must be handled and the ashes removed from the cellar. On the surface it would, therefore, appear that the automatically controlled oil burner, which does not require the handling of any fuel or ashes, would offer inducements that would not be obtained from coal. However, a most important consideration in the selection of automatic oil heat is the assurance of immediate service in case of failure or unsatisfactory opera-

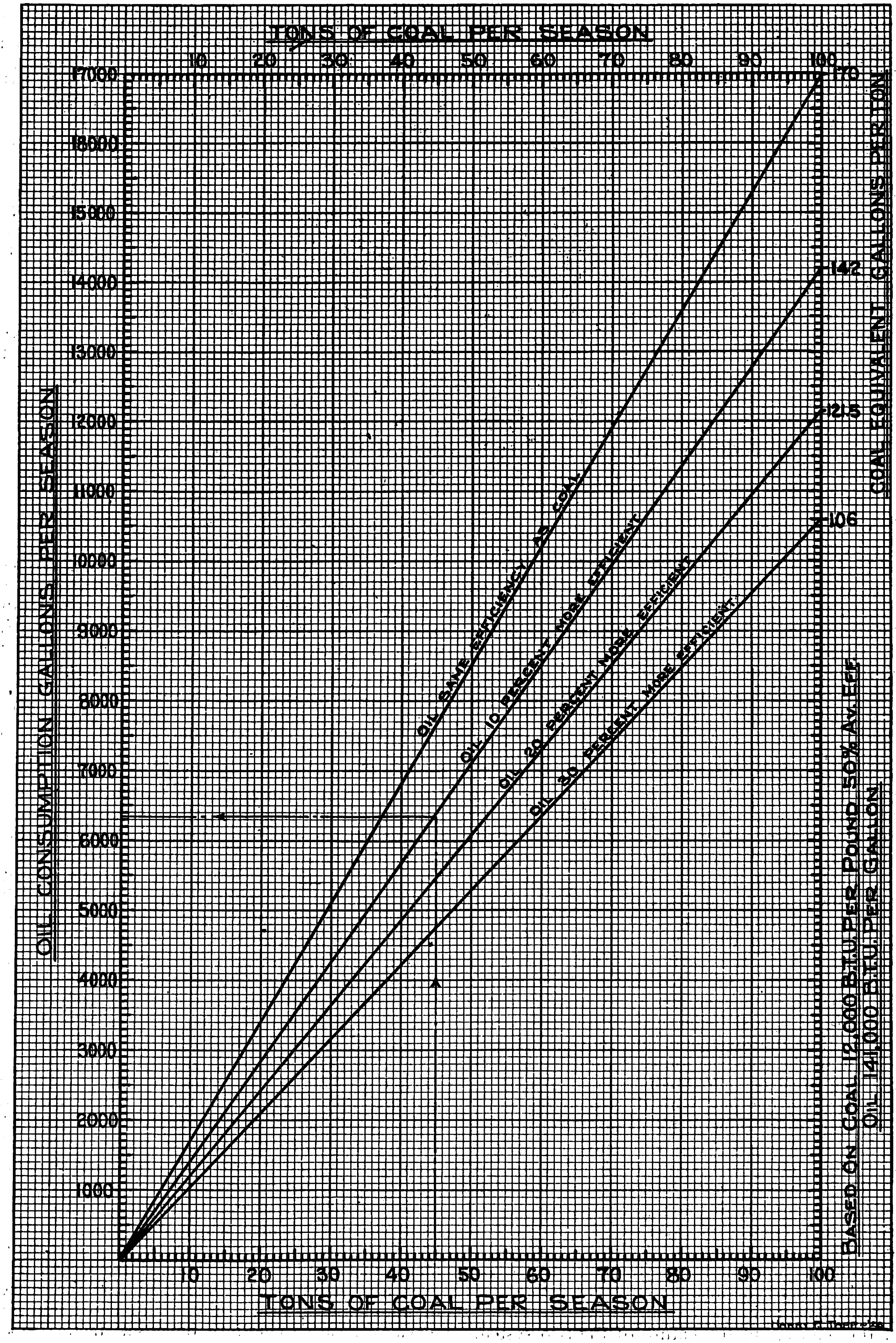

FIG. 30—OIL VERSUS COAL CONSUMPTION, B.T.U. BASIS.

tion. The question of providing adequate service is considered to be of vital importance and is being given much thought by oil burner manufacturers.

In many of the advertisements for oil burners the cleanliness of this form of heat is pointed out as one of its biggest advantages. If the burner is correctly installed, all joints in the pipe tight and the proper inspection service maintained to prevent improper operation, this is, without doubt, a feature. If, however, after the burner is sold, proper care is not taken in adjustments and follow-up, the cleanliness afforded by an oil burner is somewhat questionable. If leaks occur in the pipe line or if for any other reason oil is allowed to collect on the floor a very unpleasant odor results, and if by chance this oil happens to become ignited the house becomes coated with an oily soot that is practically impossible to remove. Great care should also be exercised in filling the tank. In installations provided with improper sized tanks, several instances have been reported where the tank was overfilled, thus creating a severe strain on the tank as well as various joints in the piping and in many cases creating leaks which allowed the oil to spread throughout the basement. In instances where this has happened it has taken months to entirely eliminate the odor. All of the objections raised in this paragraph may be completely eliminated by the correct type of service, both in caring for the heater and installation and in filling the tanks. A method of eliminating the probability of overfilling the tank is to install a tank sufficiently large to overcome the necessity of part of a load being delivered.

Fig. 30 represents the number of gallons of oil which are equivalent to a given number of tons of coal. These curves are based on the British Thermal Unit content of the two fuels, 12,000 B.t.u. per pound being assumed for coal and 141,000 B.t.u. per gallon for oil. The efficiency of the coal installation is assumed as 50 per cent, while oil installations of 50, 60 and 70 and 80 per cent are considered. This curve was prepared by Harry F. Tapp of the American Oil Burner Association. Fig. 31 represents a comparison of the amount of oil and gas based on the B.t.u. content. The oil is assumed to have 141,000 B.t.u. per gallon, and the gas B.t.u. content is varied from 300 to 1100 B.t.u. per cubic foot. The efficiency for the oil and gas is 65 and 80 per cent respectively. This figure was also prepared by Harry F. Tapp.

SERVICE AND RECORD IN SERVICE

The total number of burners sold by one large power company and which, in accord with their sales policy, are serviced by them is between 650 and 700. The average number of calls per day during the heating season is 19, only four of which are for interruptions of heat. This relatively good service record is without doubt due to the monthly inspection service which is provided free.

An oil burner dealer located in Madison, Wis., stated at the 1928 convention of the American Oil Burner Association that he had approximately 200 burners installed, and his service calls averaged between 8 and 12 a day. Many of these calls merely required minor adjustments, while others were caused by empty oil tanks.

An oil dealer in Louisville stated that an average of one call per burner per month was considered normal. Some of his calls were for the new installations where the owner had not become accustomed to the operation of the burner. If the burner remained inoperative for an extended period of time, even though the temperature of the house were normal, a service man was called when the real reason for the non-operation of the burner was that no heat was required.

In all of the instances noted above, the service was free. In the discussion at the American Oil Burner Convention, the question of reducing needless service calls was raised. One of the methods proposed was to have a definite service period, and charge for all calls after that time had expired. The dealers were somewhat divided on the advisability of doing this, but they were absolutely united in upholding the absolute necessity for prompt and efficient service.

Under existing conditions, if the number of calls per burner per month in excess of the regular inspection calls exceeds one, some action should be taken to determine the cause. In analyzing the reasons for service calls it was found that less than half of them were for interruptions of heat. Of this group, calls due to lack of oil and incorrect thermostat settings formed an appreciable part. The calls not due to interruptions of heat included minor adjustment of the burner, elimination of noise, leaks in oil line, high fuel bills and changing of the thermostat setting. There are, of course, many calls in connection with a new installation which are automatically eliminated as the house owner becomes familiar with the system. These calls, even though needless, must be given prompt attention if the good will of the owner is to be maintained.

MERCHANDISING

The three types of merchandising covered in this survey are: First, the selling as agent for one make of burner; second, the selling as agent for more than one make of burner, and third, selling the "idea" of using oil heat. There are three different methods of selling as agent for one make of burner covered by this report. The first method is for the electricity supply company to make the actual sale, install the burner and furnish the necessary service. The second method is for the electricity supply company to make the actual sale and then refer the purchaser to the dealer or agent of the burner manufacturer for the installation and service. The third method is for the power company to sell the burner and to contract with a local plumber or heating man for the installation and service. The plumber or heating man who installs the burner reports directly to the power company, but the power company does not hold itself responsible for any service to the burner.

In various cases under the second method, permanent arrangements have been made with the manufacturer to take care of the installation and service of burners sold by the power company for an indefinite period. In some instances, however, the agreement between the power company and the oil burner manufacturer may be only temporary in nature, and after sufficient time has elapsed for the power company to train its own installation and service department, the entire work is taken over by it. In selling as agent for more than one make of burner, the three different methods outlined above also apply.

There are numerous ways of selling the idea of using oil heating, either by advertising, display or personal recommendation. The actual display of several standard makes of burners by the power companies is one of the most effective methods of selling the idea. In some instances the dealers may be allotted space and furnish their own representatives to explain the principles of operation and the advantages of their respective burners. In other cases the burners may be shown by a representative of the power company, and all leads obtained from this display reported back to all of the various dealers or agents of manufacturers of the burners on display, the sale, installation and servicing being done by the manufacturer or his representative.

One large power company has been actively engaged in selling one make of oil burner for the past two years and a half. A separate department is maintained for the sale of the burner. All salesmen work on a straight commission basis. The installation and service of the burners is now done by the company. In the beginning the installation of the tank was let out to a separate contractor, but this proved a most unsatisfactory arrangement, and it was discontinued. Tanks are now installed by the company, under the cement in customers' cellars and the cement replaced; they are built up and welded in the cellar. The trouble encountered in the installation of tanks has been practically eliminated. In view of the difficulties of this company in training its service and installation department, the man in charge of this department is of the opinion that no power company should undertake the installation and servicing of any burner until an efficient department has been organized for these purposes. Rather an agreement with the oil burner manufacturer for the installation and servicing of the burners until an adequate and efficient servicing department for oil burners, if desired, is built up.

Two other important companies have recently undertaken the sale of one make of oil burner, and they have made agreements with local plumbers and heating contractors for the installation and service of the burners. No instances were found where a *permanent* agreement had been made with the oil burner manufacturer for the installing and servicing of the burners. Servicing arrangements are a local problem, and the desirable method is the one which produces best service at lowest cost.

Some companies prefer to sell the idea of oil heating rather than to sell the burners themselves. In selling the idea some care should be taken to differentiate between burners which have been investigated from a fire and casualty hazard and those which have not. It does not seem advisable to even consider burners which have not been listed as standard by the Underwriters' Laboratories.

Sales and Installation Record Forms

One company actively interested in the sale of oil burners has developed five forms, which they have found to be of great value. Form No. 1 (Fig. 94) is the Salesman's Report; it provides spaces for pertinent data concerning the prospect. Form No. 2 (Figs. 95-98) is known as the "Estimate Survey"; it provides spaces for all data influencing the making of an estimate. Form No. 3 (Figs. 99-103) is the "Installation Survey"; it provides spaces for details which affect the installation of the burner and is made up after the estimate has been accepted. Form No. 4 (Fig. 104) is used to compile all expenses actually expended in the installation of the burner; it serves as a basis for new estimates when similar conditions exist. Form No. 5 (Fig. 105) "Installation Data Sheet" provides spaces for pertinent items and acts as a history of the installation. All of the previously mentioned forms may be found in Appendix C of this report.

RADIO INTERFERENCE

It is pertinent to add a suggestion in connection with radio interference. All oil burners using electrical ignition may be the source of some radio interference unless the proper precautions are taken. The disturbance, which may be caused by types using intermittent ignition, is limited to between 5 and 30 seconds at the time of ignition. The disturbance caused by the continuous operating type may be continuous and highly objectionable unless some provision is made for its elimination.

Motors are not in themselves necessarily a source of radio interference, but may, particularly if allowed to become dirty, become serious offenders. A trap or filter like the one described in the N. E. L. A. Publication No. 267-98, "Radio Coordination," may be used to overcome the interference caused by either the ignition or motor. To insure against the possibility of disturbing interference, two separate filters may be installed, one for the ignition and one for the motor. Some burner manufacturers include filters as part of the burner equipment.

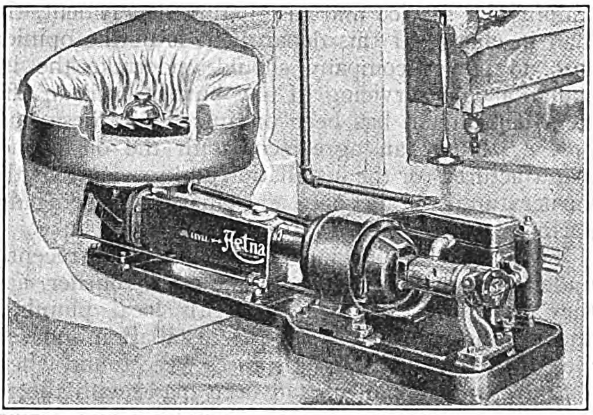

FIG. 32—THE AETNA BURNER INSTALLED.

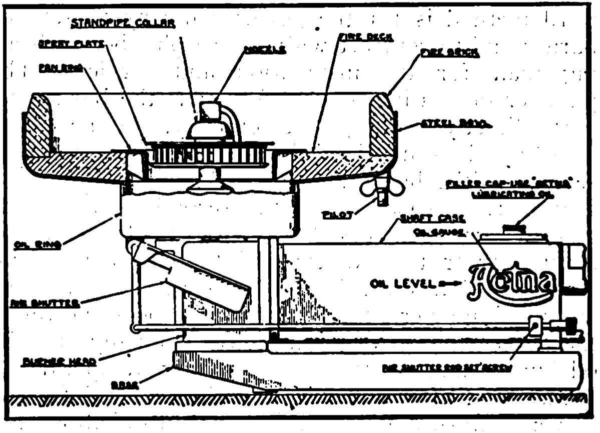
STANDPIPE COLLAR
SPRAY PLATE
FAN RING
NOZZLE
FIRE DECK
FIRE BRICK
STEEL BAND
FILLER CAP-USE "AETNA" LUBRICATING OIL
PILOT
SHAFT CASE
OIL GAUGE
OIL RING
OIL LEVEL
Aetna
AIR SHUTTER
BURNER HEAD
BASE
AIR SHUTTER ROD SET SCREW

FIG. 33—CROSS SECTION OF THE AETNA BURNER.

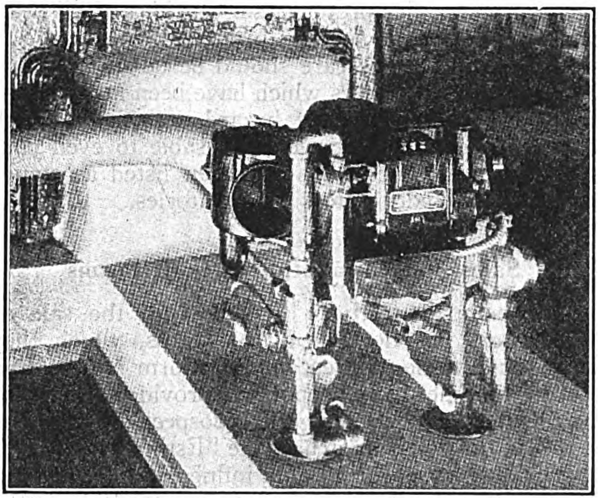

FIG. 34—THE NOKOL BURNER INSTALLED (AMERICAN NOKOL CO.).

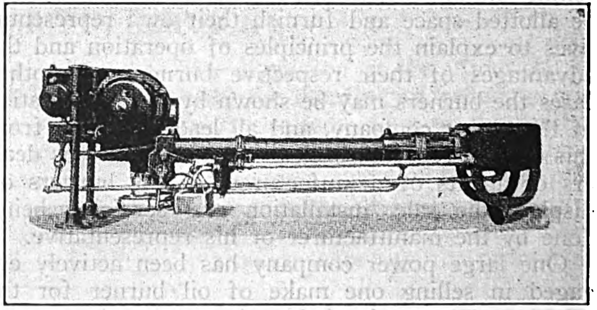

FIG. 35—THE NOKOL BURNER (AMERICAN NOKOL CO.).

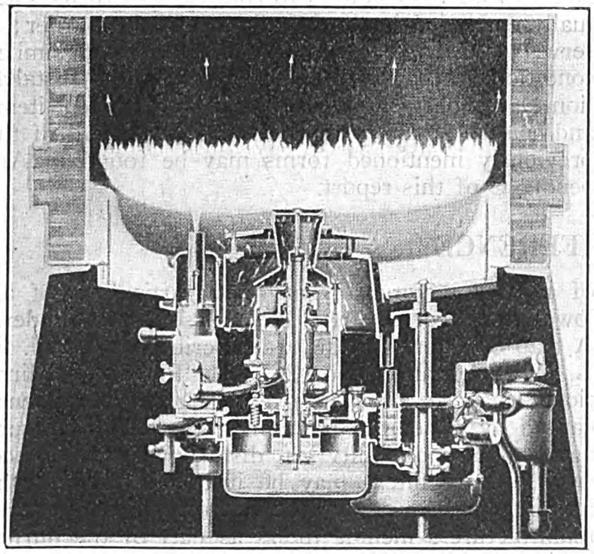

FIG. 36—THE A. B. C. BURNER INSTALLED.

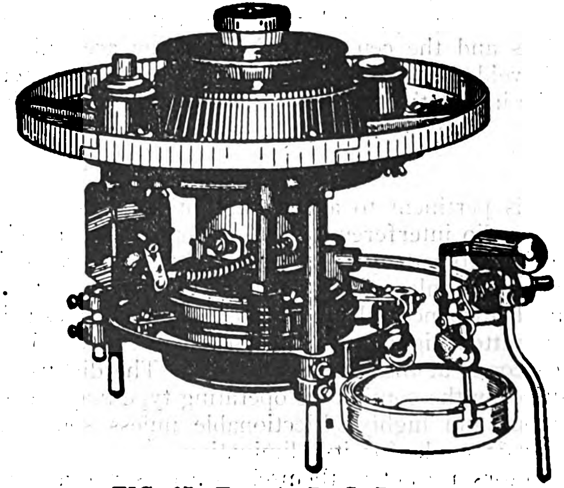

FIG. 37—THE A. B. C. BURNER.

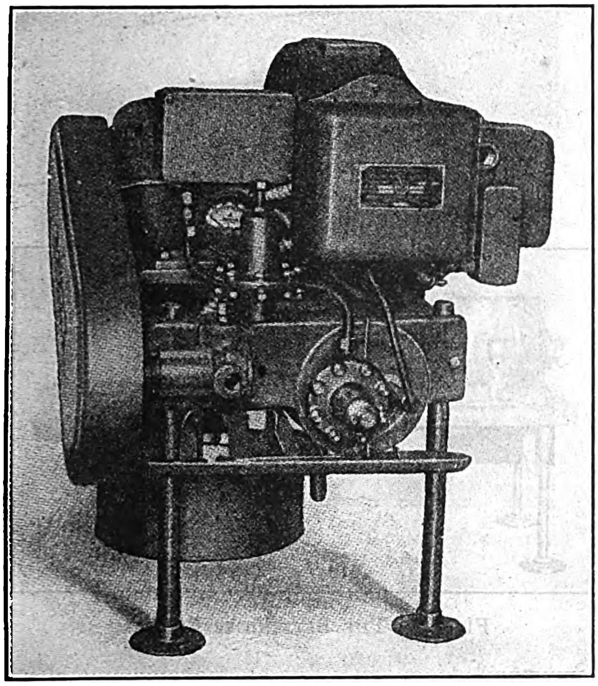

FIG. 38—THE BAKER BURNER.

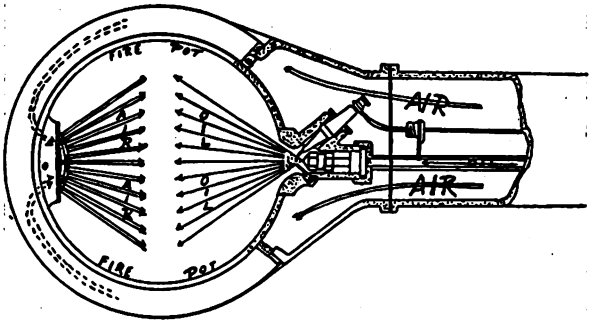
FIRE POT
AIR
OIL
AIR
AIR
OIL
AIR
FIRE POT

FIG. 39—OPERATION OF THE BAKER BURNER.

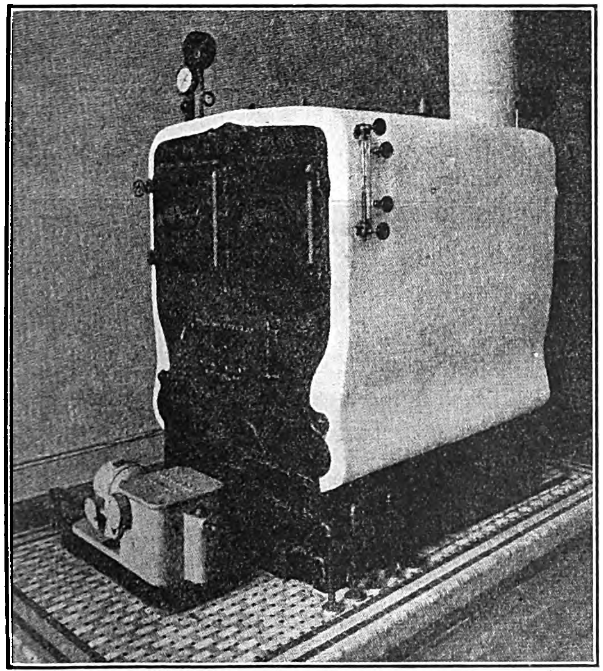

FIG. 40—THE BALLARD, JR., BURNER INSTALLED.

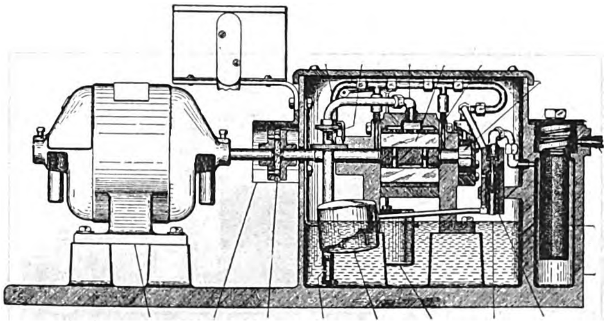

FIG. 41—CROSS SECTION OF BALLARD, JR., BURNER.

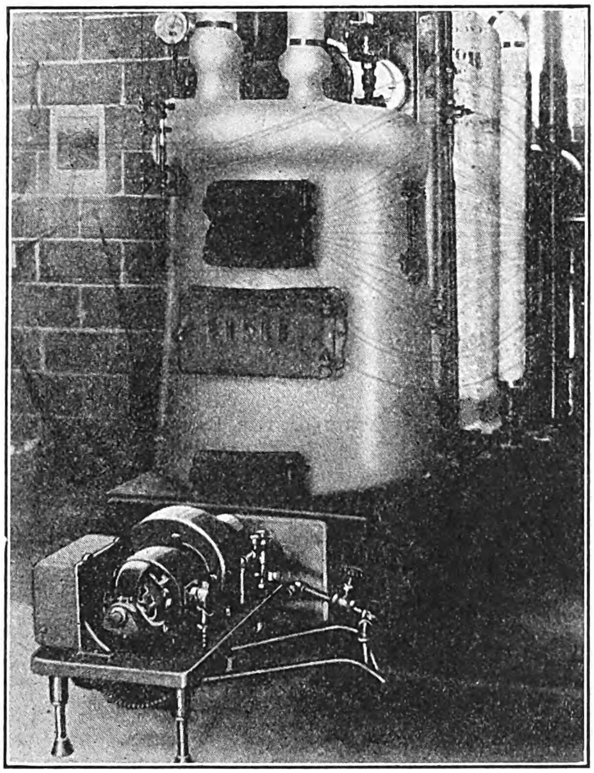

FIG. 42—THE BETTENDORF BURNER INSTALLED.

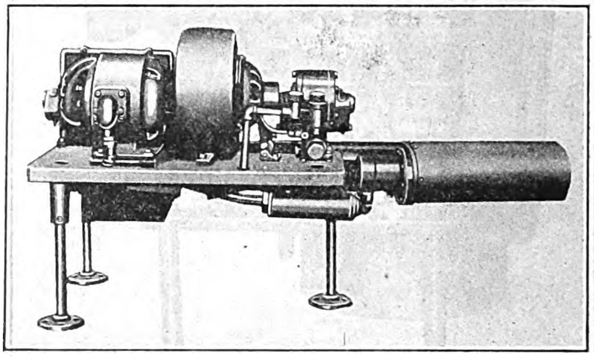

FIG. 43—THE BETTENDORF BURNER.

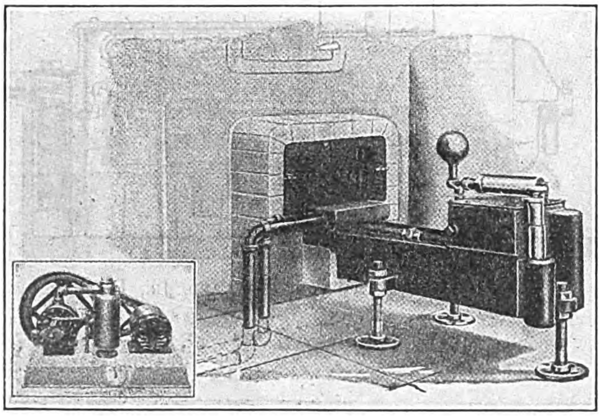

FIG. 44—THE CALOROIL BURNER INSTALLED.

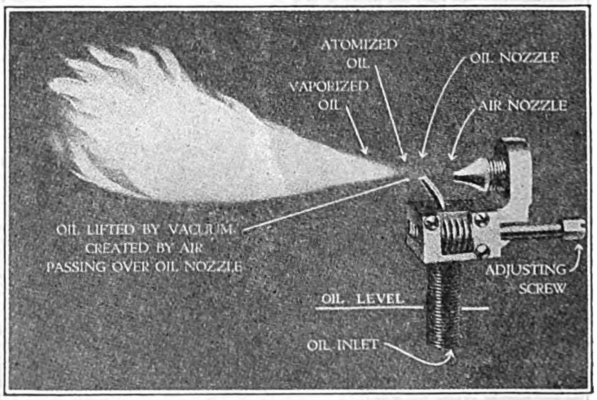
ATOMIZED OIL
OIL NOZZLE
VAPORIZED OIL
AIR NOZZLE
OIL LIFTED BY VACUUM CREATED BY AIR PASSING OVER OIL NOZZLE
ADJUSTING SCREW
OIL LEVEL
OIL INLET

FIG. 45—OPERATION OF CALOROIL BURNER.

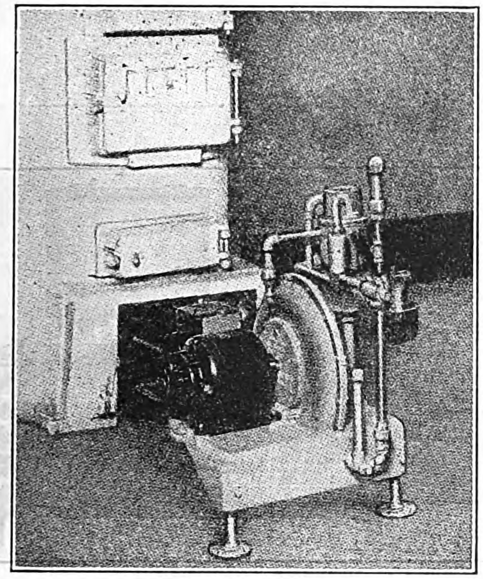

FIG. 46—THE CHALMERS BURNER INSTALLED.

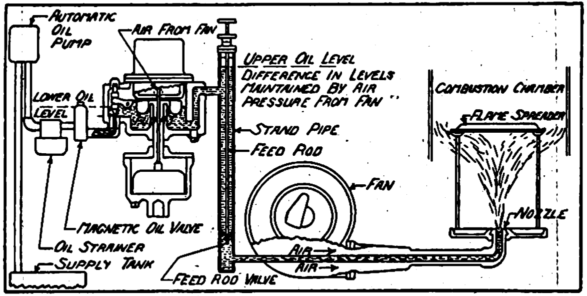
AUTOMATIC OIL PUMP
AIR FROM FAN
UPPER OIL LEVEL
DIFFERENCE IN LEVELS MAINTAINED BY AIR PRESSURE FROM FAN
COMBUSTION CHAMBER
FLAME SPREADER
LOWER OIL LEVEL
STAND PIPE
FEED ROD
FAN
NOZZLE
MAGNETIC OIL VALVE
OIL STRAINER
SUPPLY TANK
AIR
AIR
FEED ROD VALVE

FIG. 47—OIL FLOW IN THE CHALMERS BURNER.

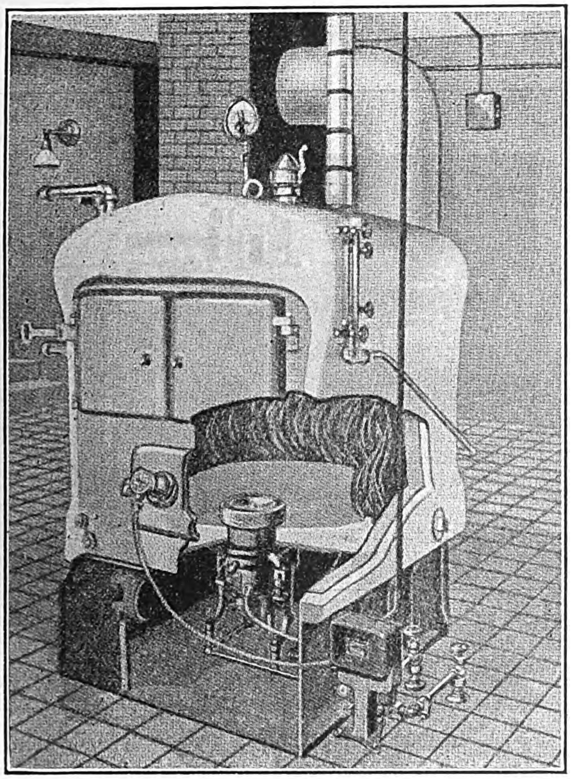

FIG. 48—TORRIDHEAT INSTALLATION (CLEVELAND STEEL PRODUCTS CORP.).

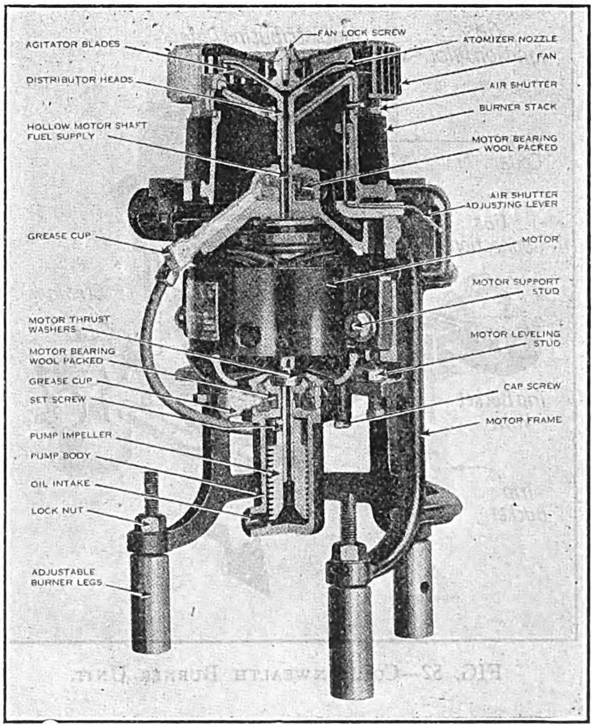
FAN LOCK SCREW
AGITATOR BLADES
ATOMIZER NOZZLE
FAN
DISTRIBUTOR HEADS
AIR SHUTTER
BURNER STACK
HOLLOW MOTOR SHAFT FUEL SUPPLY
MOTOR BEARING WOOL PACKED
AIR SHUTTER ADJUSTING LEVER
GREASE CUP
MOTOR
MOTOR SUPPORT STUD
MOTOR THRUST WASHERS
MOTOR LEVELING STUD
MOTOR BEARING WOOL PACKED
GREASE CUP
CAP SCREW
SET SCREW
MOTOR FRAME
PUMP IMPELLER
PUMP BODY
OIL INTAKE
LOCK NUT
ADJUSTABLE BURNER LEGS

FIG. 49—CROSS SECTION OF TORRIDHEAT BURNER.

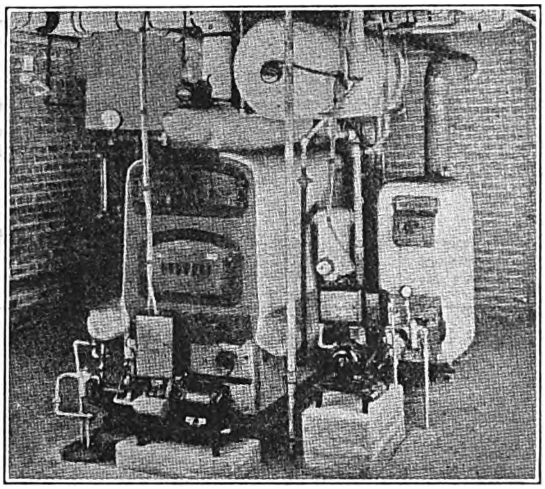

FIG. 50—COMBUSTION BURNER INSTALLATION WITH DOMESTIC WATER HEATER.

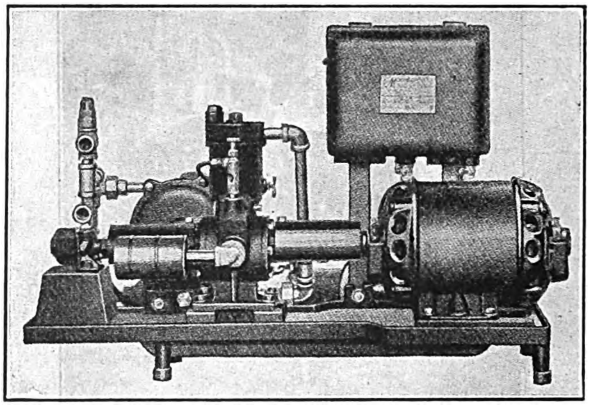

FIG. 51—THE COMBUSTION BURNER.

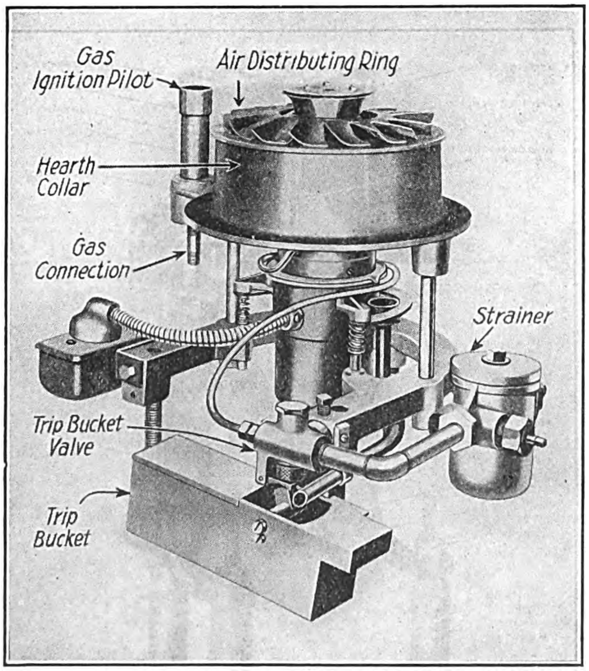
Gas Ignition Pilot
Air Distributing Ring
Hearth Collar
Gas Connection
Strainer
Trip Bucket Valve
Trip Bucket

FIG. 52—COMMONWEALTH BURNER UNIT.

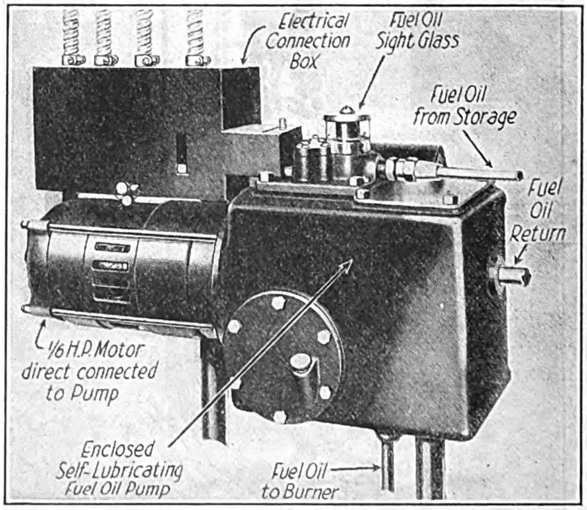
Electrical Connection Box
Fuel Oil Sight Glass
Fuel Oil from Storage
Fuel Oil Return
1/6 H.P. Motor direct connected to Pump
Enclosed Self-Lubricating Fuel Oil Pump
Fuel Oil to Burner

FIG. 53—COMMONWEALTH BURNER OIL PUMP AND ELECTRICAL ASSEMBLY.

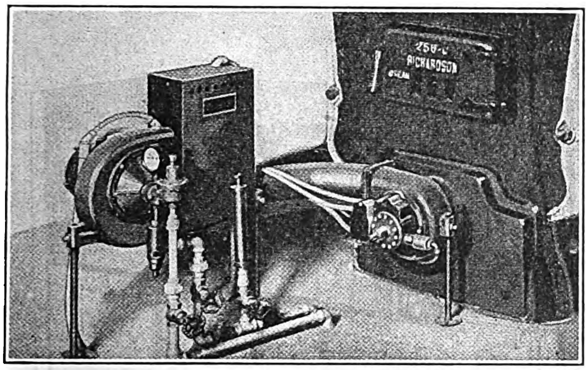
RICHARDSON

FIG. 54—ELECTROL BURNER INSTALLED.

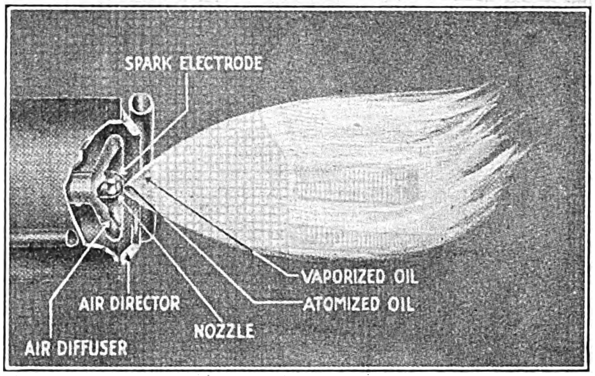
SPARK ELECTRODE
VAPORIZED OIL
ATOMIZED OIL
AIR DIRECTOR
NOZZLE
AIR DIFFUSER

FIG. 55—OPERATION OF THE ELECTROL BURNER.

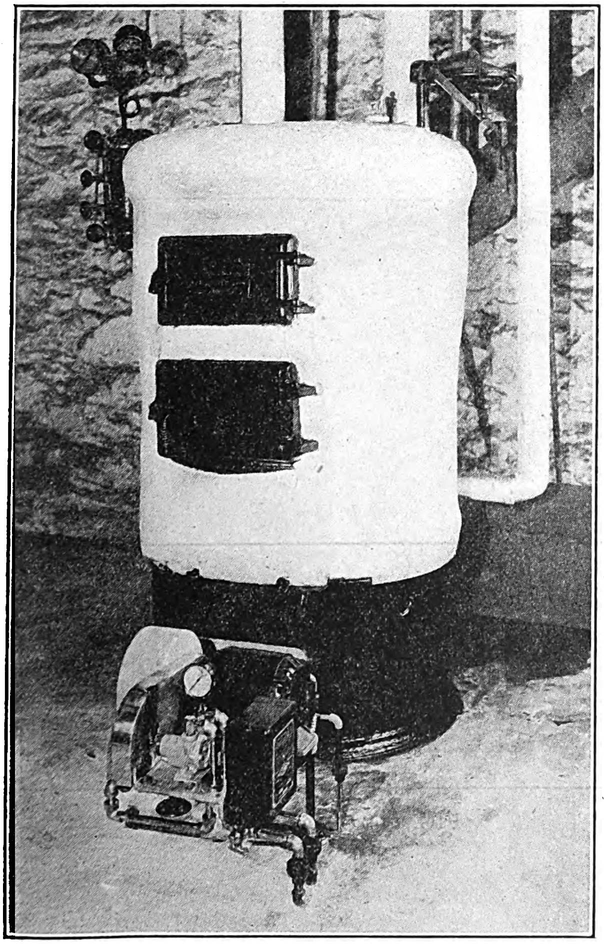

FIG. 56—FLUID HEAT BURNER INSTALLED.

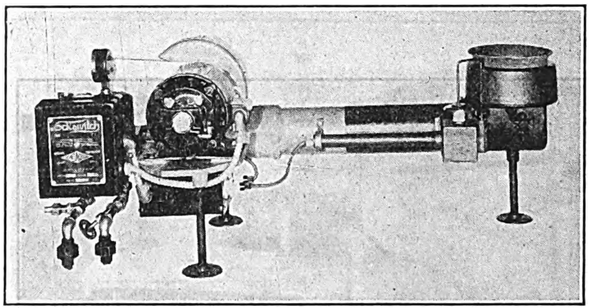

FIG. 57—MODEL "T" FLUID HEAT BURNER.

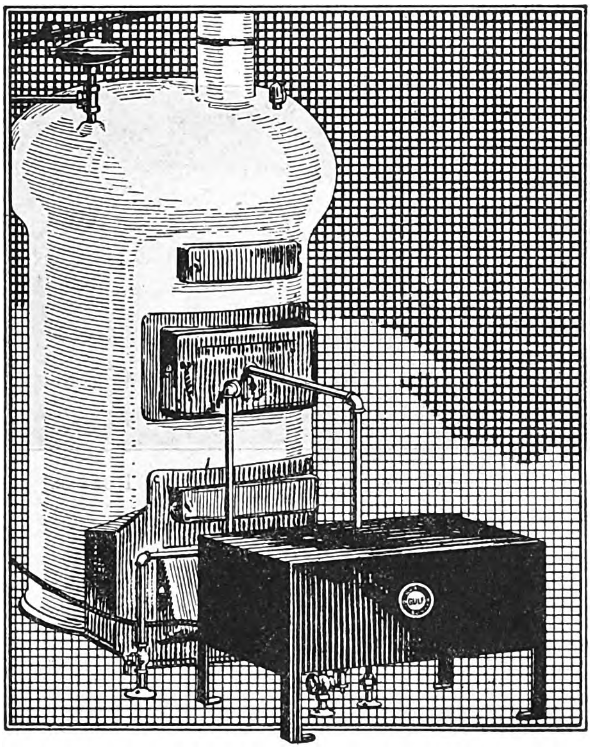

FIG. 58—GULF OIL BURNER INSTALLED.

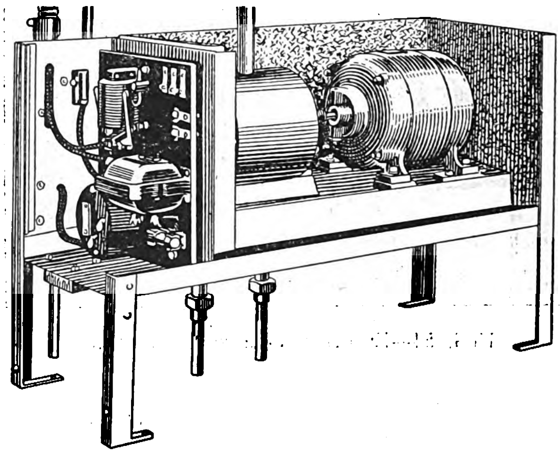

FIG. 59—CROSS SECTION OF GULF BURNER.

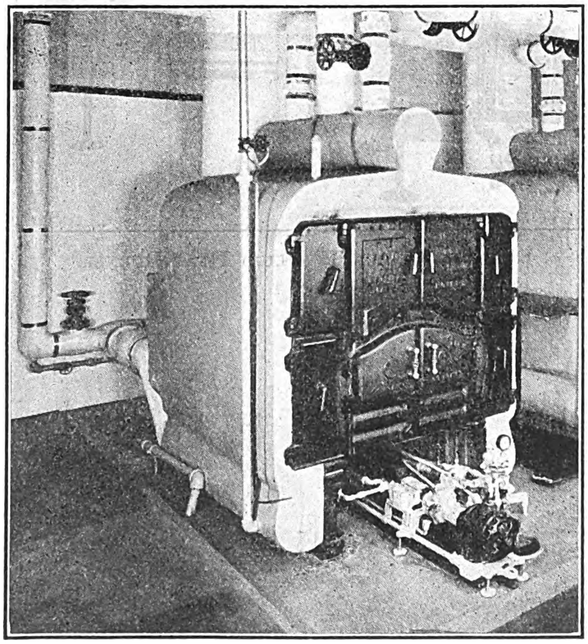

FIG. 60—HARDINGE BURNER INSTALLED.

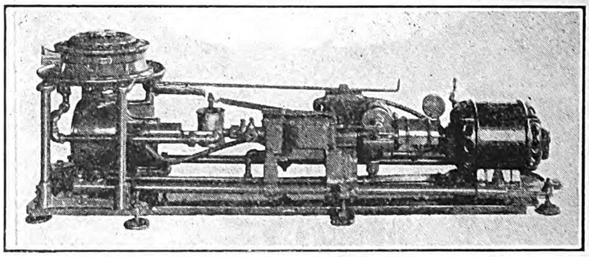

FIG. 61—HARDINGE BURNER.

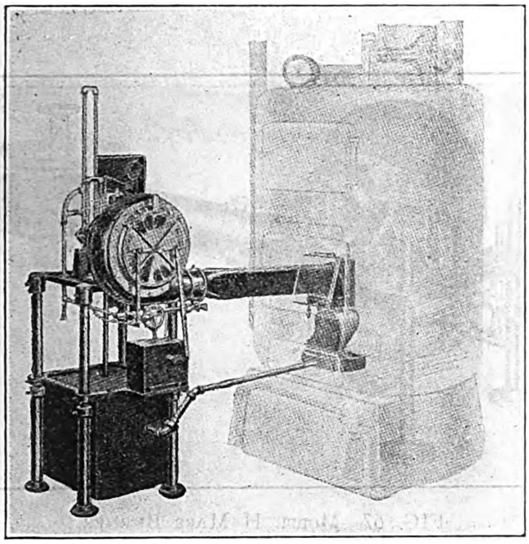

FIG. 62—THE McILVAINE BURNER INSTALLED.

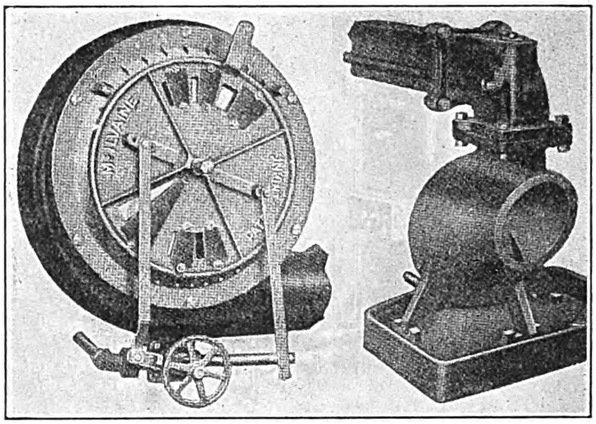

FIG. 63—FLAME CONTROLLER AND COMBUSTION CHAMBER McILVAINE BURNER.

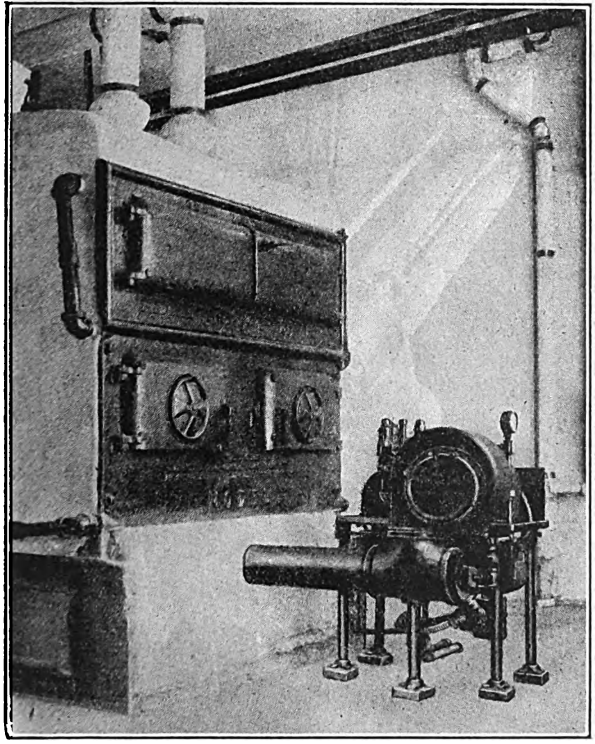

FIG. 64—THE QUIET MAY BURNER INSTALLED.

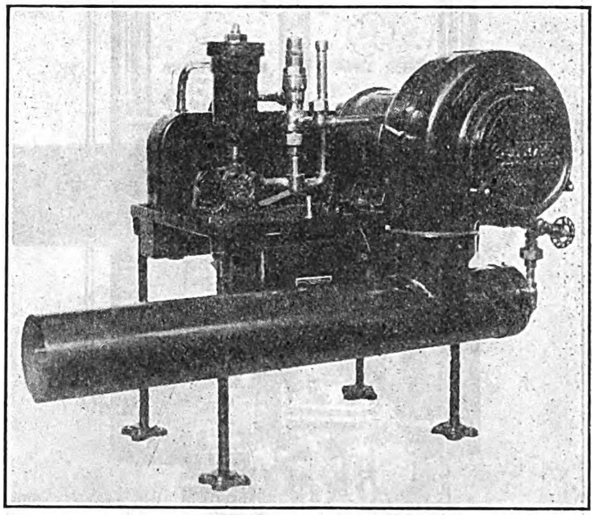

FIG. 65—TYPE L QUIET MAY BURNER.

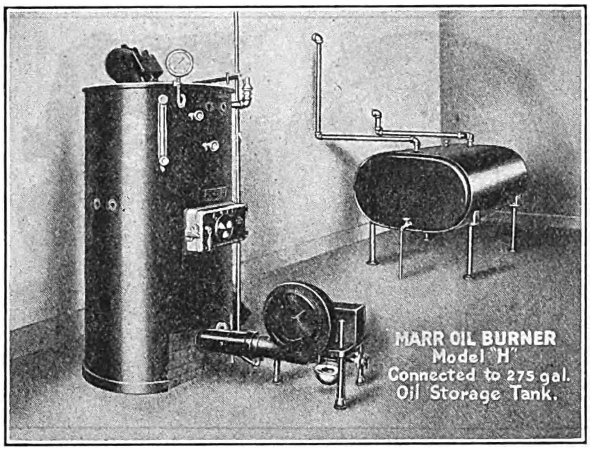
MARR OIL BURNER
Model "H"
Connected to 275 gal.
Oil Storage Tank.

FIG. 66—MODEL H MARR BURNER INSTALLED.

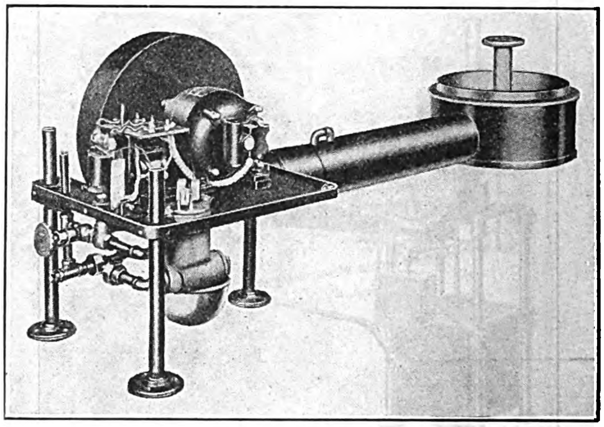

FIG. 67—MODEL H MARR BURNER.

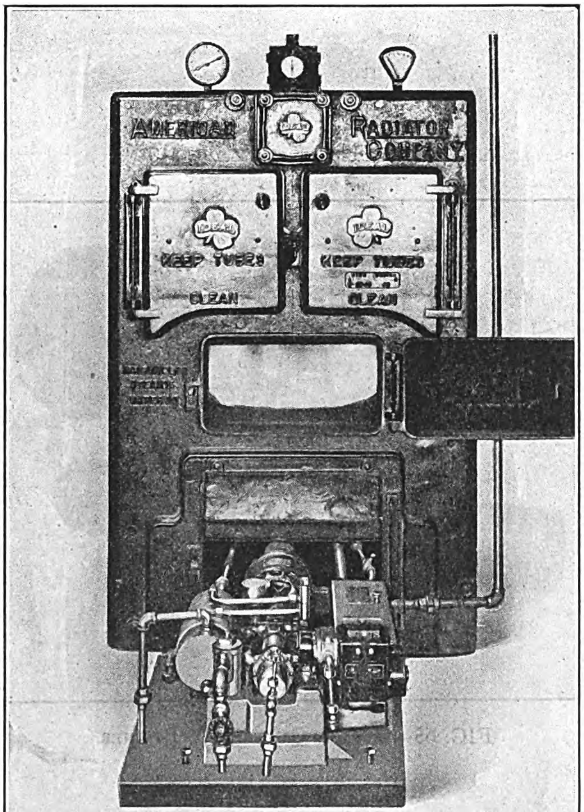
AMERICAN
RADIATOR
COMPANY
KEEP TUBES
CLEAN
KEEP TUBES
CLEAN

FIG. 68—MODEL E MARR BURNER INSTALLED.

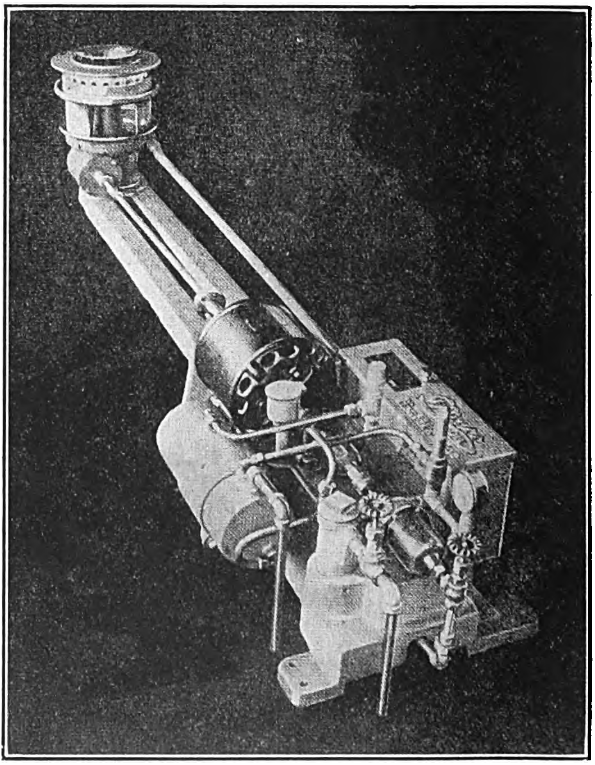

FIG. 69—MODEL E MARR BURNER.

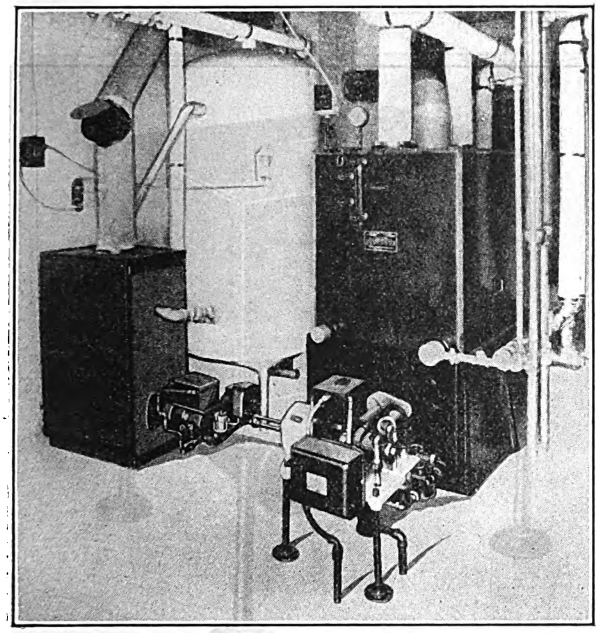

FIG. 70—NU-WAY BURNER INSTALLED.

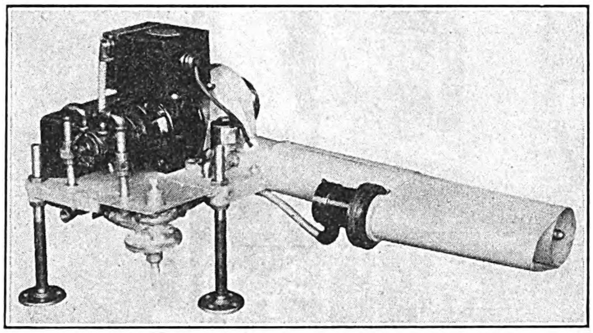

FIG. 71—NU-WAY BURNER.

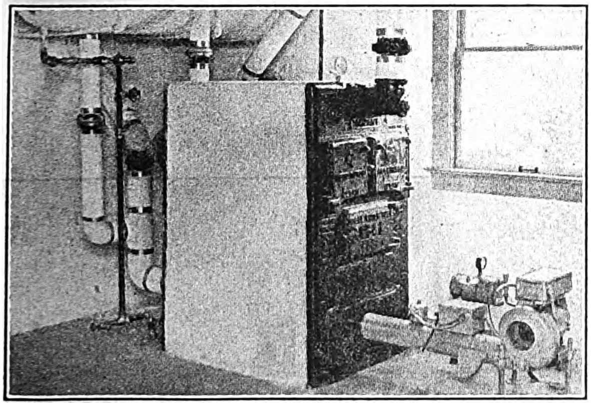

FIG. 72—HART BURNER INSTALLED (PREFERRED OIL BURNERS, INC.).

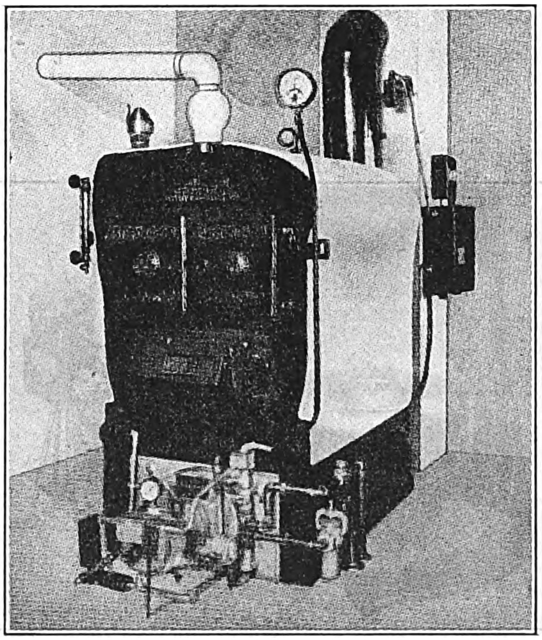

FIG. 73—RAY BURNER INSTALLED.

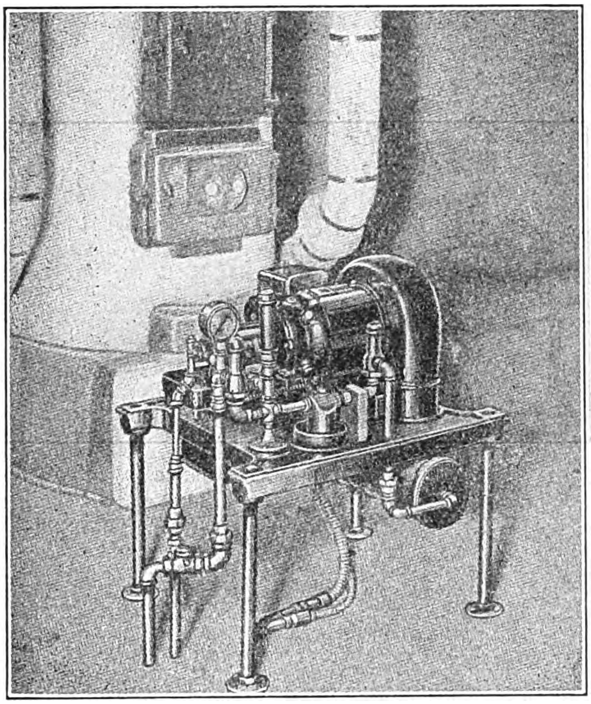

FIG. 74—Rickard Burner Installed.

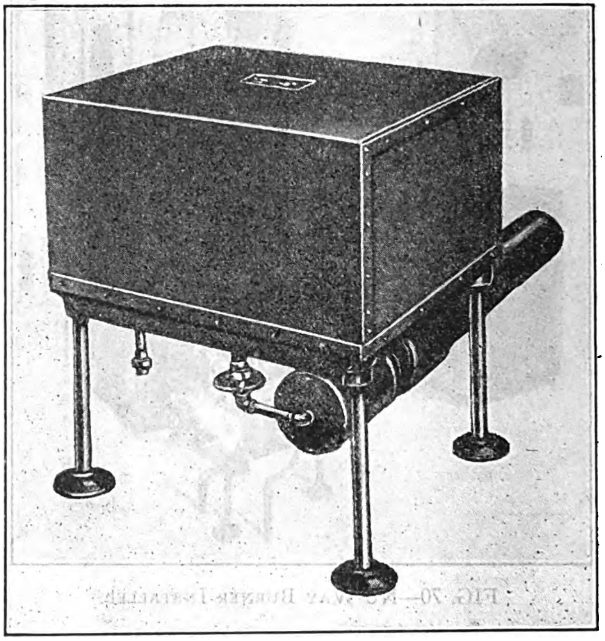

FIG. 75—Rickard Burner.

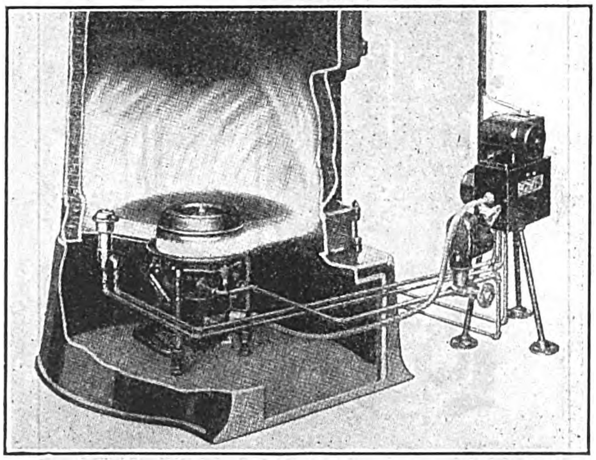

FIG. 76—The Silent Automatic Burner Installed.

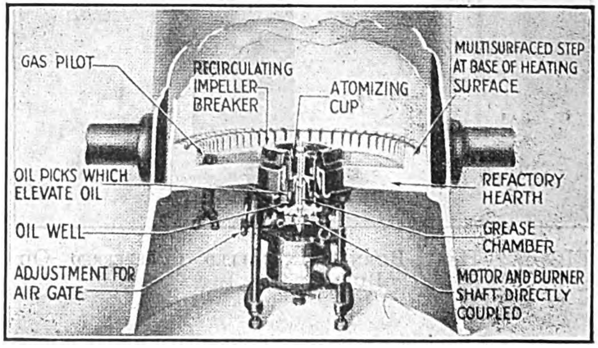
GAS PILOT
RECIRCULATING IMPELLER BREAKER
ATOMIZING CUP
MULTISURFACED STEP AT BASE OF HEATING SURFACE
OIL PICKS WHICH ELEVATE OIL
REFACTORY HEARTH
OIL WELL
GREASE CHAMBER
ADJUSTMENT FOR AIR GATE
MOTOR AND BURNER SHAFT DIRECTLY COUPLED

FIG. 77—The Silent Automatic Burner.

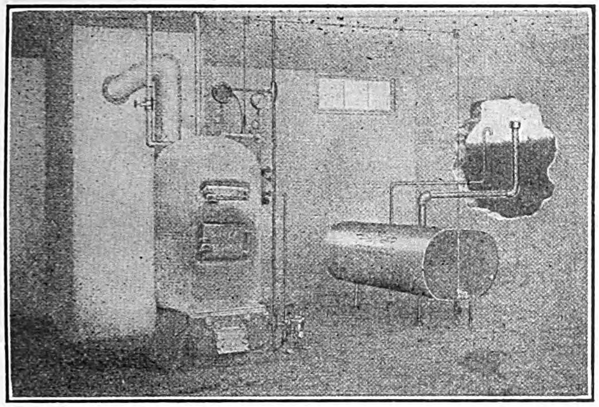

FIG. 78—THE SUPER OIL HEATOR INSTALLED.

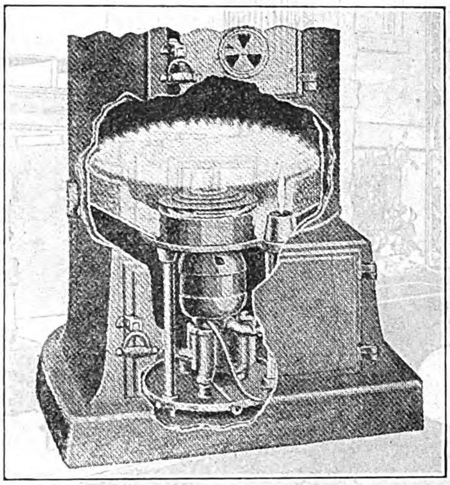

FIG. 79—THE SUPER OIL HEATOR IN OPERATION.

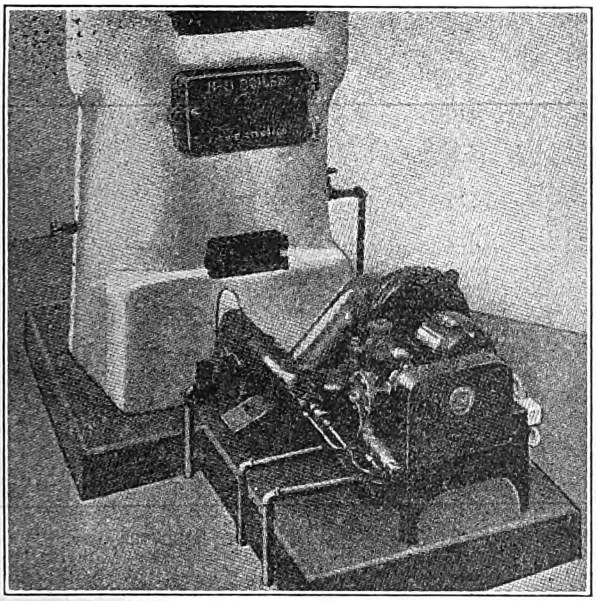

FIG. 80—THE SWORD BURNER INSTALLED.

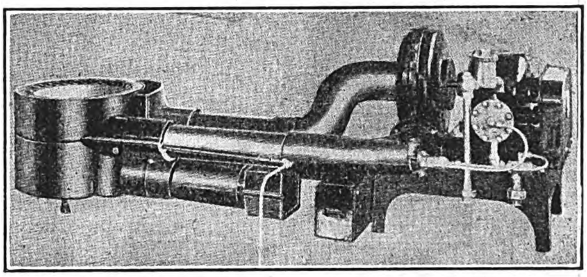

FIG. 81—THE SWORD BURNER.

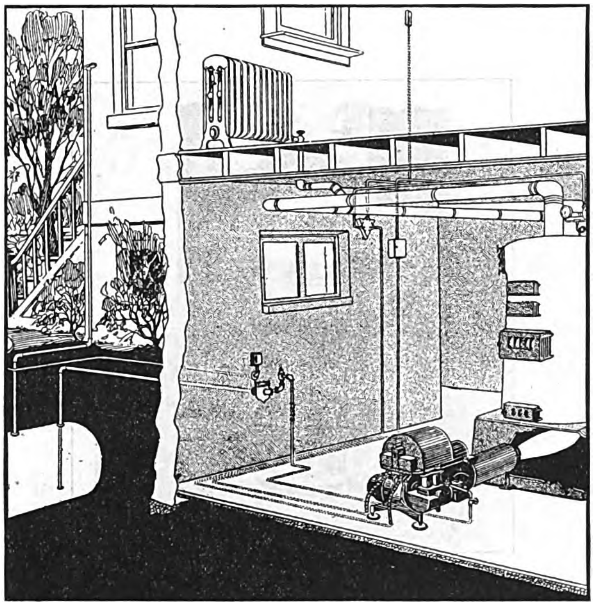

FIG. 82—TIMKEN-ARROW INSTALLATION.

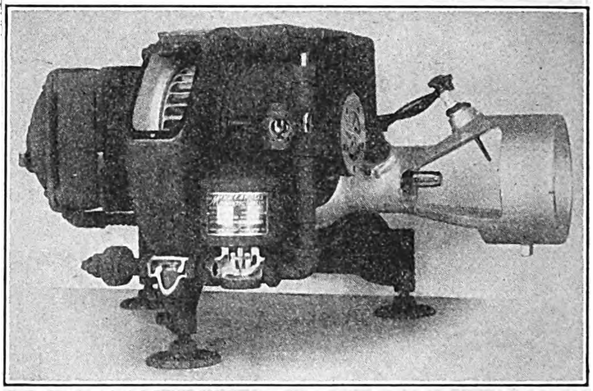

FIG. 83—MODEL 20 TIMKEN BURNER

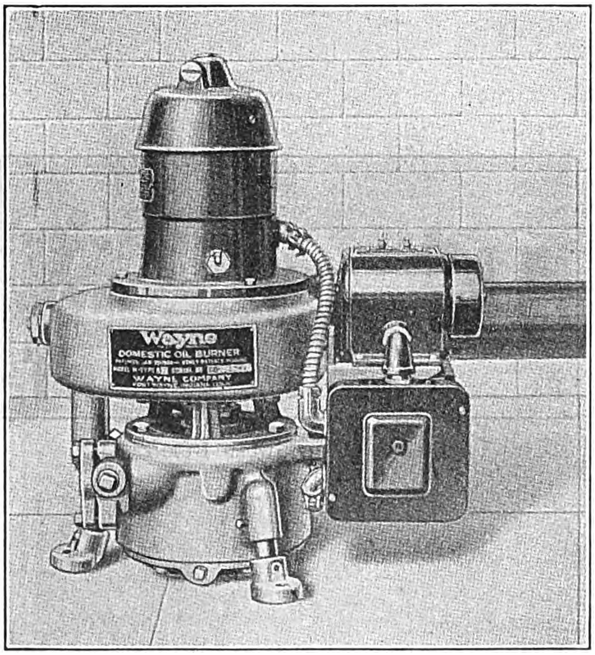
Wayne
DOMESTIC OIL BURNER
WAYNE COMPANY

FIG. 84—THE WAYNE BURNER INSTALLED.

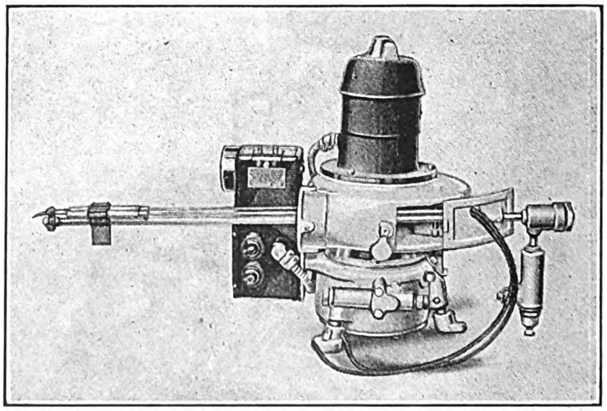

FIG. 85—THE WAYNE BURNER.

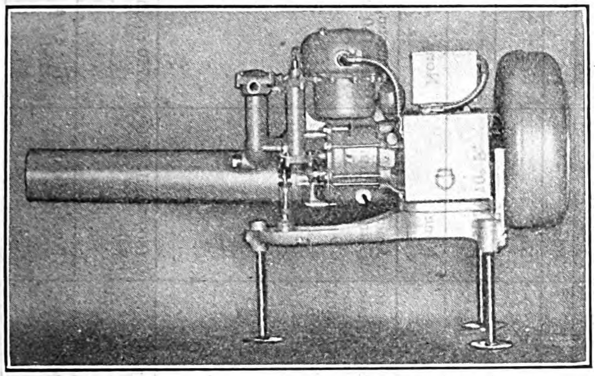

FIG. 86—THE OIL-O-MATIC BURNER.

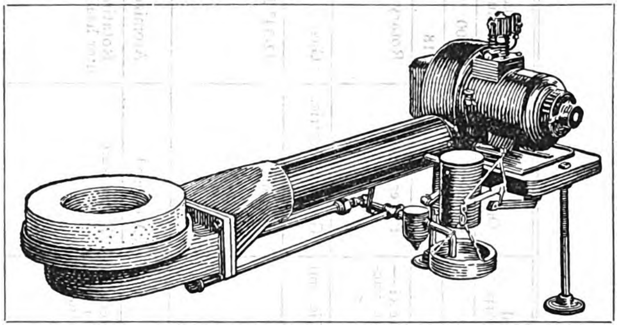

FIG. 87—THE KLEEN-HEAT BURNER (WINSLOW BOILER & ENGINEERING CO.).

MANUFACTURERS' SECTION

Part of the investigation of oil burners consisted in sending a questionnaire, covering details which were deemed to be of importance, to representative manufacturers throughout the United States. The questionnaire which was sent out is shown below:

QUESTIONNAIRE

1. Total number of burners in operation.
2. Number of burners installed in 1927.
3. Types of burners.
   (a) Picture of mechanical unit, picture of unit installed.
4. Type of ignition.
5. Grade of oil recommended.
6. Operating principles.
   (a) Is oil atomized or vaporized?
   (b) Method of atomization or vaporization.
   (c) Is the oil fed to burner under pressure?
   (d) Is compressed air used (if so, what is the pressure)?
   (e) Is it necessary to preheat oil in cold weather when stored in outside tanks?
   (f) What are the temperature limits for the oil in efficient operation?
   (g) If preheating is necessary, how is it accomplished?
7. Motor.
   (a) Make, size and type.
   (b) Characteristics—
      1. Speed.
      2. Efficiency.
      3. System of oiling.
8. Brief description of automatic and semi-automatic control.
9. Can burner be installed in any good boiler or furnace?
10. Does the shape or type of boiler or furnace affect the efficiency? If so, on which type or types is your burner most efficient?
11. What are the rating limits of your burners in radiation feet?
12. Are electrical filters or traps, to prevent radio interference, part of the original equipment?
13. List prices.

Seventy-five per cent of the companies to whom the questionnaire was sent replied in detail. The replies are tabulated in Table VII of this report. Representative illustrations of various burners and installations (Fig. 32-87, inclusive) appear on preceding pages in alphabetical order according to manufacturer.

The question which concerned the efficiency of the motor is not included in the tabulation of results, as there was a general misunderstanding of the intent of this question; some companies supplied the power factor, others the apparent efficiency, and the minority the actual efficiency. In some cases the power factor and apparent efficiency might be easily confused with the actual efficiency. For this reason, and since the motors used in the various burners were practically all of standard makes, the characteristics being available from the various motor manufacturers, it was deemed advisable to omit the answers to this question. It might also be recalled that the oil burner manufacturers were among those who subscribed to the conclusions of the joint committee on fractional horse-power motors. The characteristics may, therefore, be expected to conform with those accepted by the Committee. The report of this Committee, as given in the *Electrical World* 91-7, page 350, is contained in Appendix D of this report.

The list prices of the burners have been omitted as these data were not supplied by all of the companies, and it was not considered advisable to publish a partial list of this character. The replies, however, have been carefully tabulated, and if it is possible to complete the list before the publication of the next report, they will be included therein.

In the question, "Does the shape of the boiler or furnace affect the efficiency?", there was also an apparent misunderstanding inasmuch as some of the companies regarded the question as pertaining to combustion efficiency and not overall efficiency, which was originally intended. This possibly accounts for the statement that the shape of the particular installation does not have any effect on the efficiency.

TABLE VII

REPLIES TO QUESTIONNAIRES ON MANUFACTURERS DATA

Questions	American Nokol Co.	Automatic Burner Corp.	Baker Steam Motor Car & Mfg. Co.	Arthur H. Ballard of Mass. (Ballard Jr.)	Bettendorf Oil Burner Co.	Caloroil Burner Corp.	Chalmers Oil Burner Co.	Cleveland Steel Products Co.
1. Total number of burners in operation.	45,000	10,000	8,000	1,800	200	2,607	500	2,000
2. Number of burners installed in 1927.	6,000	1,700	1,500	900	200	616	100	518
3. Types of burners	Standard Nokol. Nokol-Rotary type. Aetna.	Centrifugal — Atomization.	Fire Pot Type 32-36 Gravity; Gun Type 28-30 Gravity.	Mechanical Atomizing.	Low pressure.	Mechanical — Low pressure vacuum oil lift.	Power type.	Rotary type.
4. Type of ignition	Gas and electric.	Gas or electric	Electric.	Both gas and electric.	Electric or combination gas-elec.	Gas, electric and electric-gas.	Gas and electric.	Gas.
5. Grade of oil recommended	St'd Nokol — 36° Baumé. Nokol Rotary. 32° Baumé. Aetna 28-30° Baumé.	28-32° Baumé.	Fire pot Type 32-36° Baumé; Gun Type 28-30° Baumé.	28-32° Baumé.	28-32° Baumé.	28° Baumé.	Gas oil.	32-34° Baumé
6. Operating Principles: (a) Is oil atomized or vaporized?	Atomized.	Atomized.	Atomized.	Atomized.	Atomized.	Atomized.	Atomized	Atomized
(b) Method of atomization or vaporization.	St'd and Nokol—Nozzle— Venturi principle. Aetna and Nokol Rotary: Centrifugal force through use of revolving spray pump.	High Speed Centrifugal.	Spray Nozzle.	Special emulsion pump.	Low pressure wet blower pump.	Oil is lifted by vacuum from level 2⅛" below the tip of oil nozzle.	H. pressure	Rotating distributor head.
(c) Is oil fed to burner under pressure?	No.	No.	Yes.	Yes.	No.	No.	Yes.	No.
(d) Is compressed air used. Pressure?	No.	No.	No.	1.5 lbs.	2-6 lbs.	3.5-5 lbs.	Pump.	No.
(e) Is it necessary to preheat oil in cold weather when in outside tanks?	No.	No.	No.	No.	No.	No.	No.	No.
(f) Temperature limits of oil eff. operation.			0°.	0°	50-70° F.		Best at 70° F.	
(g) If preheating is necessary, how accomplished?	None.	None.	None.	None.	None.	None.	None.	None.
7. Motor: (a) Make, size, type.	Aetna Burner: Holtzer-Cabot ⅙ to ½ h.p. Repulsion Induction and Westinghouse 2 h.p. Rep. Ind. Nokol Rotary: Ohio 1/12 h.p. split phase. Standard Nokol: Westinghouse 1/10 to ¼ h.p. split phase.	1/12 h.p. Universal.	Westinghouse ¼ h.p. No. 45 R.B.-A.R.60~110-220 v. ¼ h.p. No. 45 R.A.-A.R.30~110-220 v. ¼ h.p. No. 45 5B.-C.D.H.-D.C. ½ h.p. No. 45 R.A.-A.R.60~110-220 v.	Westinghouse A.R.S.-¼ h.p.	Emerson ¼, ⅓ and ¾ h.p. repulsion induction.	Century. ¼ to 3 h.p. Split phase in ¼ h.p. size repulsion induction in all other sizes.	Janette R.I. ⅙, ¼, and ⅓ h.p.	Emerson, single phase 110 volts 60 cycles.
(b) Speed.	Aetna and Nokol Rotary 1750 r.p.m. Standard Nokol 3500 r.p.m.	12,000 r.p.m.	1750, 1450, 1750, 3450 r.p.m. respectively.	1725 r.p.m.	1150 to 1750 r.p.m.	1750 r.p.m.	1800 and 3600 r.p.m.	1750 r.p.m.
(c) System of oiling.	Wool packed bronze sleeve bearings.	Wick with Large Reservoir. (once yearly.)	Oil cups.	Underfed wicking.	Wool packed bearing.	Wool packed bearings.	Wool packed.	Sleeve wool packed.

TABLE VII—(*Continued*)

REPLIES TO QUESTIONNAIRES ON MANUFACTURERS DATA

Questions	American Nokol Co.	Automatic Burner Corp.	Baker Steam Motor Car & Mfg. Co.	Arthur H. Ballard of Mass. (Ballard Jr.)	Bettendorf Oil Burner Co.	Caloroil Burner Corp.	Chalmers Oil Burner Co.	Cleveland Steel Products Co.
8. Automatic and semi-automatic control	Aetna: Standard Minneapolis No. 10 Protecto System in conjunction with low voltage thermostat. Nokol Rotary: Minneapolis Jr. Series 10. Protecto System is used with a low voltage series 10 thermostat. Standard Nokol Honeywell System comprised of a low voltage thermostat in conjunction with their type "D" regulator.	Trip bucket, 3 ball check valve, thermostat, boiler control, Minneapolis protectorelatand pyrostat or equivalent.	Minneapolis Series 10 controls.	Full automatic control using the Mercoid Corp's Visa flame control with either Pressurestat or Aguastat boiler controls. If hot air furnace, hot air control and governed by room thermostat.	Minneapolis Series 10 controls.	Minneapolis and Honeywell.	Minneapolis and Honeywell.	Minneapolis Heat Controls No. 10.
9. Can burner be installed in any good boiler or furnace?	Yes.	Yes: fire box dimensions greater than 18".	Yes.	Yes.	Yes.	Yes.	Yes.	Yes.
10. Does the shape of the boiler or furnace affect the efficiency? Type best suited for particular burner?	Efficiency of Burner not affected. General operation more efficient in special boilers for oil or gas, followed by steel boilers, horizontal cast iron, water tube and sectional and last the round type vertical boiler.	Of course: One with combination of greatest prim heating surface — longest flue travel.	No, except the longer the gas travel the better the efficiency.	No.	Yes. Boiler with long gas travel.	No. Not as a general rule.	Surely. Burner efficiency the same boiler efficiency varies due to leakage of air, insufficient section, excessive radiation.	No.
11. What are the rating limits of your burners in radiation feet?	Aetna: 12 sizes. 300 h.p. to 500 sq. ft. steam, 800 sq. ft. hot water. Nokol: 10 different sizes. Max. 4690 sq. ft. steam, 7500 sq. ft. hot water; min. domestic hot water heaters. Rotary minimum 1250 sq. ft. steam.	3000 ft. steam actual load.	No. 10. 960 ft. steam, No. 20 1800 ft., No. 30-4500 ft., No. 50-1800 ft., No. 60-6000 ft. steam.	No. 5. Junior 100-1000 ft. No. 7—500-2500 ft. No. 9—2000-5000 ft. No 11 — 4000-10,000 ft.	300-4000 ft. steam	Standard units to 10,000 ft. steam. special units for any size.	350-3000 ft.	
12. Are electrical traps of filters to prevent radio interference part of original equipment?	No.	No.	No.	Yes.	No.	No. Only on request.	Only used when trouble occurs.	No.

TABLE VII—(*Continued*)

REPLIES TO QUESTIONNAIRES ON MANUFACTURERS DATA

Questions	Combustion Fuel Oil Burner Co.	Commonwealth Engineering Co.	Electrol Inc.	The Fluid Heat Corp.	Gulf Oil Burner Co.	Hardinge Bros. Inc.	Lammert & Mann Co.
1. Total number of burners in operation.	9494	498	17,000-18,000.	319	2500		3000
2. Number of burners installed in 1927.	1723	300	Approx. 3500-4000.	228	1700	2000-3000	1000
3 Types of burners.	Air jet atomizing.		3 types. All mechanical draft.		5 types.	Gravity or pressure feed.	
4. Type of ignition.	Gas or electric.	Gas.	Electric.	Gas or electric.	Gas and electric.	Manual, gas, gas-electric.	Gas and electric.
5. Grade of oil recommended.	24° Baumé or higher. Atomized.	32-36° Baumé Gas oil.	As low as 28° Baumé and Pacific Diesel of 25° Baumé.	28° Baumé.	28° Baumé and up.	Gravity 32° Baumé. Automatic. 28-32° Baumé. With preheaters 18-24° and 18-22° Baumé.	28° Baumé.
6. Operating Principles: (a) Is oil atomized or vaporized?	Air jets.	Atomized.	Atomized.	Atomized.	Atomized.	Atomized.	Atomized.
(b) Method of atomization or vaporization.		Rotary cup.	Mechanical. Oil delivered under pressure to atomizing nozzle.	Pressure.	Positive pressure pump.	Mechanical cup.	Nozzle.
(c) Is oil fed to burner under pressure?	Yes.	Gravity pressure from pump.	Yes.	No.	Yes.	Low pressure pump or gravity.	Yes. 7 lbs.
(d) Is compressed air used. Pressure?	2-6 lbs.	No.	No.	No.	1 1/8 lbs.	Low pressure.	5 lbs.
(e) Is it necessary to preheat oil in cold weather when in outside tanks?	Not for recommended oil. Heavier oils heated for flowage.	No.	Sometimes.	No.	No.	With heavy oil. At or near combustion chamber.	No.
(f) Temperature limits of oil in eff. operation.	Independent of temp. above flowage point.	0°.	40° F.			140-180° F.	60-175° F.
(g) If preheating is necessary, how accomplished?	Water coils — electric heaters	None.	Electric preheater between pump on the burner and atomizing nozzle.	None.	None.	Indirect heater.	Steam.
7. Motor: (a) Make, size, type.	Standard makes ¼ to 3 h.p. Repulsion induction and polyphase.	G. E. pump motor ⅙ h.p. split phase, Burner motor 1/20 h.p. polyphase. Note: Pump motor is a combination frequency changer set furnishing 180 cycle current to the polyphase burner motor.	G. E., Century, Ohio, and Emerson split phase ⅙ h.p.	G. E. ¼ h.p. type R.S.A.	G. E. ¼ h.p. R.I.	Century Motors on A.C. Star Motors D.C. ¼, ⅓ and ½ h.p. single phase incorporate repulsion start principle. Polyphase all 3 phase squirrel-cage induction. D.C. motors all compound wound.	Baldor and G. E. Depends on installation.
(b) Speed.	1150 r.p.m.	Frequency changer 3600. Polyphase 10,300 r.p.m.	1750 and 1150 r.p.m. respectively.	1725 r.p.m	1750 r.p.m.	1750 r.p.m.	1200-1750 r.p.m.
c) System of oiling.		Frequency changer, oil one end, splash system other end. Polyphase centrifugal through hollow shaft.	Wool pack.	Wool packed bearings.		Wool yarn wicking. Grease cups.	

TABLE VII—(*Continued*)

REPLIES TO QUESTIONNAIRES ON MANUFACTURERS DATA

Questions	Combustion Fuel Oil Burner Co.	Commonwealth Engineering Co.	Electrol Inc.	The Fluid Heat Corp.	Gulf Oil Burner Co.	Hardinge Bros. Inc.	Lammert & Mann Co.
8. Automatic and semi-automatic control.	Automatic control is accomplished by means of thermostats and safety features protecting against overheated boilers, failure to ignite or any other sub-normal condition.	Thermostat, boiler control.	Electrol burners are entirely automatically controlled, being turned on by a room thermostat and being turned off either by a room thermostat or a controlling device responsive to conditions in the boiler or furnace. Electrol burners are equipped with a safety mechanism which is responsive to temperature conditions in the combustion chamber.	Minneapolis series 10 controls.	Combustion control "Stackstat" own make.	For automatic operation with gas ignition gas valves of own manufacture. Electrical equipment usually high voltage type consists of pressurestat, aquastat, thermostat and a hyrostat for regulating hot water supply in summer. With gas electric ignition, an electrically operated gas valve, a relay for ignition timing and a combustion safety control in addition to regular electrical equipment. Semi-Automatic. Boiler control either manual or automatic.	Mercoid
9. Can burner be installed in any good boiler or furnace?	Burner is universal sizes available in any boiler or furnace.	Yes.	Yes.	Yes.	Yes.	Yes.	Yes.
10. Does the shape of the boiler or furnace affect the efficiency? Type best suited for particular burner?	No, excepting so far as the particular furnace happen to be an inefficient heat transformer.	Burner seems most efficient in hot air plant.	Owing to difference in design and structure of furnaces, the results would be better in some instances than others.	No.	Not much.	The shape or type of boiler naturally effects the efficiency of operation or combustion. A boiler with ample combustion space will make a better steamer than one with restricted chamber volume.	No.
11. What are the rating limits of your burners in radiation feet?	300 sq. ft.—up to any size whatever.	1500 ft. steam, 2000 hot water.	TJ.—600-800 sq. ft. steam. Model T. up to 3000 sq. ft. steam. Model TD up to 8000.	2500 ft. steam.	200-6000 sq. ft. actual radiation.	300-25,000 sq. ft. steam.	800-30,000 sq. ft.
12. Are electrical traps or filters to prevent radio interference part of origina equipment?	No.	No.	Upon request — without charge.	No.	No.	No, but are willing to.	No.

TABLE VII—(*Continued*)

REPLIES TO QUESTIONNAIRES ON MANUFACTURERS DATA

Questions	Marr Oil Heat Machine Corp.	McIlvaine Burner Corp.	May Oil Burner Corp.	Nu-Way Corp.	Preferred Oil Burner Inc.	Ray Mfg. Co.	Rickard Engineering Corp.
1 Total number of burners in operation.	5000	About 600.	10,000.	5,000.	Approx. 11,000.	45,000.	About 200.
2. Number of burners installed in 1927.	600	About 200.	3,912.	1,500.	Approx. 2000.	No figures.	About 150.
3. Types of burners.	Models E, G and H.	Continuous flame, mechanical draft.	Type "L," Type "C." Type "A."		Model D-1, D-2, D-3 and Junior.	Horizontal rotary.	Mechanical atomization.
4. Type of ignition.	"E" and "G" gas pilot; "H" gas and oil pilot.	Manual.	Electric.	Comb. gas and electric or electric.	Electric or comb. gas-electric.	Gas, electric, gas-electric.	Electric.
5. Grade of oil recommended.	Models E and G 24° Baumé and up. Model H 32° Baumé and up.	36° Baumé.	28-45° Baumé. Diesel oil 25° Baumé.	28-30° Baumé.	28-32° Baumé.	25° Baumé or lighter.	Oil No. 4 usually 28° Baumé.
6. Operating Principles: (a) Is oil atomized or vaporized?	"E" and "G" atomized — "H" vaporized.	Vaporized.	Atomized.	Atomized.	Atomized.	Atomized.	Atomized.
(b) Method of atomization or vaporization.	"E" and "G" rotary atomizer. "H" oil and gas mixed before combustion.	Contact with hot combustion chamber.	Specially designed atomizer.	Pressure.	Oil is whirled against air from a sirocco fan.	Rotary cup.	Mechanical.
(c) Is oil fed to burner under pressure?	No.	Gravity.	Yes.	No.	Vacuum feed..	Yes.	Yes.
d) Is compressed air used. Pressure?	None.	2 inches for mechanical draft.	No.	No.	2-6 lbs.	No.	No.
e) Is it necessary to preheat oil in cold weather when in outside tanks?	No.	No.	No.	No.	No.	No.	No.
(f) Temperature limits of oil in eff. operation.					30° or over.	Between 60-120°.	Depends on oil.
(g) If preheating is necessary, how accomplished?		None.	None.	None.	None.	None.	None.

TABLE VII—(*Continued*)

REPLIES TO QUESTIONNAIRES ON MANUFACTURERS DATA

Question	Marr Oil Heat Machine Corp.	McIlvaine Burner Corp.	May Oil Burner Corp.	Nu-Way Corp.	Preferred Oil Burner Inc.	Ray Mfg. Co.	Rickard Engineering Corp.
7. Motor: (a) Make, size type.	"E" and "G": —Century ¼ h.p. "H" G. E. 1/20.	Janette 1/20 h.p. split phase.	Type "A":—G. E. split phase—⅙ h.p. Type "L":—Century ¼ h.p. Repulsion Induction. Type "C": —Century ½ h.p. Repulsion Induction.	Emerson 1/20-⅙-h.p. split phase ⅙-⅓-¾ h.p. Repulsion Induction.	Emerson or Wagner Repulsion Induction. Model D-1, ⅙ h.p.; Model D-2, ¼ h.p. Model D-3, ½ h.p.	Westinghouse Induction ⅛-10 h.p.	Janette ⅙ h.p. Repulsion Induction 60 cycle A.C. only.
(b) Speed.	1725 r.p.m.	750 r.p.m.	1750 r.p.m.	1800 and 1200 r.p.m.	1725 and 1440 r.p.m.	3450 r.p.m.	1750 r.p.m.
(c) System of oiling.	Wick with reservoir.	Oil reservoir packed with lamb's wool.	Wool yarn.	Wool packing.	Oil reservoir and yarn wicks.	Automatic oil ring on pressure burner, worm on pump burners.	Oil packed bearing.
8. Automatic and semi-automatic control.	Model E-g Honeywell low voltage program. Model "H" —"Contactor" high voltage.	5 point thermostat, 5 point regulator and 3 wire safety switch. This model gives five operating stages from low to high in accordance with the demand for heat.	Honeywell or Minneapolis.	Minneapolis Protecto Relay or Mercoid S.D.P. Controls.	Preferred Hart System, timing switch, flue safety switch, heat control and recycling switch.	Automatic Honeywell or contactor controls fixed fire or high and low fire. Semi-automatic control of oil, air and draft.	Standard Honeywell system.
9. Can burner be installed in any good boiler or furnace.	Yes.	Yes.	Yes.	Yes.	Yes.	Yes.	Yes.
10. Does the shape of the boiler or furnace affect the efficiency? Type best suited for particular burner?	Not much. Round or square boilers are the most efficient with slight drop in the rectangular type.	Laboratory tests show practically no effect on efficiency by shape or type of boiler.	Square section as opposed to round boilers are found to be more efficient for oil heat. Many special types of steel water tube and fire tube boilers recently developed for oil heat are very good.	No.	Our burner develops the same efficiency in all boilers or furnaces. However different kinds of boilers or furnaces give different efficiencies and of course an oil burner's performance is governed to a large extent by these limitations.	No.	The burner is the same but design of boiler can affect overall efficiency tremendously. Most good coal burning boilers are also good oil burning boilers.
11. What are the rating limits of your burners in radiation feet?	Model E 16,000 ft. steam. Model H 1000 ft. water.	6 sizes 400-2400 sq. ft. of steam. Twin units up to 4,800 sq. ft.	Type A. 600 sq. ft. steam, 1000 sq. ft. hot water. Type L. 2400 sq. ft. steam, 4000 sq. ft. hot water. Type C. 8400 sq. ft. steam, 14,000 sq. ft. hot water.	50-6000 ft.	Junior 350 sq. ft. steam. D-1 600 sq. ft. steam. D-2 2000 sq. ft. steam. D-3 3000 sq. ft. steam.	600-150,000 ft.	500-15,000 ft. steam.
12. Are electrical traps or filters to prevent radio interference part of original equipment?	Yes.	No.	With type A.	No.	No.	Yes, but optional.	No.

TABLE VII—(*Continued*)

REPLIES TO QUESTIONNAIRES ON MANUFACTURERS DATA

Questions	Silent Automatic Corp.	Super Oil Heator Co.	Sword & Kimber Co.	Timken-Detroit Co.	Wayne Co.	Williams Oil-O-Matic Heating Corp.	Winslow Boiler & Engineering Co.
1. Total number of burners in operation.	About 13,000.	Between 5 and 6000.	2200.	Approx. 9000.	3000.	Between 60 and 70,000.	
2. Number of burners installed in 1927.	About 5,000.	2000.	650.	Approx. 2750.	1000.	Approx. 15,000.	
3. Types of burners.	Centrifugal atomization plus "gasification."	Rotary.	Pot type. Model "L" and Model "J."	Arrow and Model 20.	B-3, B-4, B-6.	Two types.	Kleen Heet Series 800. Kleen Heet type G.J.
4. Type of ignition.	Gas and electric.	Gas and electric.	Gas and electric.	Electric.	Gas, electric, gas-electric.	Electric or gas.	Electric.
5. Grade of oil recommended.	36-40° Baumé distillate.	28-32° Baumé.	36-40 °Baumé.	Arrow 35° Model 20 28° Baumé.	Not heavier than 28° Baumé.	28-30° Baumé.	28-32° Baumé.
6. Operating Principles: (a) Is oil atomized or vaporized?	Atomized and vaporized.	Atomized.	Model "L" atomized. Model "J" vaporized.	Atomized.	Atomized.	Atomized	Atomized
b) Method of atomization or vaporization.	Atomization by centrifugal force. Vaporization by mixture with hot gases.	Compressed air.	Model "L" gun and target. Model "J" heat of return gases.	Arrow, Compressed air. Model 20 low pressure air.	Pump pressure and nozzle.	Special atomization vane pump.	Winslow stem-tip nozzle assembly.
(c) Is oil fed to burner under pressure?	No.	No.	Model "L," pump. Model "J," gravity.	No.	Suction pump.	Yes, special metering pump.	Yes.
(d) Is compressed air used? Pressure.	No.	4 lbs.	No.	Arrow, 5-18 lb. Model 20—No.	No.	Mixture of air and oil 2 lbs	No.
(e) Is it necessary to preheat oil in cold weather when in outside tanks?	No.	No.	No.	No.	No.	No.	No.
(f) Temperature limits of oil in eff. operation.		Outside temp. of 0°.	0° F.	0° F.	Not less than 25° F.		
(g) If preheating is necessary, how accomplished?	None.	None.	None.	None.	None.	None.	None.
7. Motor: (a) Make, size, type.	Ohio — split phase induction 1/12 h.p.	Leland ⅙ and ¼ h.p. vertical repulsion induction.	G. E. ⅙ h.p.	Arrow: Robbins & Meyers ¼ h.p. repulsion induction. Model 20: Robbins & Meyers ⅙ h.p. split phase.	G. E. ⅙-¼ and ½ h.p. repulsion induction.	Baldor, ¼ h.p. repulsion induction.	Series 800: Century ⅙ h.p. repulsion induction. Type G.J. Westinghouse ⅙ h.p. repulsion induction.
(b) Speed.	1750 r.p.m.	1140 and 1725 r.p.m.	1750 r.p.m.	3500 and 1750 r.p.m. respectively.	1725 r.p.m.	1200 and 1800 r.p.m.	1750 r.p.m.
(c) System of oiling	Wool packed bearings.	Large ball bearings wool yarn. Perpetual lubrication lower bearing.	Packed bearings.	Wick and wool pack.	Oil cups.	Front bearings bath of fuel oil. Rear motor bearings oil cup.	Standard Century motor.

TABLE VII—(*Concluded*)

REPLIES TO QUESTIONNAIRES ON MANUFACTURERS DATA

Questions	Silent Automatic Corp.	Super Oil Heator Co.	Sword & Kimber Co.	Timken-Detroit Co.	Wayne Co.	Williams Oil-O-Matic Heating Corp.	Winslow Boiler & Engrg. Co.
8. Automatic and semi-automatic control.	Complete automatic controls consisting essentially of a motor program switch, a thermostat, a pressure or temperature limiting device on the heater and a combustion safety device.	110 v. controls in series.	Complete automatic control either Minneapolis or Federal gauge.	Minneapolis.	Honeywell control system.	Full automatic, thermostat and boiler; high voltage thermostat, direct control also manual.	Automatic controls, Minneapolis type using room thermostat and boiler controls operating through Minneapolis protecto relay with protectostat controlling burner operation from the action of the flame upon the protectostat diaphragm.
9. Can burner be installed in any good boiler or furnace?	Yes.	Yes—of proper size.	Yes.	Yes.	Yes.	Yes.	Yes.
10. Does the shape of the boiler or furnace affect the efficiency? Type best suited for particular burner?	The shape of boiler or furnace does not affect the efficiency of combustion.	Some. Round type.	Inefficient boilers will not give efficient results with any oil burner. The Sword burner is adaptable to any shape or type of boiler with heating requirement within its range.	No.	Not a great degree.	Any good heating plant can be used effectively.	Series 800. No. Oil burning is most efficient, of course, in those boilers in which the indirect or flue heating surfaces permit the gases to completely yield their heat before entering the chimney. Type GJ. Round and square house boilers.
11. What are the rating limits of your burners in radiation feet?	250-5000 sq. ft.	650 steam. 1100 hot water	Model "L," 2000 ft. hot water. Model "J," 1000 ft. hot water.	Arrow, 2000 steam. Model 20: 1000 steam.	B-3 1250, B-4 3500, B-6 3000—all direct steam.	1200 r.p.m. burner-limit 1500 sq. ft. direct steam, 2500 sq. ft. hot water. 1800 r.p.m. burner limit 4000 sq. ft. direct steam, 6300 direct water	Series 800. 600-6800 sq. ft. steam, 1200 sq. ft. steam load.
12. Are electrical traps or filters to prevent radio interference part of original equipment?	No.	No.	No.	No.	No.	No.	No.

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APPENDIX A

OIL FUEL SPECIFICATIONS*

Variation of Fuel Oils

Unfortunately gravity alone is not a true indication of the burning quality of an oil. Whereas one oil of a given gravity may flow readily and light with comparative ease, another of the same gravity may have a higher or lower flash point, be more viscous and in general have properties quite different from the first. The difficulties encountered by the oil burner manufacturer and the purchaser of the fuel oil are many. For example, the story is told of the manufacturer who designed his burner to satisfactorily ignite and operate on a 28 deg. Baumé fuel oil, advertised the burner extensively and guaranteed its operation on this basis. The burner was doing all that he claimed for it on the 28 deg. oil that he was getting in that territory, but when the burners were shipped to another territory it was impossible to get them to operate on the 28 deg. oil that was available in that locality, due to the fact that it had a higher viscosity and flash point, and differed radically in the properties of the oil for which the burner had been designed. This variation is due in part to the fact that the characteristics vary with the different crudes from which they are produced, and also to the fact that the oil companies mix or "blend" different grades in order to make one having the desired gravity. Consequently where gravity alone is the only specification mentioned in the purchase of the oil, it is practically impossible to expect any kind of uniformity in quality and characteristics.

Nomenclature. Designations of oil fuel properties and grades are confusing to the initiate in the business for the reason that they cannot be pinned down definitely and tangibly. In the sense that it is used to head this chapter "fuel oil" is meant to include all oils that are used for fuel burning purposes, regardless of their origin or use. When so used it includes kerosene, distillate, residuum and even crude oil. In market quotations and in the parlance of the filling station and oil burner man, "fuel oil" is the residual product remaining after the so-called kerosenes, distillates and gas oils have been distilled off in the refining process—providing, of course, that the residual product is not intended for lubrication stock or some purpose other than burning. It will be noted that the oils above 38-40 gravity, grouped as "burning oils," are principally kerosenes. Under the "fuel oil" group the gravity range, for distillates, is from 36 deg. to 40 deg. principally, with lower ranges in California. The most common range for gas oil is 32 deg. to 36 deg., and the majority of the oil for burning that is below 32 deg. is known as fuel oil. It is customary, at the present time, in buying oils to specify them on a gravity basis, but it is a well-known fact that gravity is not a reliable index to the quality of the oil and its combustion characteristics.

Classification. Because of the fact that gravity does not provide definite classification of fuel oils, the American Oil Burner Association has in the past three years made a study of the various characteristics of oil, and with the data that were collected in making this study has adopted a set of specifications covering the various grades of fuel oil that are in use today. The following table gives the specification number and name, together with the old designation and approximate gravity range.

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A O B A DESIGNATION		OLD DESIGNATION	
Specification Number	Name	Gravity Range	Name
		48-44	Light Kerosene
		44-40	Kerosene
1	Furnace Oil—Light	40-36	Distillate
2	Furnace Oil—Med.	36-32	Gas Oil
3	Furnace Oil—Hvy.	32-28	Light Fuel Oil
4	Fuel Oil—Light	24-28	Medium Fuel Oil
5	Fuel Oil—Medium	24-18	Heavy Fuel Oil
6	Fuel Oil—Heavy	18-12	Very Hvy. Fuel Oil

The specifications which have been adopted by the Association were compiled by the Association's Committee on Uniform Oil Specifications with the aid and cooperation of the American Petroleum Institute and Committee D2 of the American Society for Testing Materials.

UNIFORM OIL FUEL SPECIFICATIONS OF THE AMERICAN OIL BURNER ASSOCIATION

OIL NO. 1.

Name: Furnace Oil—Light

Scope

1—This specification covers a light distillate oil for use in burners where a high grade fuel is required.

Properties

2—This oil shall conform to the following requirements: It shall be a hydrocarbon oil free from water, acid, grit and fibrous or other foreign matter likely to clog or injure the burner or valves.

(a) Flash Point:
  Minimum—[1] Legal or (Pensky-Martens Closed Tester) .... 110° F. or legal
  Maximum—(Pensky-Martens Closed Tester) 165° F.
(b) Water and Sediment, maximum 0.05%
(c) Pour Point, maximum .... 0° F.
(d) Distillation Test:
  When 10 per cent has been collected in the receiver, the thermometer reading shall not exceed .... 420° F.
  The end point shall not be higher than...... 600° F.

Methods of Testing[2]

3—The properties enumerated in these specifications shall be determined in accordance with the following methods of test of the American Society for Testing Materials, except as specified in paragraph (a).

(a) Flash Point:
  [1] Minimum—the flash point, instrument and method for determining minimum flash point shall be that legal for the locality in which the oil is sold. In absence of legal requirements, the minimum flash point shall be determined in accordance with the Standard Method of Test for Flash Point by means of the Pensky-Martens Closed Tester (Serial Designation D 93).
  Maximum—Standard Method of Test for Flash Point by means of the Pensky-Martens Closed Tester (Serial Designation D 93).
(b) Water and Sediment:
  Standard Method of Test for Water and Sediment in Petroleum Products by Means of Centrifuge. (Serial Designation D 96).
(c) Pour Point:
  Tentative Method of Test for Pour Points of Petroleum Products (Serial Designation D 97-27 T).
(d) Distillation Test:
  Standard Method of Test for Distillation of Gasoline, Naphtha, Kerosene and similar Petroleum Products (Serial Designation D 86).

[2] In event changes are made in the Methods of Tests by the A S T M, the current Method of Test is to be used rather than those mentioned in the specifications.

OIL NO. 2.

Name: Furnace Oil—Medium

Scope

1—This specification covers a grade of distillate oil for use in burners where a high grade fuel is required.

Properties

2—This oil shall conform to the following requirements: It shall be a hydrocarbon oil free from water, acid, grit and fibrous or foreign matter likely to clog or injure the burner or valves.

(a) Flash Point:
  Minimum—[1] Legal or (Pensky-Martens Closed Tester) .... 125° F. or legal
  Maximum—(Pensky-Martens Closed Tester) 190° F.
(b) Water and Sediment, maximum 0.05%
(c) Pour Point, maximum .... 0° F.
(d) Distillation Test:
  When 10 per cent has been collected in the receiver, the thermometer reading shall not exceed .... 440° F.
  When 90 per cent has been collected in the receiver, the thermometer reading shall not exceed .... 620° F.

Methods of Testing[2]

3—The properties enumerated in these specifications shall be determined in accordance with the following methods of test of the American Society for Testing Materials, except as specified in paragraph (a).

(a) Flash Point:
  [1] Minimum—The flash point, instrument and method for determining minimum flash point shall be that legal for the locality in which the oil is sold. In absence of legal requirements, the minimum flash point shall be determined in accordance with the Standard Method of Test for Flash Point by means of the Pensky-Martens Closed Tester (Serial Designation D 93).
  Maximum—Standard Method of Test for Flash Point by means of the Pensky-Martens Closed Tester (Serial Designation D 93).
(b) Water and Sediment:
  Standard Method of Test for Water and Sediment in Petroleum Products by Means of Centrifuge (Serial Designation D 96).
(c) Pour Point:
  Tentative Method of Test for Pour Points of Petroleum Products (Serial Designation D-97-27 T).
(d) Distillation Test:
  Tentative Method of Testing Gas Oils (Serial Designation D 158-25 T).

[2] In event changes are made in the Methods of Tests by the A S T M, the current Method of Test is to be used rather than those mentioned in the specifications.

OIL NO. 3

Name: Furnace Oil—Heavy

Scope

1—This specification covers a grade of oil, generally known to the trade as light fuel oil intended for general industrial consumption, for use in burners where a medium low viscosity fuel is required.

Properties

2—This oil shall conform to the following requirements: It shall be a hydrocarbon oil free from water, acid, grit and fibrous or foreign matters likely to clog or injure the burner or valves.

(a) Flash Point:
  Minimum—[1] Legal or (Pensky-Martens Closed Tester) .... 150° F. or legal
  Maximum—(Pensky-Martens Closed Tester) 200° F.
(b) Water and Sediments, maximum........... 0.1%
(c) [2] Pour Point, maximum .... 0° F.
(d) Distillation Test:
  When 10 per cent has been collected in the receiver, the thermometer reading shall not exceed .... 460° F.
  When 90 per cent has been collected in the receiver, the thermometer reading shall not exceed .... 675° F.
(e) Viscosity, Saybolt Universal, at 100° F., maximum .... 55 sec.

Method of Testing [3]

3—The properties enumerated in these specifications shall be determined in accordance with the following methods of test of the American Society for Testing Materials, except as specified in paragraph (a).

(a) Flash Point:
  [1] Minimum—The flash point, instrument and method for determining minimum flash point shall be that legal for the locality in which the oil is sold. In absence of legal requirements, the minimum flash point shall be determined in accordance with the Standard Method of Test for Flash Point by means of the Pensky-Martens Closed Tester (Serial Designation D 93).
  Maximum—Standard Method of Test for Flash Point by means of the Pensky-Martens Closed Tester (Serial Designation D 93).
(b) Water and Sediment:
  Standard Method of Test for Water and Sediment in Petroleum Products by Means of Centrifuge (Serial Designation D 96).
(c) Pour Point:
  Tentative Method of Test for Pour Points of Petroleum Products (Serial Designation D 97-27 T).
  [2] The maximum pour point shall be 0° F., except for localities where the average temperature between Oct. 1 and May 1 is 40° F., or above, in which case the pour point may be plus 15° F. (see Fig. 18).
(d) Distillation Test:
  Tentative method of Testing Gas Oils (Serial Designation D 158-25 T).
(e) Viscosity:
  Standard Method of Test for Viscosity of Petroleum Products and Lubricants (Serial Designation D 88).

[3] In event changes are made in the Methods of Tests by the A S T M the current Method of Test is to be used rather than those mentioned in the specifications.

OIL NO. 4

Name: Fuel Oil—Light

Scope

1—This specification covers a grade of oil generally known to the trade as light fuel oil intended for general industrial consumption. It is for use in burners adapted to a medium viscosity fuel.

Properties

2—This oil shall conform to the following requirements: It shall be a hydrocarbon oil free from water, acid, grit and fibrous or other foreign matters likely to clog or injure the burner or valves.

(a) Flash Point:
  Minimum (Pensky-Martens Closed Tester).. 150° F.
  Maximum (Pensky-Martens Closed Tester). 250° F.
(b) Water and Sediment, maximum............. 1.0%
(c) Pour Point, maximum...................... 15° F.
(d) Viscosity, Saybolt Universal at 100° F., maximum .... 125 sec.

Method of Testing [1]

3—The properties enumerated in these specifications shall be determined in accordance with the following methods of test of the American Society for Testing Materials:

(a) Flash Point:
  Standard Method of Test for Flash Point, by means of the Pensky-Martens Closed Tester (Serial Designation D 93).
(b) Water and Sediment:
  Standard Method of Test for Water and Sediment in Petroleum Products by Means of Centrifuge (Serial Designation D 96).
(c) Pour Point:
  Tentative Method of Test for Cloud and Pour Points of Petroleum Products (Serial Designation D 97-27 T).
(d) Viscosity:
  Standard Method of Test for Viscosity of Petroleum Products and Lubricants (Serial Designation D 88).

[1] In event changes are made in the Methods of Tests in the A S T M, the current Method of Test is to be used rather than those mentioned in the specifications.

OIL NO. 5

Name: Fuel Oil—Medium

Scope

1—This specification is that of the Federal Specifications Board for Bunker Fuel Oil "B" and covers a grade of fuel oil suitable for burners adapted to oil of medium heavy viscosity.

Properties

2—The oil shall conform to the following specifications: It shall be a hydrocarbon oil free from grit, acid and fibrous or other foreign matters likely to clog or injure the burner or valves. If required, it shall be strained by being drawn through filters or wire gauze of 16 meshes to the inch. The clearance area through the strainers shall be at least twice the area of the suction pipe, and the strainers shall be in duplicate.

(a) Flash Point:
  Minimum (Pensky-Martens Closed Tester).. 150° F.
(b) Water and Sediment, maximum........... 1.0%
(c) Viscosity, Saybolt Furol at 122° F., maximum .... 100 sec.

Methods of Testing [1]

3—The properties enumerated in these specifications shall be determined in accordance with the following methods of test of the American Society for Testing Materials:

(a) Flash Point:
  Standard Methods of Test for Flash Point by means of the Pensky-Martens Closed Tester (Serial Designation D 93).
(b) Water and Sediment:
  Standard Method of Test for Water and Sediment in Petroleum Products by Means of Centrifuge (Serial Designation D 96).
(c) Viscosity:
  Standard Method of Test for Viscosity of Petroleum Products and Lubricants (Serial Designation D 88).

[1] In event changes are made in the Methods of Tests by the A S T M the current Method of Test is to be used rather than those mentioned in the specifications.

OIL NO. 6

Name: Fuel Oil—Heavy

Scope

1—This specification is that of the Federal Specifications

Board for Bunker Fuel Oil "C" and covers a grade of fuel oil suitable for burners adapted to oil of high viscosity.

Properties

The oil shall conform to the following specifications: It shall be a hydrocarbon oil free from grit, acid and fibrous or other foreign matters likely to clog or injure the burner or valves. If required it shall be strained by being drawn through filters or wire gauze of 16 meshes to the inch. The clearance area of the strainers shall be at least twice the area of the suction pipe and the strainers shall be in duplicate.

(a) Flash Point:
Minimum (Pensky-Martens Closed Tester) .. 150° F.
(b) Water and Sediment, maximum 2.0%
A deduction in quantity will be made for all water plus sediment in excess of 1.0 per cent.
(c) Viscosity, Saybolt Furol at 122° F., maximum 300 sec.

Methods of Testing[1]

3—The properties enumerated in these specifications shall be determined in accordance with the following methods of test of the American Society for Testing Materials:

(a) Flash Point:
Standard Method of Test for Flash Point by means of the Pensky-Martens Closed Tester (Serial Designation D 93).
(b) Water and Sediment:
Standard Method of Test for Water in Petroleum Products (Serial Designation D 95-27) (U. S. G. S. S. Method 300.11) U. S. Government Standard Specification Method 300.2 for sediment.
(c) Viscosity:
Standard Method of Test for Viscosity of Petroleum Products and Lubricants (Serial Designation D 88).

[1] In event changes are made in the Methods of Tests by the A S T M the current Method of Test is to be used rather than those mentioned in the specifications.

Methods of Testing Procedure

Complete information regarding the procedure for making tests specified can be obtained from the American Society for Testing Materials, 1315 Spruce Street, Philadelphia. Oils No. 5 and No. 6 are specified in the Bureau of Mines—Technical Paper No. 323B. This publication can be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C. The price is 15 cents.

Properties of Fuel Oil

The properties set forth in the above specifications are primarily those which are important from the standpoint of burner operation, with limits fixed that are practical from the standpoint of the refinery operations and at the same time insure a uniformity that is necessary for satisfactory burner performance.

Flash. The flash point of an oil is the temperature at which sufficient vapor is given off, when the oil is slowly heated, to momentarily flash when a small standard flame is brought near the surface of the oil, the fire becoming extinguished instantly for lack of fuel. When the oil is heated beyond the flash point a temperature is reached at which sufficient vapor is given off to burn continuously when once ignited. This temperature is termed a fire point. These properties are important as regards the readiness with which the oil will ignite and burn. It is essential that the flash and fire points be sufficiently high to guard against dangerous inflammability, but at the same time they should be low enough so that when used in a burner the oil will ignite instantly and continue to burn.

The minimum flash point is necessary for compliance with legal requirements. Due to the very wide variations in the regulations of different States and municipalities, it is not possible to specify the flash point or instrument to be used in determining the minimum flash point because there is such a wide variation. Accordingly, the instrument and minimum flash point, as indicated by the authorities, which are legal for the locality in which the oil is to be sold, should be ascertained by the user of the specifications and be included in them. A maximum flash point is desirable in oils No. 1 to No. 4 inclusive, to take care of automatic ignition requirements. Since legal considerations do not enter here, the standard instrument and method of test given in the forms may be used.

Water and Sediment. Water and sediment in the fuel is more than a total loss; in addition to the fact that it has no heating value, it actually requires heat to bring it up to the furnace temperature. A large amount of water in the oil results in poor combustion, and there is some liability of extinguishing the flame. The amount of water and sediment is determined by centrifuging a given quantity of the oil in a standard centrifuge machine which causes the water and sediment to separate out, due to its greater weight.

Pour Tests. The pour point is the lowest temperature at which oil will pour or flow, when it is chilled, without urging under specified conditions. The oil is put into a standard test jar and tightly sealed with a cork which has a thermometer extending through its center. The temperature of the oil is brought down until the oil retains its form when inclined so the surface is vertical. This temperature is known as the solid point. A temperature 5 deg. higher than this is known as the pour point.

The pour test should be applied to oils No. 1 to No. 4 inclusive, since it is essential that the consumer be protected against wax-bearing distillates.

Distillation Range. This test is to determine the temperature at which definite percentages of oil are vaporized. The temperature at which this vaporization begins is called the "initial point"; that at which it ends is called the "end point." The initial point, or slightly beyond, is a reasonably good indication of the temperature required for a sufficient amount of vapor to form to support combustion continuously, and the end point gives a relative comparison of the temperature at which all of the oil can be vaporized and burned.

A distillation requirement is necessary for oils No. 1 to No. 3 inclusive to limit deliveries to the type of oil desired and to insure proper fluidity and volatility. Except for oil No. 1 only the 10 per cent and 90 per cent points are specified, the former to insure the proper amount of readily volatile material, and the latter to protect against excessive amounts of high boiling constituents.

Viscosity. Viscosity is the internal friction or resistance to flow offered by the individual oil particles in contact with each other or surfaces to which they can adhere. The time required for a definite amount of oil to flow through an orifice of standard size is a relative measure of the oil's viscosity. If it takes a long time, the number representing the seconds is large and the substance is said to have a high viscosity. If the substance is very fluid the time required is less and consequently the viscosity is said to be low. Heat makes viscous substances more fluid or, in other words, reduces their viscosity. Oils of low gravity are generally, though not necessarily, those of high viscosity. For example, an oil 12 or 14 deg. A. P. I. gravity in cold weather has very much the characteristics of molasses—much more so than one of the 28-30 or 38-40 gravity. Circulating the oil in contact with steam coils or otherwise heating it will thin it appreciably and generally make it easier to atomize and to handle.

Since there is no universally recognized standard instrument or method of measuring viscosity, the term means nothing unless there are also stated the names of the instruments used and the viscosity and temperature at which the viscosity was determined. Common types of viscosimeters, or instruments for measuring the viscosity of oil, are the Saybolt, Engler and Tagliabue. A Saybolt Standard Universal Viscosimeter is used almost exclusively in this country. Other viscosimeters in use are the Scott, Redwood, Pennsylvania Railroad pipet and others. The Engler viscosimeter is used extensively in Germany and the Redwood viscosimeter in England.

APPENDIX B

REPORT OF TEST ON "OIL HEAT MACHINE,"* PHILADELPHIA, PA.

Description

The Oil Heat Machine was a mechanical atomizing type of oil burner.

The machine consisted of the following principal parts:

a. A ¼ h.p. General Electric 110-220 volt., 60 cycle, A. C. 1725 r.p.m. motor.
b. An oil pump to supply fuel to the burner.
c. A metering device to measure oil supplied for burning.
d. A pressure regulating valve to maintain fuel from the pump, under pressure, through the metering device.
e. Fan and atomizing cone, and collar driven from the same shaft within the furnace to supply through centrifugal action a fine spray of oil and sufficient air for proper burning.
f. A fire brick basin beneath the fan and atomizing cone.
g. A ring gas jet burner in basin, and gas pilot.
h. Safety device.
i. Program switch controlling the operation of the machine and actuated by the room thermostat.

The moving parts of the machine were operated through a shaft coupled to each end of the motor. The fuel pump and metering device was driven from one end of the motor, and the centrifugal atomizer and fan from the other.

The operation of the machine was controlled by a thermostat located in the living room of the above residence.

When the room temperature fell below that set on the thermostat the action of the thermostat operated the "program switch" on the machine. The operation of this switch caused the motor to start, and gas to flow through the ring jet burner where it was ignited by the pilot flame. The atomized oil whirled out over the atomizing collar and in presence of the air supplied by the fan was ignited, and positive burning of the atomized fuel was obtained by the maintaining of the ring gas flame for a period of about two minutes. At the end of this time the fire brick basin was heated enough to carry on regular operation.

The fuel supply for continuous burning was obtained by the fuel pump drawing oil from the storage tank through a strainer, and forcing it under the adjusted pressure through the metering device—a stationary and movable disk with a one-eighth inch hole in each disk allowing oil to pass only when the holes coincided to the atomizing cone. The excess oil pumped was returned to the storage tank, through the return line.

When the proper temperature in the living room was attained the thermostat opened the "program switch" and stopped the operation of the machine. At the same time a governor type valve in the metering device closed the pump discharge line ahead of the two measuring disks, preventing any further flowing of oil.

Object

This test was conducted in order to determine the operating characteristics, and the season heating cost, of this type of burner.

Installation

The burner was installed in an American Radiator Company's Areo 3-23, W-Series No. 23-1B hot water boiler, to which was connected 580 sq. ft. of radiation.

The house contained eight rooms, including an inclosed porch, also a heated garage in the basement. It was located in a row, with northern exposure at the rear and southern exposure at the front. The construction was brick with frame bay windows in the rear first and second floors.

The construction for heat insulation could be classed as ordinary.

The boiler and the risers in the basement were not covered.

Method of Test

The oil consumption was obtained by depth gage measurements in the oil storage tank. This method of measurement gave readings accurate within 0.3 of a gallon.

The current consumption was obtained by an integrating kilowatt-hour meter installed in the motor circuit. The number and length of operating periods were obtained from charts of a graphic ammeter installed in the motor circuit.

The temperatures of the supply and return water to the heating system inside and outside air temperatures were obtained by thermocouples attached to a recording potentiometer. The thermocouples used for obtaining the water system temperatures were secured to the outside of the

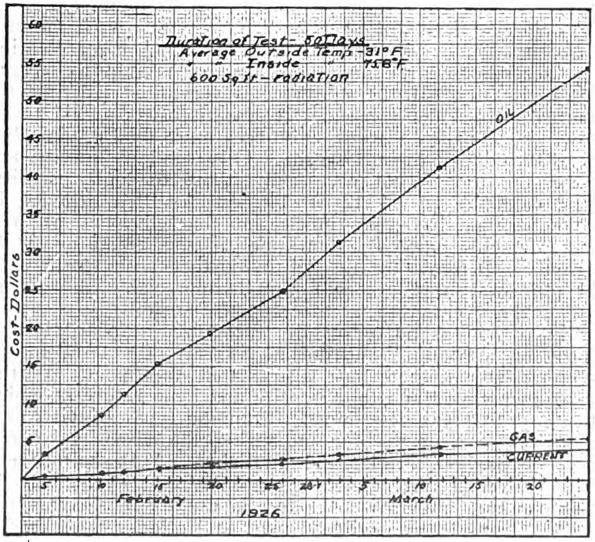

FIG. 88—TOTAL COST OF OPERATION.

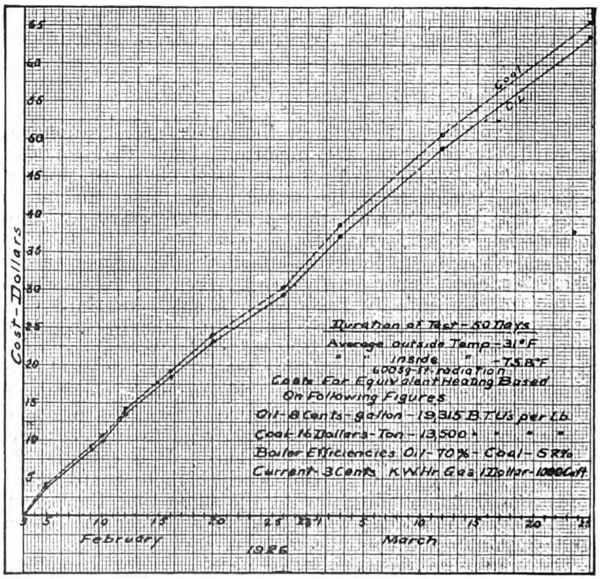

FIG. 89—TOTAL HEATING COST OIL VS. COAL.

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*Test made by The Philadelphia Electric Company.

pipes at the boiler with cement and covered with asbestos and tape. The temperature gradient of the pipe was obtained by difference of thermocouple, and standard thermometer readings under the same conditions with the thermometer in a well in direct contact with the water.

The stack temperature was obtained by a recording thermometer, the bulb of which was placed in a stack at the connection to the boiler. The flue gas obtained from point of leaving boiler, was analyzed by an orsat apparatus. The air supplied for combustion was measured by an anemometer and wind tunnel constructed around the burner.

Several analyses of samples of the fuel burned were made in order to check uniformity of shipments.

The gas consumption was obtained by gas meter readings during the period when the heat machine only was using gas.

Record of the different temperatures and oil and current consumption was taken at intervals of four or five days throughout the test, which began 10 A. M., Feb. 3, 1926, and concluded March 25, 1926, at 10 A. M.

The date from which boiler efficiency was calculated was obtained during period March 24 to 25.

A summary of the results of the test is given in Table V of the main report.

The values in Table V are plotted in Fig. 88 and 89.

Test Data

Oil Analysis

Specific Gravity, 0.855 (33.8° Baumé)

Flash point	185° F.
Fire point	210° F.
Sulphur	1.37%
B.t.u. per lb.	19,315

Boiler Test Data 3/24/25 26

Average analysis flue gas	
CO_2—13.6%	Heating hours—14.81 Mean water temperatures—120.5° F.
O_2—1.7%	Average room temperature—73° F. Average stack temperature—620° F.
CO—0.0	Oil consumed 5.75 gal.—kw-hr.—1.3 oper. hr.—4.75

Average air supplied per hour, 65° F., cu. ft.	1,872
Per cent excess	14%

Boiler Efficiency—70%		
Avg. kw-hr. per gal. of oil burned	0.1955	During Test Period—50 days—600 sq. ft. radiation Average outside temperature, 31° F., inside 75.8° F.
Avg. cu. ft. gas per gal. of oil burned	8.2200	
Avg. gal. oil per oper. hour	1.3250	
Avg. operating hours per day	10.2500	

BOILER EFFICIENCY (OIL)

(*Radiation Data*)

B.t.u.'s supplied heating system in 14.8 heating hours—544,000 B.t.u.'s.

B.t.u.'s supplied to burner—790,000 B.t.u.'s.

$$\text{Boiler efficiency } \frac{544,000}{790,000} = 68.9\%$$

BOILER EFFICIENCY

(*Combustion Data*)

	B.t.u.'s.	Per cent
Stack loss	91,900	11.64
Loss due hydrogen in oil	70,200	8.89
Radiation loss	74,000	9.37
	236,100	29.90

Boiler efficiency, 100.00—29.90—70.1%.

COST DATA

Cost over test period—50 days, from 2-3-26 to 3-25-26.
Average outside temperature, 31 deg. F.
Average inside temperature, 75 deg. F.

Oil	
Gallons burned—678.25, at 8 cents per gal.	$54.25
Electricity	
Kw-hr.—132.5, at 3 cents per hour	3.98
Gas	
Cubic feet—5576, at $1 per 1000 cu. ft.	5.58
Total cost, 50 days	$63.81
Average cost per day	1.28

Estimated cost of equivalent heating with coal at $16 a ton—2240 lb., and containing 13,500 B.t.u.'s per lb., with a boiler efficiency of 52 per cent:

Tons of coal required—4.1, at $16 per ton	$65.60
Cost per day	1.31

Difference in cost of equivalent operation over test period: Oil, 2.73%, or 3 cents per day less than coal.

ESTIMATED SEASON'S HEATING

Heating period, 210 days.
Average outside temperature for season, 40 deg. F.
Average inside temperature, 75 deg. F.
Using quantities from curve of Average Quantities:

Oil	
Gallons oil—2100, at 8 cents per gal.	$168.00
Electricity	
Kw-hr.—420, at 3 cents per kw-hr	12.60
Gas	
Cubic feet, on basis of average—111 cu. ft. per day—23,300, at $1 per 1000 cu. ft.	23.30
Total cost	$203.90
Cost per day	0.97

Equivalent Coal Heating Cost

Boiler efficiency 52 per cent—13,500 B.t.u.'s per lb. $16 per ton—2240 lb.

Tons of coal required—12.85, at $16 per ton	$205.50
Cost per day	0.98

Difference in cost of equivalent operation:
Oil—1.17 per cent, or 1 cent per day less than coal.

Estimated season's heating covering same period with average outside temperature of 40 deg. F. and average inside temperature 70 deg. F.

Oil	Total cost, $185.00	$0.881 per day
Coal	Total cost, $186.00	0.886 per day

Discussion of Results

The results obtained during the fifty days of this test indicate that the inside temperature was maintained at a higher temperature than any normal operation on coal would probably give. The operating cost of the machine shown in the cost data, therefore, is relatively higher than would be expected. However, figured on the basis of equivalent heating with coal, the cost of oil operation is less by the margin of about 3 per cent.

Boiler efficiency was figured in two ways: first, on the basis of heat transfer through radiation surface, and second, from the combustion data obtained during operating periods.

The efficiencies obtained of 68.9 per cent and 70.1 per cent respectively indicate a close check and show an operating condition under ordinary home installations that could not be obtained by coal operation without added expense and inconvenience and would be questionable there.

The boiler efficiency from radiation data was obtained by taking the mean temperature of the heating medium over the number of heating hours as shown by the thermocouple chart from the recording potentiometer, and figuring the heat omission of a square foot of radiating surface for each type of radiator, taking into account the number of sections, columns and height. From this data the average number of B.t.u.'s omitted per hour was obtained. The efficiency figured from the combustion data was obtained from analysis of flue gas samples taken during the operating periods. The average CO_2 content of the flue gas for nine samples taken was 13.6 per cent, indicating excellent combustion for the burner. A check on this percentage of CO_2 of 14 per cent excess air was obtained by measuring the air supplied per operating hour to the burner, by anemometer.

In figuring the losses up the stack and that, due to the hydrogen in the oil, values of 85 per cent carbon and 12.5 per cent hydrogen per pound of oil were assumed, on the basis of comparison between specific gravity degrees Baumé and B.t.u. per pound with the table of Chemical Analysis of similar oils.

The average figure of 0.2 of a kilowatt-hour per gallon of oil burned over the average of 10 operating hours per day, giving a current consumption of 2.0 kw-hr. per day seems to be a reasonable figure as a season's average for a home with 600 sq. ft. of radiation, and ordinary construction.

The gas consumption per season for the burner would be the same regardless of the size of the home heated. The only variation from the average of 100 cu. ft. of gas a day consumed by the pilot flame would be the number of operating periods. The gas consumption in the first two minutes of operating on starting was 2 cu. ft., representing the gas supplied to the ring jet.

The burner operated 42.7 per cent of the test period as compared to a season average of operation of 30 per cent.

Discussion of Charts

The chart showing "Total Quantities" (Fig. 90) is an accumulative chart, showing in progressive stages the total operating hours and current, gas and oil consumption through the test, and indicates a fairly uniform increase in each quantity.

The chart for "Daily Quantities" (Fig. 91) shows the variation in current and oil consumption, operating hours and outside and inside temperatures, in the form of averages for periods between readings. It will be noted that the temperature scale for this chart is inverted so that no confusion would result when observing increases in current oil and operating hour quantities during low temperature periods.

The chart indicates in its contour the effect of outside temperature on heating.

This temperature was obtained from a section of the dining room adjacent to the window and about one foot from the wall having northern exposure.

The chart showing "Average Quantities" (Fig. 92) represents the variation of the gallons of oil—operating hours and kilowatt-hours per day for periods of average temperatures ranging from 20 deg. to 40 deg. F. and for the condition of a home containing 600 sq. ft. of radiation, ordinary construction, and average inside temperature of 75 deg. F. The values plotted in these curves were obtained from calculations based on test averages and indicated an accurate curve, for, if the curves were continued along the same slope, the trio would meet at a point just beyond 70 deg. F.

The "Operation—Radiation Chart" (Fig. 93) also obtained from test averages shows the variation in quantities considered in previous charts for varying amounts of radiation, ordinary construction, and based on 70 deg. F. inside temperature, for average outside temperature of 32 deg. F. and 40 deg. F. respectively. A factor of 0.60

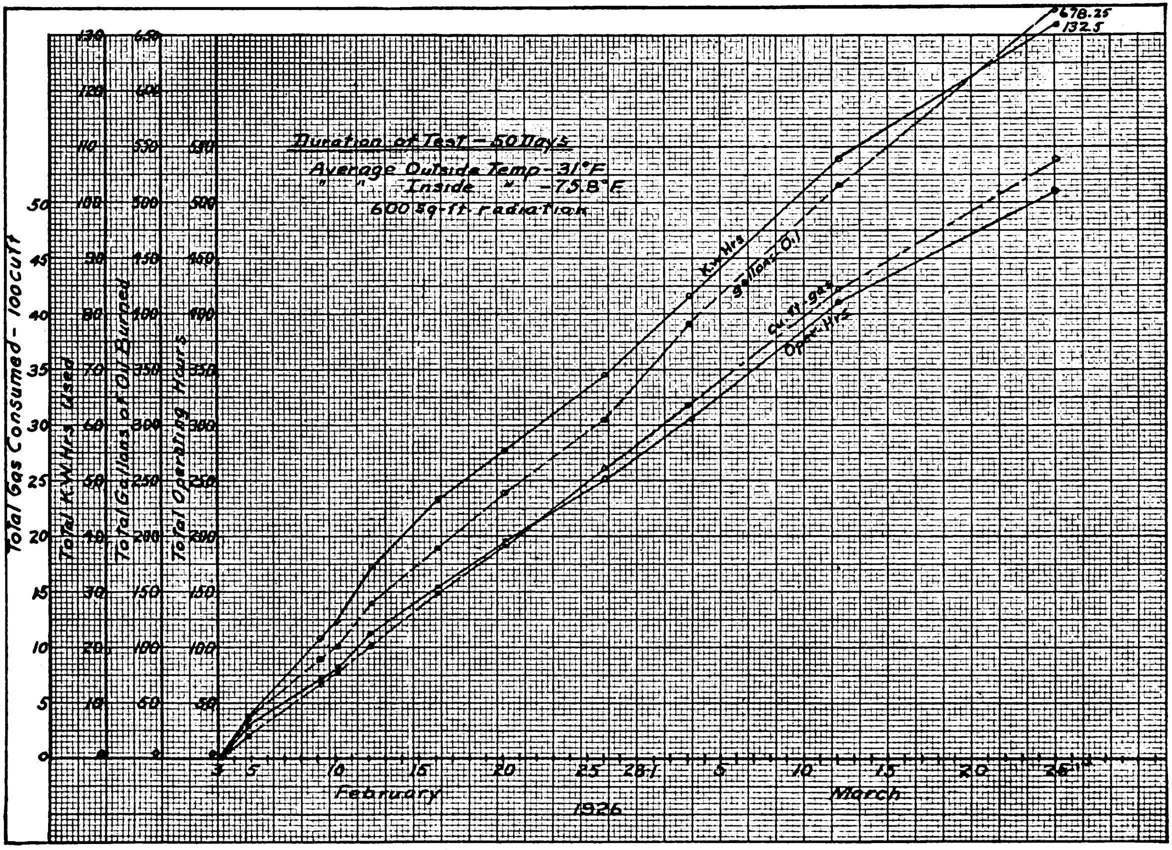


FIG. 90—TOTAL QUANTITIES.

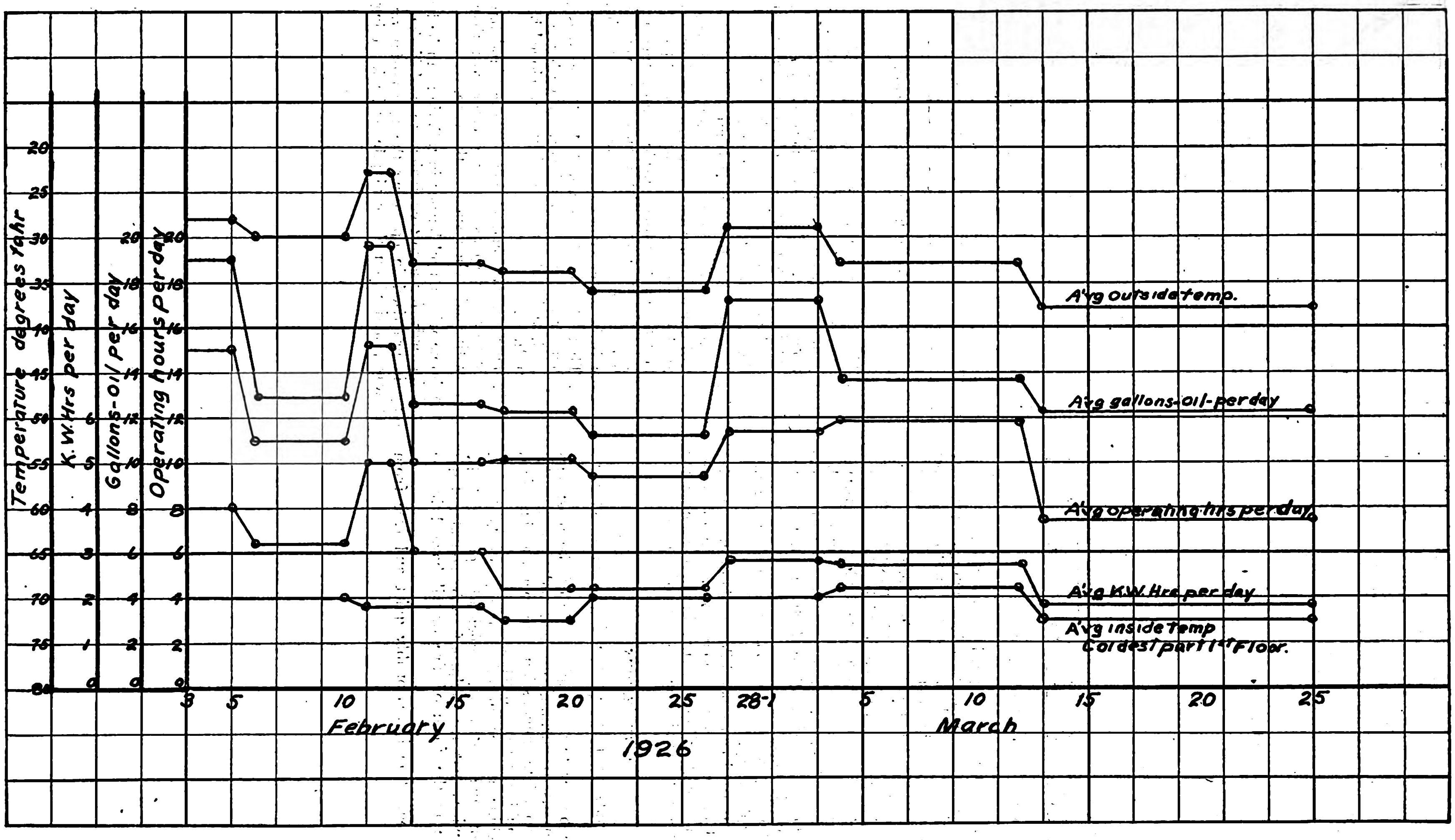


FIG. 91—DAILY QUANTITIES.

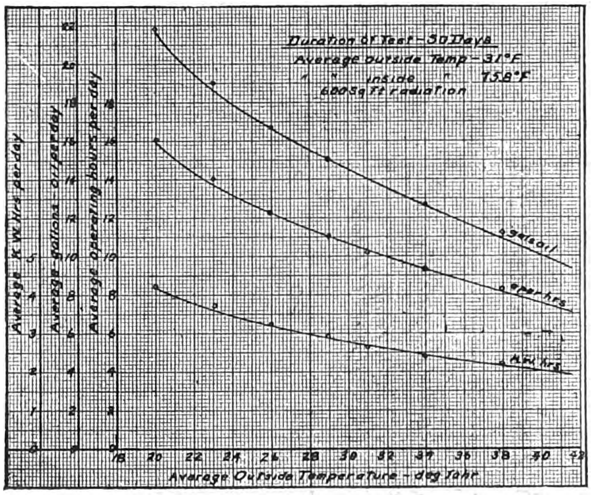


FIG. 92—AVERAGE QUANTITIES.

used for good construction applied to each curve would give quantities for the well insulated home. From the chart, then, could be figured the average heating cost per season of any residence by adding to the cost of oil and current obtained there from the cost of 23,000 cu. ft. of gas. The chart also indicates that the maximum number of square feet the oil heat machine could handle, under the condition of test operation and ordinary building construction during a period averaging 32 deg. F. would be between 1200 and 1400 sq. ft. For good construction, the burner would take care of 1800 to 2000 sq. ft. under the same weather conditions.

The chart showing costs of oil operation and oil against coal are self-explanatory.

NOTE—The rate of 3 cents per kilowatt-hour used in this report is based on the fact that homes operating oil burners would burn enough kilowatt-hours in three months for light and other uses to obtain the new rate of 3 cents.

Conclusions

From the results of this test the following conclusions are drawn:

1. That the burner tested employs one of the most successful means of burning oil fuel, and showed a degree of complete combustion that perhaps but few, if any, could equal or surpass.
2. The machine is mechanically strong, simple in arrangement and operation, sufficiently protected by safety devices that are foolproof to be considered not a menace in the form of fire or oil hazard in the home.
3. That its operation is reasonably quiet and free from odor.

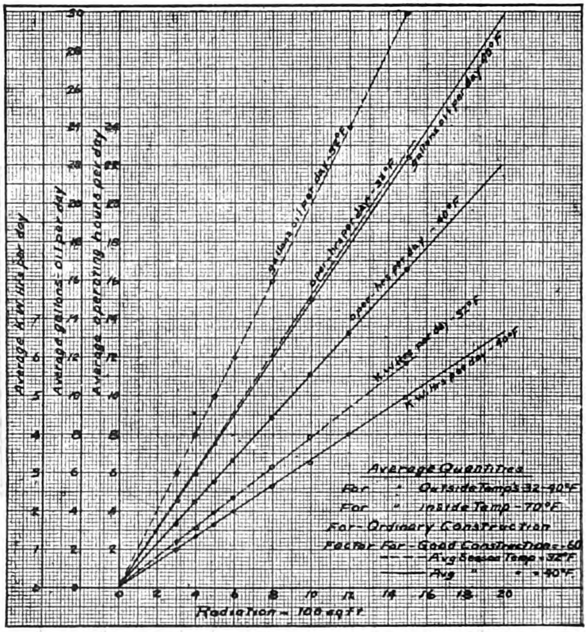


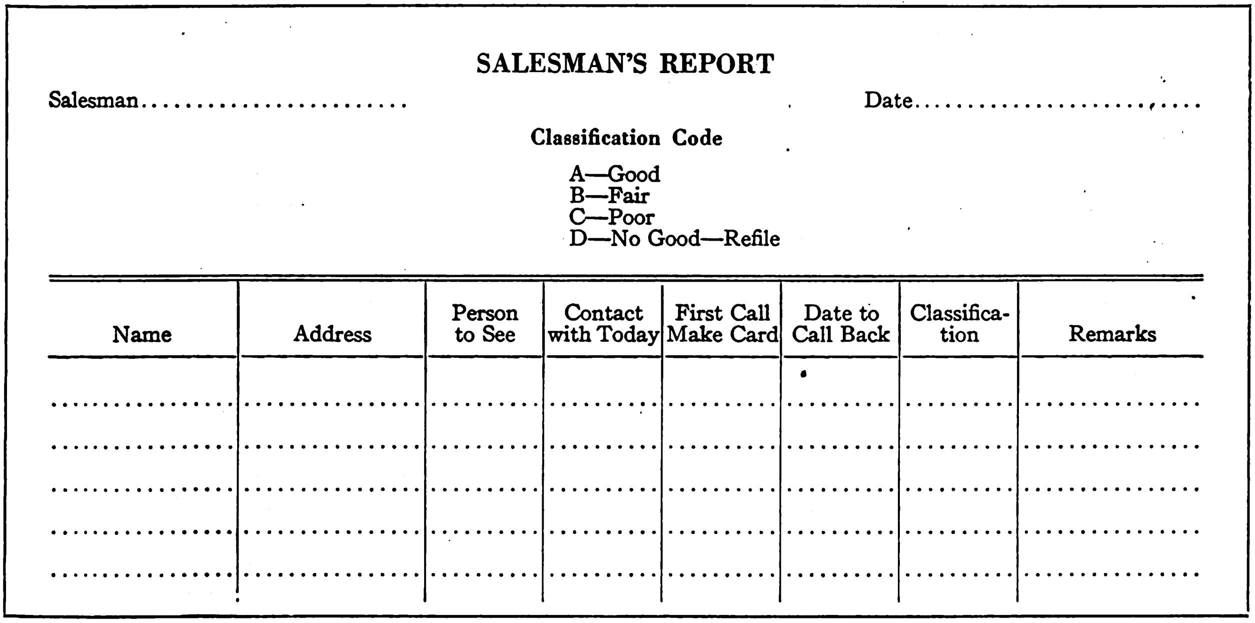
FIG. 93—OPERATION—RADIATION CHART.

4. That the economy obtained during this test could be improved if the boiler was insulated. This alone would probably increase the boiler efficiency 5 to 6 per cent. A still farther increase in efficiency could be obtained if a boiler with efficient heating surface was available. This gain would be obtained by reducing the stack loss to a minimum.
5. That perhaps hydrostatic control of the heat machine would be more preferable than the thermostatic control employed during the test. A uniform temperature of the heating medium per day would probably maintain a more uniform inside temperature per day than a heating medium that varies from very hot to relatively cold when thermostatically controlled and with a little better economy.
6. That the total electrical load per season per oil burner compares very favorably with the refrigerator load, and is deserving of being developed by the public utilities.
7. That the personal element in the home having an oil burner is responsible for greater cost than operation with coal, when such is the case.

A home with an oil burner installation can be heated more satisfactorily for a cost equivalent to coal if the same economy is practised in operating the thermostat or hydrostat as was practised on the coal pile or back saving in firing

APPENDIX C

SALES AND INSTALLATION FORMS



SALESMAN'S REPORT

Salesman........................ Date........................

Classification Code

A—Good
B—Fair
C—Poor
D—No Good—Refile

Name	Address	Person to See	Contact with Today	First Call Make Card	Date to Call Back	Classification	Remarks
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....

FIG. 94—FORM 1

ESTIMATE SURVEY

Name........................

Estimate No............

Address...............................

Job No...............

....

TYPE OF HEATING SYSTEM

Warm Air

Basement air...........
Upstairs air............
Outside air............

Steam

One pipe..................
Two pipe..................
Vacuum pump.............
Specialties.................

Hot Water

Honeywell heat generator..........
Mueller system..................
D. & T.........................
Open expansion tank.............

Vapor

One pipe..................
Two pipe..................
Vacuum pump.............
Specialties.................

BOILER

Manufacturer..
Type..
Size..
Serial No..
Rating..

Grates

Length.................................... Width....................................
Diameter.................................. Height....................................
Ash pit depth below floor...
Control equipment..
....

Accessories

Damper regulator..
....

PIPING

Mains in basement insulated...
....

SMOKE PIPE

Size.. Length..

FLUE

Size.. Height..
Openings...
Condition...

FIG. 95—FORM 2, SHEET 1

DOMESTIC HOT WATER

Coal..........
Gas..........
Kerosene..........
Electric..........

SIZE TANK..........
Horizontal..........
Vertical..........
Insulated..........

TANK HEATER
Manufacturer..........
Size..........
Serial No..........
Rating..........

Grates
Length..........
Diameter..........
Width..........
Length above floor..........
Ash pit depth below floor..........
Damper regulator..........
Control equipment..........
....
Insulated..........
Smoke pipe—size.......... Length..........
Flue—size.......... Height..........
Openings..........
Condition..........
....
....
....
....
....
....
....
....
Electric refrigeration..........
Ironer..........
Clothes dryer..........
....
....
....
....

FIG. 96—FORM 2, SHEET 2

ELECTRIC SYSTEM

Is oil burner outlet provided..

Where..

....

Where make connection if not specially provided..

Voltage..

Phase..

Thermostat location..

....

BUILDING CONSTRUCTION

1st floor..

2nd floor..

3rd floor..

When built..

Architect..

Builder..

No. rooms..

Previous fuel consumption..

Coal used (tons per year)..

Cost per ton.......................... Total..........................

Gas..

Stock on hand (coal).................... Cost to owner....................

Type floor in basement..

Type wiring in basement..

MAXIMUM STEAM PRESSURE OR **WATER TEMPERATURE** DURING COLDEST WEATHER..........

HAS HEATING BEEN SATISFACTORY—If not, in what way? What rooms unsatisfactory—

....

....

....

....

....

....

....

WARM AIR

Uptakes	No.	Size	Sq. In.	Downtakes	No.	Size	Sq. In.
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....

(Are additional uptakes contemplated?)

FIG. 97—FORM 2, SHEET 3

HOT WATER OR STEAM RADIATION

Type	Column	Section	Height	Wall		Sq. Ft.	Radiation
				Height	Width		
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....

(Are additional radiators contemplated?)

TANKAGE LOCATION

Distance from burner..

Fill line..

Location..

Distance from tank..

Grade..

Vent line..

Location..

Disposition of excess excavation..

....

....

Sewer pipe..

Rock, etc..

SKETCH

FIG. 98—FORM 2, SHEET 4

XXXX OIL HEATING SERVICE

Installation Survey

Name.. Job No.............

Address.. Date...............

TANKAGE AND OUTSIDE WORK

Tank size................................ Openings—Suction.........................

Length................................ Return.........................

Diameter................................ Vent.........................

Fill.........................

Manhead.........................

Manhead well.........................

EXCAVATION AND BACK FILL

Location of tank..

....

....

Location of fill line..

....

....

Location of vent line..

....

....

Location of basement opening..

....

....

REMARKS...

....

....

....

....

....

....

....

....

....

Disposal of surplus material...

....

....

EXCAVATION BY...

....

FIG. 99—Form 3, Sheet 1

INSIDE WORK

BURNER INSTALLATION

Kind..........

....

Size..........

....

Current..........

....

Control system..........

Boiler control..........

Thermostat..........

POWER UNIT

Location..........

Motor..........

Blower..........

Pump..........

Drive..........

Large strainer..........

BURNER UNIT

Draft pipe size..........

Draft pipe length..........

Nozzle..........

Small strainer..........

Relief valve..........

Control system..........

Thermostat..........

Boiler control..........

Stack safety..........

System of heating..........

BOILER—Name..........

Size..........

Grates..........

Tie..........

FIRE BRICK—Standard..........

Splits..........

CEMENT—High temperature..........

Portland..........

Asbestos..........

Bolts expansion..........

Asbestos..........

Sand..........

FIG. 100—FORM 3, SHEET 2

INSIDE WORK

Low water cut-out..

AUXILIARY—Pumps..

Tanks..

....

....

....

AIR PIPE—Size..

Length..

Ells..

Sleeves..

PIPING

	Outside Work						Inside Work					
	Fill and Gauge		Vent		Suction and Return		Suction		Return		Power Unit to Boiler Unit	
	No.	Size	No.	Size	No.	Size	No.	Size	No.	Size	No.	Size
Fill box........												
Caps........												
Vent cap........												
Foot valve........												
Suction stub........												
Check valve........												
A. S. valve........												
Gate valve........												
Ells........												
St. ells........												
Tees........												
Bushings........												
Unions........												
Couplings........												
Plugs........												
Nipples........												
Nipples........												
Nipples........												
Nipples........												
Pipe........												
....												
....												

FIG. 101—FORM 3, SHEET 3

ELECTRICAL WORK

Location current supply..

....

....

Location safety switch...

....

....

Location thermostat..

....

Location boiler control..

....

Location stack control...

....

Location relay...

....

	BX Cable	Conduit	Under Floor	Voltage	
				High	Low
Current supply to safety switch					
Safety switch to burner					
Burner to stack switch					
Burner to boiler control					
Burner to thermostat					

MATERIAL

	Number	Size
Safety switch		
Fuse		
Condulet tees		
Condulet ells		
Conduit		
BX cable		
Thermostat wire		
Knock out box		
BX adapter		
Greenfield loom		
Capulet		

....

....

....

FIG. 102—Form 3, Sheet 4

DOMESTIC HOT WATER

Heater..

Tank..

Insulation..

Controls..

Thermostat wire...

Duplex panel..

....

....

....

....

....

SPECIAL SKETCHES

FIG. 103—FORM 3, SHEET 5

No.	Items	List		Discount			Net, Each		Amount	
				Per Cent	Amount					
	Brought forward	......	......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......	......	......	......
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......	......	......	......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......	......	......	......
	Carried forward									

Name.. Location......................

Est. by.......... Checked by.......... Date.......... Job.......... Est........... Sheet........of.....

....

....

FIG. 104—FORM 4

INSTALLATION DATA SHEET

Name.. Estimate No........... Job. No..........

Mailing address.................................... Phone............... Att...............

Fuel del. address.................................. Phone............... Att...............

Tankage—Length.............. Diameter.............. Gallons.............. Tank table No...........

Fill line size..................... Lock cap..................... Location..................................

Fuel del. zone........... Fuel price del. our routing..........c. Fuel price del. their order..................c

Deliver fuel our routing, date.......................... By.......................................

Deliver fuel their order, date.......................... By.......................................

Gauge stick in gallons delivered........................ To.......................................

Gauge stick inches delivered........................... To.......................................

Tank table delivered................................... To.......................................

Tankage installation promised.......................... Burner installation promised................

Entire installation to be turned over to owner, promised..

Permission to erect sign, by........................... Date.....................................

Bldg. permit date.......... Val. given $.......... Smoke div. per. date.......... Val. given $...........

Burner.. Special equipment.........................

Boiler control.. ....

Thermostat.. ....

Anti siphon valve....................................... ....

Contract price $.......................... Salesman..................................

Date signed............................... % commission.............................

Down payment $............................ Amount $......................

Due when tankage is installed $............ When due......................

Due when instal. is completed $.............

Due 1—.................................... Copy No. 1—to office file..................

2—.................................... No. 2—to acc't. dep't...............

3—.................................... No. 3—to stock dep't................

4—.................................... No. 4—to fuel del. dep't.............

A O H S Form 1.

FIG. 105—FORM 5

APPENDIX D

RULES FOR FRACTIONAL HORSEPOWER MOTORS*

By a process of open discussions between all interested groups and through the workings of a cordial spirit of co-operation the joint committee on fractional-horsepower motors has obtained agreements which are expected to bring about very desirable results. In a series of meetings held during the past twelve months the committee has brought about a greatly improved situation in the industry. This committee was composed of representatives of the National Electric Light Association, the National Electrical Manufacturers' Association, the American Washing Machine Manufacturers' Association, the Association of Edison Illuminating Companies and, in addition, unorganized appliance manufacturers were represented by individuals. The committee was initiated by Prof. C. F. Hirshfeld of the Detroit Edison Company and worked with L. W. W. Morrow of the *Electrical World* as chairman.

The work of the committee dealt with improving fractional-horsepower motors through agreements as to minimum specifications for efficiency, power factor, starting current and apparent efficiency. The economic cost to the industry as a whole has been weighed and each group has contributed a share of the burden. The committee feels that its work will react to the benefit of the industry and will stabilize the fractional-horsepower motor situation for some years. It asks for the hearty cooperation of all groups in the industry so that its recommendations may be put into operation.

Summary of Action

After careful consideration the committee decided that there should be two general classes of fractional-horsepower motors, as follows: (1) Long-hour use motors. (2) Short-hour use motors. Long-hour use motors are those which operate a large number of hours per month in the aggregate and consume sufficient energy to make efficiency of economic importance. Specific applications for these motors agreed upon by the committee are electric refrigerators and electric oil burners. Short-hour use motors are those which are in operation a relatively small number of hours per month so that their consumption of energy is small. Typical applications of these motors are washing machines, dish washers and home food choppers.

MINIMUM SPECIFICATIONS FOR LONG-HOUR USE MOTORS OPERATING ON 110-VOLT, 60-CYCLE CIRCUITS AT 1800 R.P.M.

Rating in hp.	⅛	1/6	¼	⅓	½	¾
Power factor in per cent....	52	56	60	61	63	65
Efficiency in per cent.......	53	58	62	63	65	67
Apparent efficiency in per cent	30	36	42	44	47	49
Locked rotor amps..........	20	20	20	20	26.6	40
Locked rotor amps. at 75 per cent load	15	15	15	15	20	30

Minimum specifications for long-hour use motors and for short-hour use motors operating on 110-volt, 60-cycle circuits at 1800 r.p.m. as agreed on are given in the accompanying tables. The short-hour and long-hour use motors have the same current specifications and approximately the same power-factor specifications. The major difference is in efficiency values. These efficiency differences are expected to be reflected in motor prices.

MINIMUM SPECIFICATIONS FOR SHORT-HOUR USE MOTORS OPERATING ON 110-VOLT, 60-CYCLE CIRCUITS AT 1800 R.P.M.

Rating in hp.	⅛	1/6	¼	⅓	½	¾
Power factor in per cent....	50	52	56	58	60	62
Efficiency in per cent.......	41	46	51	54	58	61
Apparent efficiency in per cent	24	27	32	35	39	42
Locked rotor amps..........	20	20	20	20	26.6	40
Locked rotor amps. at 75 per cent load	15	15	15	15	20	30

NOTE.—Where the product of the minimum values of power factor and efficiency, as shown in the table, do not equal the apparent efficiency it is understood that either the power factor or the efficiency values will be increased by the manufacturer to make the product of power factor and efficiency equal to the stated apparent efficiency.

Exception for Washing Machine Motor

The values given apply to all 4-pole, 110-volt, 60-cycle fractional-horsepower motors with the exception of the washing-machine motor. It must conform to efficiency, power factor and apparent efficiency specifications, but not to locked rotor ampere values. After careful study the joint committee felt that time should be given for working out the washing machine problem and it agreed that the washing machine situation warranted, for the present, an exception in regard to the locked rotor ampere values for all other applications.

The ¼-hp. long-hour use motor should meet these specifications as of Jan. 1, 1928. Motor manufacturers agreed to develop the other sizes and types to meet the specifications as soon as possible and an ultimate date of Jan. 1, 1929, was agreed upon as the time all new motors should conform to the new specifications. Motors characterized by these specifications represent a great improvement on existing motors and necessitate a complete redesign of the majority of fractional-horsepower motors now made. The time element was considered a minimum in view of the time required to redesign, retool and get production in factories.

These specifications apply to motors which are normally connected to lighting circuits and which may be expected to operate at times during lighting hours. The values given are minimum values obtained by test after the motor has operated a reasonable time (at least 24 hours) to limber it up. It was agreed upon as desirable that motors of the 1800-r.p.m., ¼-hp., 110-volt, 60-cycle size should be produced as soon as possible with a full-load efficiency of at least 70 per cent and a full-load power factor of 65 per cent, giving an apparent efficiency of at least 45.5 per cent. It was thought such motors for refrigerators and oil burners would be justified in price by capitalizing the cost of energy used as compared to a cheaper but less efficient motor.

The joint committee adopted the new specifications for use in this country. Motor manufacturers are committed to an expense of upward of $1,000,000 in redesign and retooling costs. The utilities promised to do their part toward securing the use of the proposed motors and to urge that all central-station companies adopt uniform rulings in agreement with the recommendations of the joint committee because the use of present motors seriously affects utility service. Appliance manufacturers promised to follow the specifications and principles agreed upon by the joint committee.

The report of the committee was submitted for approval to the associations represented on the committee and already has the approval of the majority of the individual appliance manufacturers. The joint committee believes prompt action should be taken by the parent organizations and that, if approved, this report be distributed to each member so that he may be guided by the committee findings.

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*Reprinted from *Electrical World*, Feb. 18, 1928.

THE ELECTRIC FARM EQUIPMENT MARKET

AS INDICATED BY AN ANALYSIS OF THE TERRITORY SERVED BY THE NORTHERN STATES POWER CO.

Introduction

Rural electrification has developed to a point where one of its most important problems is "How to build the load." Obviously this is a merchandising as well as a service or promotional problem, and for that reason a solution is being sought through the joint efforts of the Merchandise Sales National Committee and the Rural Electric Service National Committee.

At the September, 1928, meeting of the latter Committee, Marshall E. Sampsell, Chairman of the Commercial National Section, presented a plan for a closer working arrangement. As a result of the discussion, the Electric Farm Equipment Subcommittee of the Merchandise Sales Committee was formed with three members appointed from the latter Committee and two from the Rural Electric Service Committee. In the words of Mr. Sampsell, "the sole purpose of such Subcommittee is to devise ways and means of merchandising current-consuming devices for the farm." The Subcommittee was also requested "to consider for such sales purpose the entire farm operation including the home."

The Subcommittee realized from the beginning that its work is effective only to the extent that it stimulates increased action along proper lines in utility company organizations. Its efforts are intended to help those companies who wish help in selling more of the proper farm electric equipment.

To bring the problem and any possible solutions more directly to the attention of operating executives, the National Subcommittee urged the formation of similar organizations in each geographic division. It was also recommended that such division Subcommittees should include a commercial man and a rural service man from each State, so as to insure the closest possible cooperation between the two groups everywhere. These geographic division Subcommittees are already pretty well organized, and the idea has also spread to some State utility associations.

Sales Requirements

Since farm electrification is a new development in our business, the Subcommittee believes that it calls for specialized attention, and that specialized men are required to handle it.

The Subcommittee also feels that the promotional, development and engineering work of rural electrification is properly the duty of a separate rural service department, but that the merchandise department which actually sells the farm equipment also needs men with extensive experience or training, and with such up-to-date and authoritative information that they can talk to the farmers about almost any phase of electric service for the farm.

The Subcommittee, therefore, strongly recommends that any utility which desires to successfully develop rural electrification divide the work into two parts, namely:

1. Rural service development or new business development.
2. Actual selling of farm electric equipment.

The National Rural Electric Service Committee of the N. E. L. A. has made a number of recommendations concerning the duties of rural service departments, and it does not fall within the scope of this Committee to deal with them, but the success of merchandising to farmers depends in no small measure on how well the rural service department carries on its part of the work.

The second part, or the merchandising of farm electric equipment, is strictly a merchandising job and is the job in which this Subcommittee is chiely interested. Naturally, someone must contact the farmers if merchandise is to be sold, and the first question is what kind of a man should be hired to carry on this work?

He should have sales ability—for his chief function is to sell merchandise to farmers. Inasmuch, however, as the farmer is not as familiar with utilities as are the urban people and has not had as much experience with electrical devices as has his city neighbor, and inasmuch as the farmer has many varied uses for electric service, this man should be more than an ordinary salesman if he is to get results.

He should be familiar with the company's rules, wiring policies and requirements, and he should understand the fundamentals of the public utility business, for the farmer is surely going to ask him many questions about the company. He should have a general understanding of farming and be able to discuss intelligently improved farm methods. He should be well informed on the practical uses of electricity on the farm, and he should keep up-to-date on this subject by reading the great mass of material that is available. He should remember that he is talking about a new kind of power to a group of people who are not familiar with it, and he should exercise a great deal of patience and diplomacy.

This Subcommittee appreciates that these are the specifications for a rather high-grade man, but it believes that such a man is necessary at this time in the selling of farm electric equipment.

The second question that will arise is how many of these rural service men should be employed. The Committee recommends that there should be at least one such man for every 500 farm customers. A larger number than this is necessary in the beginning of an intensive rural electric development pro-

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Publication No. 289-92, Serial Report, Merchandise Sales Committee.

gram. It is recommended that eventually there be such a man in each district office where the company does business in rural territory.

SUGGESTED DISTRICT ORGANIZATIONS UNDER DIFFERENT CONDITIONS

Amount of Farm Business Connected or in Prospect	Development Work Handled by	Sales Work Handled by
Very little	District Manager	District Manager
Less than 300 customers	District Manager	½ Salesman
Over 300, less than 600 customers	District Manager	1 Salesman
Over 600 customers.	Rural service specialist.	1 or more salesmen.

As a source of some of the data on rural electric service which everyone connected with this development requires, the National Subcommittee has undertaken to supply to the Division Subcommittee the best literature on this subject. This consists of the bulletins, pamphlets and periodicals giving the most accurate, complete and up-to-date information. It then becomes the duty of the Division Subcommittees to bring such material to the attention of county agricultural agents and others interested in the best agricultural development. And it should be the duty of rural salesmen and service men to familiarize themselves with the following material:

1. At least one national farm paper.
2. Agricultural Engineering, a local farm paper, or Electricity on the Farm.
3. The C. R. E. A. Bulletins and News Letters, especially Vol. 4, No. 1, entitled "Electricity on the Farm and in Rural Communities."
4. The reports of State experimental projects.
5. Agricultural bulletins on electric service, water supply, etc.
6. The N. E. L. A. pamphlets entitled "More Power to the Home."
7. Home Equipment Primer, Part 2, issued by the General Federation of Women's Clubs.
8. Manufacturers' data bulletins and installation directions.

What, When and How to Sell

The next question is what electric farm equipment to sell and how and when to sell it. And this is a problem that can best be handled by the geographic division Subcommittees. For selecting the equipment best adapted to the various farm jobs in each geographic division, it is urged that the Subcommittee and the Rural Electric Service Committee hold joint or cooperative meetings. All members of both Committees should bring in their recommendations and criticisms of the competing machines now on the market, and the group should decide upon an acceptable list of equipment, giving

Trade names
Manufacturers
Size
Capacity
Operation details
Power requirements
Installation features.

Such accepted lists should be made available to all member companies of the division. They should also be reported to the National Subcommittee accompanied by the definite, specific and detailed reasons why other existing equipment was not included. The National Subcommittee will act as a clearing house for this information and will offer constructive criticisms to the manufacturers who wish to eliminate the objectionable features of their products.

Rural salesmen and service men and all others having intimate contact with actual farm needs can aid in this work by reporting the performance of new devices as well as the requests and possibilities for equipment not yet developed.

It is also recommended that the geographic division Subcommittees discover and report the most outstanding examples of success in selling farm equipment that have been attained by companies in each division. In this connection it is important that the particular point of excellence as to organization and methods be reported. The National Subcommittee will digest these reports and make them available.

Data Available for Analysis

Intelligent merchandising of electrically operated equipment to the rural field involves specific and detailed knowledge regarding types of agriculture, financial ability of the farmer, natural purchasing seasons and buying habits of the prospective customers. Fortunately, there is a large amount of statistical information available which, when digested, analyzed and summarized, will yield important information for the merchandise manager and salesman. To be most effective this information should be worked up for the individual company's territory. The primary sources of statistical agricultural information are as follows:

1. U.S. Census of Agriculture: 1925, issued by the U. S. Department of Commerce, Bureau of the Census, Washington, D. C.
2. "Statistical Guide to the 'Other Half of America's Market'," obtainable from Wallace C. Richardson, Inc., 250 Park Ave., New York, N. Y., and Standard Farm Papers, Inc., 307 N. Michigan Ave., Chicago, Ill.
3. Other State and national agricultural papers.
4. The State Departments of Agriculture.
5. Agricultural experiment stations and agricultural extension divisions.

The statistical information used in the following analysis was obtained from No. 1 and 2 above and "Northwestern Farm Facts and Figures," published by "The Farmer," St. Paul, Minn. The compilation was made by the rural electric service department and the rates statistical department of the Northern States Power Co., Minneapolis, Minn. As shown on the accompanying map (Fig. 1), this company and its subsidiaries operate in five States, Minnesota, Wisconsin, North Dakota, South Dakota and Illinois, through thirteen division offices, several of which are subdivided into districts. To simplify the method of presentation, the analysis is here shown for only two of the thirteen divisions, the Fargo Division of the Union Light, Heat & Power, which is a subsidiary company of the Northern States Power Co., and the Southwestern Division of the Northern States Power Co. Agricultural statistics are presented on the basis of county units which makes it possible to analyze the sales possibilities by counties and then, through a combination of this information, build up the merchandising possibilities by divisions and, by combining the division information, develop it for the company as a whole. The territory of the Northern States Power Co. and its subsidiaries covers approximately 42,000 square miles, embracing 69 counties with approximately 168,000 farms. In this territory, between eight and nine thousand farms have central station service.

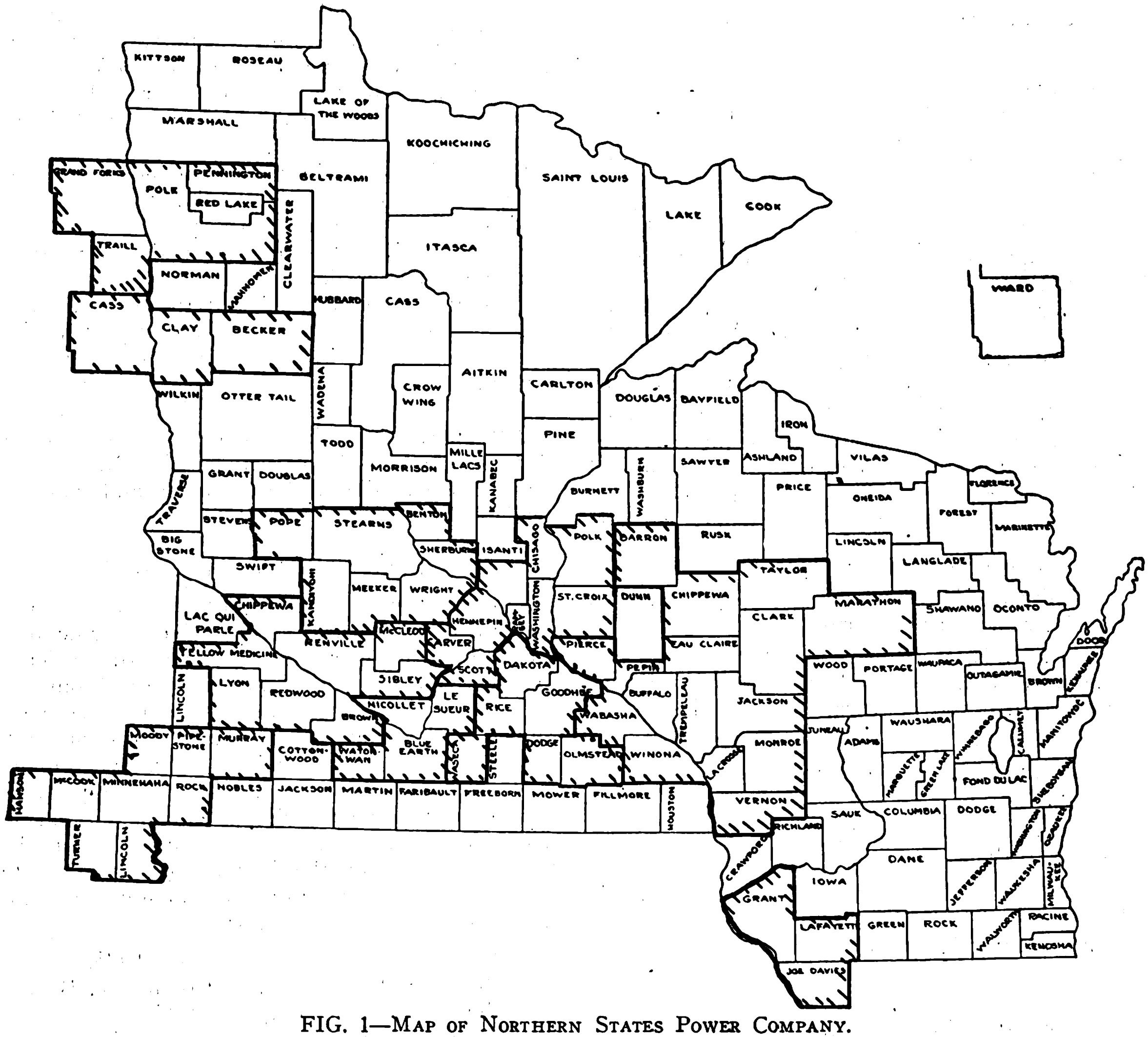
KITTSON
ROSEAU
LAKE OF THE WOODS
MARSHALL
KOOCHICHING
GRAND FORKS
PENNINGTON
POLK
RED LAKE
BELTRAMI
SAINT LOUIS
LAKE
COOK
CLEARWATER
TRAILL
NORMAN
MAHNOMEN
ITASCA
WARD
CASS
HUBBARD
CASS
CLAY
BECKER
WADENA
CROW WING
AITKIN
CARLTON
DOUGLAS
BAYFIELD
WILKIN
OTTER TAIL
IRON
PINE
TODD
MORRISON
MILLE LACS
KANABEC
ASHLAND
VILAS
GRANT
DOUGLAS
SAWYER
WASHBURN
BURNETT
PRICE
ONEIDA
FLORENCE
TRAVERSE
STEVENS
POPE
STEARNS
BENTON
FOREST
MARINETTE
BIG STONE
SHERBURNE
ISANTI
CHISAGO
POLK
BARRON
RUSK
LINCOLN
SWIFT
KANDIYOHI
MEEKER
WRIGHT
LANGLADE
TAYLOR
CHIPPEWA
ST. CROIX
DUNN
CHIPPEWA
MARATHON
SHAWANO
OCONTO
LAC QUI PARLE
HENNEPIN
RAMSEY
WASHINGTON
CLARK
DOOR
MCLEOD
CARVER
RENVILLE
YELLOW MEDICINE
PIERCE
EAU CLAIRE
DAKOTA
SCOTT
PEPIN
WOOD
PORTAGE
WAUPACA
OUTAGAMIE
BROWN
KEWAUNEE
LINCOLN
LYON
REDWOOD
SIBLEY
GOODHUE
BUFFALO
TREMPEALEAU
JACKSON
NICOLLET
LE SUEUR
RICE
BROWN
WABASHA
WAUSHARA
WINNEBAGO
CALUMET
MANITOWOC
JUNEAU
ADAMS
MONROE
MOODY
PIPESTONE
MURRAY
COTTONWOOD
WATONWAN
BLUE EARTH
WASECA
STEELE
DODGE
OLMSTED
WINONA
LA CROSSE
MARQUETTE
GREEN LAKE
FOND DU LAC
SHEBOYGAN
HANSON
MCCOOK
MINNEHAHA
ROCK
NOBLES
JACKSON
MARTIN
FARIBAULT
FREEBORN
MOWER
FILLMORE
HOUSTON
VERNON
SAUK
COLUMBIA
DODGE
WASHINGTON
OZAUKEE
TURNER
LINCOLN
RICHLAND
CRAWFORD
DANE
JEFFERSON
WAUKESHA
MILWAUKEE
IOWA
GRANT
LAFAYETTE
GREEN
ROCK
WALWORTH
RACINE
KENOSHA
JOE DAVIESS

FIG. 1—MAP OF NORTHERN STATES POWER COMPANY.

The two divisions here considered are in the territory which agricultural analysts classify as the North Central Dairying Section. While these two divisions are in the same general agricultural territory, an analysis of the statistical information clearly shows that there is a divergence in the agriculture, so much so in fact as to suggest some difference in merchandising policies for developing the farm markets. In the Fargo Division the farm income is derived chiefly from the sales of grain crops and potatoes, while the Southwestern Division is much more of a livestock region, although there is a sizable income from the sale of grain crops.

Table I shows that a large percentage of the population lives on farms, in fact, there is only one city, Fargo, of over 10,000 population and only two other cities of over 5000 population. According to the census classification which lists all cities and towns under 2500 as rural, there are only six cities and towns classed as urban and 37 cities and towns

TABLE I

DISTRIBUTION OF POPULATION

(Northwestern Farm Facts and Figures)

	Population		Farm Population in PerCent of Total	Number of Cities and Towns					
	Total	Farm		500 to 1000	1000 to 2500	2500 to 5000	5000 to 10000	10000 to 15000	15000 and over
FARGO DIVISION	92 166	35 478	38.5	4	3	1	1	--	1
Becker, Minn.	25 124	13 318	53.0	1	1	1	--	--	--
Clay, "	22 992	10 116	44.0	3	1	--	1	--	--
Class, N. D.	44 050	12 044	27.3	--	1	--	--	--	1
SOUTHWESTERN DIVISION	138 164	79 459	57.5	21	9	3	--	--	--
Chippewa, Minn.	17 003	8 036	47.3	3	--	1	--	--	--
Lyon, "	20 603	9 301	45.1	3	1	1	--	--	--
McLeod, "	21 437	12 204	56.9	2	1	1	--	--	--
Redwood, "	22 313	13 026	58.4	3	1	--	--	--	--
Renville, "	23 923	14 934	62.4	5	3	--	--	--	--
Sibley, "	15 688	10 864	69.3	4	1	--	--	--	--
Yellow Medicine	17 197	11 094	64.5	1	2	--	--	--	--

between 500 and 2500 classed as rural. This indicates that when the territory is developed electrically it is necessary to have a rural merchandising policy to meet the situation.

Table II shows that the average size of the farms in these two divisions is relatively large, with a consequently low density per square mile, varying from 1.40 for Cass County in the Fargo Division to 4.97 in McLeod County, Southwestern Division. The farm land area in per cent of total county area in these two divisions varies from 53.7 per cent Becker County, Fargo Division, to 96.8 per cent in Yellow Medicine County, Southwestern Division.

Analysis of Fargo Division

An analysis for the Fargo Division of the data presented in Tables III and IV shows the following: From the standpoint of income, dairying is an important activity which insures these farmers a regular monthly income. Butterfat is the chief product sold, and there are 16 creameries in this territory. It is evident that a larger percentage of the farmers' income in Becker County is derived from dairy products than is the case in Clay and Cass Counties. Clay and Cass Counties market some whole milk, the majority of it undoubtedly going to Fargo.

In only one county, Cass, is swine production of importance.

Sheep husbandry is of decidedly minor importance.

It is evident that, generally speaking, poultry products are of minor commercial importance. From the data it can be assumed that these are used in the main for home consumption.

There is some income from the sale of livestock, chiefly cattle and hogs.

The most important source of income is from the

TABLE II

NUMBER OF FARMS AND FARM ACREAGE

(U. S. Census of Agriculture: 1925)

	Total Number of Farms	Total Area of County Acres	Total Area of Farm Land Acres	Farms in % of Total Area	Average Size of Farm Acres	No. of Farms per Sq.Mi.
FARGO DIVISION	7 368	2 659 200	1 997 632	75.1	271.1	1.77
Becker, Minn.	2 867	863 360	463 673	53.7	161.7	2.13
Clay, "	2 032	667 520	538 127	80.6	264.8	1.95
Cass, N. D.	2 469	1 128 320	995 832	88.3	403.3	1.40
SOUTHWESTERN DIVISION	15 896	3 192 500	2 973 283	93.1	187.0	3.19
Chippewa, Minn.	1 568	378 240	339 873	89.9	216.8	2.65
Lyon, "	1 849	453 120	410 943	90.7	222.3	2.61
McLeod, "	2 464	317 440	300 319	94.6	121.9	4.97
Redwood, "	2 625	563 840	517 149	91.7	197.0	2.98
Renville, "	3 016	625 920	585 320	93.5	194.1	3.08
Sibley, "	2 195	374 400	355 814	95.0	162.1	3.75
Yellow Medicine	2 179	479 360	463 865	96.8	212.9	2.91

TABLE III

ACREAGE AND PRODUCTION OF PRINCIPAL CROPS

(U. S. Census of Agriculture: 1925)

	FARGO DIVISION	Becker Minn.	Clay Minn.	Cass N.D.	SOUTH-WESTERN DIVISION	Chippewa Minn.	Lyon Minn.	McLeod Minn.	Redwood Minn.	Renville Minn.	Sibley Minn.	Yellow Medicine Minn.
CORN												
Total Acreage	166 974	24 572	33 631	108 771	766 144	90 463	126 502	52 664	153 286	148 744	68 311	126 174
Harvested Grain Bu	501 462	70 078	131 833	299 551	16273 416	2146 100	2836 880	995 319	3346 055	2901 512	1476 879	2570 671
Silage Cut Tons	82 201	19 871	32 391	29 939	270 005	26 534	43 707	55 083	38 397	49 121	22 238	34 925
WHEAT												
Total Acreage	337 617	19 645	65 134	252 838	212 589	25 453	12 092	22 624	27 325	45 736	33 214	46 145
Bushels	6452 597	431 445	1360 246	4660 906	5020 069	631 580	283 748	582 771	618 042	1047 596	766 831	1089 501
OATS												
Total Acreage	280 295	52 259	96 422	131 614	628 477	87 013	107 407	43 028	123 963	119 489	46 831	100 746
Threshed Grain Bu	9731 784	1910.085	3411 765	4409 934	29958 539	4077 077	5170 755	2280 133	6005 480	5521 812	2143 541	4759 741
BARLEY												
Total Acreage	148 011	20 767	46 922	80 322	69 621	9 527	11 509	5 754	12 197	14 768	5 992	9 874
Bushels	4249 440	637 494	1495 727	2116 219	2282 062	338 517	384 705	187 981	406 449	456 721	180 009	327 680
RYE												
Total Acreage	58 145	6 940	9 022	42 183	60 757	5 599	2 670	7 281	16 527	11 027	12 325	5 328
Bushels	1271 348	141 561	181 628	948 159	1374 669	107 754	58 063	167 922	410 435	226 943	269 356	134 196
HAY												
Total Acreage	220 549	72 283	77 201	71 065	362 149	35 302	39 195	58 612	47 304	77 035	61 269	43 432
Tons	191 799	68 864	52 757	70 178	380 334	36 177	49 074	70 470	53 966	66 224	53 870	50 553
POTATOES												
Total Acreage	67 348	9 627	42 756	14 965	6 609	794	506	704	1 366	1 260	1 193	786
Bushels	5769 591	956 779	3920 466	892 346	752.486	102 244	51 326	91 278	137 916	138 862	132 755	98 105
FLAX												
Total Acreage	98 693	9 994	17 992	70 707	102 631	13 169	15 618	6 479	13 222	26 156	7 682	20 305
Bushels	844 472	94 732	169 346	580 394	1252 416	158 869	209 391	79 281	169 263	281 863	86 507	267 242

TABLE IV

LIVESTOCK ON FARMS AND LIVESTOCK PRODUCTS

(U. S. Census of Agriculture: 1925)

	FARGO DIVISION	Becker Minn.	Clay Minn.	Cass N.D.	SOUTH-WESTERN DIVISION	Chippewa Minn.	Lyon Minn.	McLeod Minn.	Redwood Minn.	Renville Minn.	Sibley Minn.	Yellow Medicine Minn.
CATTLE												
Total Number	110 285	34 222	29 895	46 168	291 106	26 567	40 424	43 400	48 081	51 635	38 233	42 766
No. of Cows Milked	46 456	18 543	13 473	14 440	124 615	11 075	12 382	26 649	17 578	21 741	20 521	14 669
SWINE												
Total Number	84 689	11 349	13 518	59 822	460 476	43 311	55 894	43 370	85 674	99 587	61 393	71 247
SHEEP												
Total Number	16 302	6 444	1 444	8 414	18 946	2 019	3 336	1 162	3 439	2 263	2 544	4 183
CHICKENS												
Total Number	514 261	144 060	151 416	218 785	2080 521	193 830	241 132	298 712	364 976	384 619	302 474	294 778
DAIRY PRODUCTS												
Milk Produced Gallons	20140 265	8715 210	5591 295	5833 760	56025 603	5028 050	5386 170	13297 851	7910 100	9022 515	9029 241	6351 677
Av. per Cow Milked	434	470	415	404	450	454	435	499	450	415	440	433
Butter made on farms lbs.	1373 953	319 649	385 165	669 139	1598 758	296 040	247 253	19 510	332 977	297 344	46 865	358 769
Butterfat sold lbs.	3949 039	2098 701	920 312	930 026	13941 475	1043 528	1286 379	3450 979	1909 420	2373 881	2519 808	1357 480
Cream sold gallons	115 061	10 710	28 321	76 030	134 824	10 103	16 777	17 166	38 599	23 080	15 273	13 826
Whole milk sold gal.	1367 499	145 369	722 860	499 270	1902 835	101 711	84 613	1398 463	75 928	111 830	57 037	73 253
EGGS AND CHICKENS												
Eggs Produced Dozens	2186 163	635 593	783 729	766 841	9448 999	886 191	1005 279	1363 919	1689 474	1743 863	1250 125	1510 148
Chickens Raised No.	612 863	172 440	175 037	265 386	2699 359	227 944	331 798	378 468	469 359	519 620	377 488	394 682

TABLE V

FARM VALUE, FARM DEBT AND FARM INCOME

(U. S. Census of Agriculture: 1925)

	FARGO DIVISION	Becker Minn.	Clay Minn.	Cass N.D.	SOUTH-WESTERN DIVISION	Chippewa Minn.	Lyon Minn.	McLeod Minn.	Redwood Minn.	Renville Minn.	Sibley Minn.	Yellow Medicine Minn.
VALUE OF FARM PROPERTY												
All Farm Property	126886 619	24827 369	36281 579	65777 671	336068 946	35597 815	47379 542	41529 458	54476 863	62237 363	43552 559	51295 346
Land and Buildings	110779 022	21299 674	31768 018	57711 330	294830 416	31303 180	41573 511	35550 255	49797 454	53830 391	37534 585	45241 040
Implements Machinery	7598 484	1394 860	2306 801	3896 823	17246 233	1763 932	2319 541	2414 653	2874 298	3266 518	2375 847	2231 444
Livestock on Farms	8509 113	2132 835	2206 760	4169 518	26992 297	2530 703	3486 490	3564 550	4805 111	5140 454	3642 127	3822 862
AVERAGE VALUE												
All Farm Property per Farm	17 221	8 660	17 855	26 641	21 142	22 703	25 624	16 854	21 896	20 636	19 842	23 541
FARMS OPERATED BY OWNERS												
Number	4 810	2 218	1 233	1 359	9 810	892	970	1 958	1 451	1 769	1 563	1 207
Per Cent of Total	65.3	77.4	60.7	55.0	61.7	56.9	52.5	79.5	55.3	58.7	71.2	55.4
Number Reporting Mortgage Debt	2 761	1 243	693	825	4 683	543	602	605	753	897	508	775
Per Cent	57.4	56.0	56.2	60.7	47.7	60.9	62.1	30.9	51.9	50.7	32.5	64.2
FARMS OPERATED BY FULL OWNERS												
Ratio:Mortgage Debt to Value (Per Cent)	41.4	45.0	40.5	40.0	43.2	41.8	43.2	41.1	46.0	43.7	41.3	43.2
TOTAL FARM INCOME												
Thousands of Dollars	29 962	5 731	9 884	14 347	75 561	8 626	10 165	8 779	13 216	14 459	8 728	11 588
AVERAGE INCOME PER FARM	4 067	1 999	4 864	5 811	4 753	5 501	5 498	3 563	5 035	4 794	3 976	5 318
***INDEX OF PURCHASING POWER**	175	86	200	258	209	236	246	159	218	207	181	234

*From "The Other Half of America's Market," pp. 52, 54 and 70, issued by the Standard Farm Paper Unit.

cash crops, wheat, barley, potatoes and rye. The corn, oats and hay produced are used mostly for livestock feeds.

This is a great potato region. This means that the income from crops will be concentrated from the fall, through the winter, and on into the spring, when these various products are marketed.

Table V shows that one of these counties, Cass, ranks very high as to farm value, farm income and consequently farm purchasing power, while Becker County is correspondingly low in these factors, with Clay County ranking very well, leading to the direct conclusion that sales efforts can be much more profitably expended in Clay and Cass Counties than in Becker.

The information in these statistics can be supplemented by certain significant facts obtained from a personal knowledge of the territory:

Turkey raising is developing and probably will become of major importance.

Butterfat in large quantities is being shipped to commercial creameries located outside of the territory, which indicates that more creameries will probably be established.

Dairying is on the increase.

A goodly percentage of the crop is sold for seed in southern markets.

There are practically no farms which specialize in producing poultry products. This further substantiates the conclusion that the poultry raised is chiefly for home consumption.

As a rule, specialized farming is practised, and over a period of years is profitable.

Cass and Clay Counties furnish a larger percentage of Master Farmers than the average county within the company territory.

Becker County is a summer resort region with numerous lakes.

Because such a large percentage of the farmer's income is obtained from cash crops, there are years when he is much more prosperous than others.

From the above analysis it is evident that the chief outlets for electrical equipment will relate to household uses, water pumping, dairy operations and potato grading and handling.

Cass and Clay Counties offer far more promising sales territory than is the case in Becker County.

There is some monthly income from the dairy industry which will be used to pay monthly operating expenses, including the bill for electric service, and might suffice for monthly payments on minor electrical appliances. However, the major part of the farm income to be used for the purchase of electrical appliances will undoubtedly be obtained from the cash crop income which is available at irregular intervals from October until spring work opens. These facts indicate that it is particularly desirable to keep a close watch on the conditions of the crops in the territory, and plan major sales campaigns when crop prospects are good and slightly ahead of the season of the year when the major farm income is received. While the monthly payment can be used for small sums, it is entirely possible that where sales are not made for cash, major payments should be arranged to coincide with the time when the farmer's major cash income will be received. This will involve the use of notes.

Analysis of Southwestern Division

A similar analysis of the Southwestern Division shows the following: From Table V, it is evident that with the exception of two counties, McLeod and Sibley, the Index of Purchasing Power and average income per farm are high, indicating that when this district is electrically developed it will be promising territory for the sale of electrical equipment. However, there are compensating factors in McLeod. The density of farms, 4.97 per square mile, and the number of cows milked, 26,649, producing 13,297,851 gallons, an average of 499 gallons per cow, clearly indicate that its possibilities for electrical development are relatively greater than the general income figure would lead one to believe.

In four of the counties in this division, Lyon, McLeod, Redwood and Renville, dairying is of major importance.

On the average, swine production is of more importance in the farm income than was the case in the Fargo Division.

Sheep husbandry is of minor importance.

While it appears that the average number of chickens per farm is not large, indicating that this is on the farm flock basis, there will be some income derived from the sale of eggs and poultry.

Dairy products are sold chiefly in the form of butterfat as indicated by the number of creameries, 58 in the division. In McLeod County the sale of whole milk is important.

The amount of dairying and general livestock production in this territory indicates that practically all the corn, oats and hay raised is fed to livestock on the farms. On the average, the income from the sale of the cash crops, wheat, barley, rye, potatoes and flax, while large enough to be an important factor, particularly in Renville and Yellow Medicine Counties, is relatively less important than was the case in the Fargo Division.

Index of Purchasing Power

The Index of Purchasing Power mentioned above and shown in Table V for each county considered depends on the income per farm and the value of land and buildings. In combining these two factors it has been necessary to set up an index for each of them. The index of land and buildings per farm is the ratio, expressed as a percentage, between the average value per farm in each county and $8,350, which is the national average. Expressed as a formula, this becomes: Index of land and buildings

$$\text{value} = \frac{\text{Value per farm}}{\$8{,}350} \times 100$$

Similarly, the index of farm income is the percentage relationship between the average farm income of the county in question and the average for the nation as a whole which is set at $2,350. Thus,

$$\text{Index of income per farm} = \frac{\text{Income per farm}}{\$2{,}350} \times 100$$

The index of purchasing power is a weighted average of these two index numbers. Since the value of land and buildings represents borrowing power, while the actual income may be more readily used for purchases, the index of farm income is arbitrarily made twice as important as the index of land and buildings value, and is counted twice in making the weighted average.

The formula is:

Index of purchasing power —

$$\frac{(\text{Index of farm income} \times 2) + \text{Index of land \& bldg.}}{3}$$

In addition to the statistics cited, personal investigations reveal the following facts about the Southwestern Division:

1. Several centers for the intensive production of chickens have been developed under the supervision of able hatchery men whose interest is to extend their services to the farm flock.
2. Sweet cream is shipped from McLeod County to very remote markets.
3. The western portion is developing rapidly toward diversified farming, with possible heavy swine production in the future.
4. Most of the farm homes in this territory are above the average for the country.
5. A large number of champion butter makers have come from these counties, thus indicating pride in the dairy industry.
6. The majority of the butter made is sold through the Land-of-Lakes Cooperative Association.
7. The water table from which the domestic water supply is obtained is relatively deep.

From the above analysis, the following general facts regarding the sale of electrically operated equipment appears. This division promises a field of increasing importance for the sale of dairy equipment. There are possibilities of encouraging increased attention to the farm poultry flock, thereby opening up additional sales possibilities. Water pumping equipment will be required. There should be a large demand for deep well pumps. There is every indication that the farmer will be interested in electrically operated household equipment.

It is obvious that in this district, particularly in McLeod County, the monthly payment may be the most desirable form of time payment, as a large percentage of the income is obtained from dairy products. But an optional payment plan involving the use of notes will be of advantage on many farms where the income from cash crops is spread over the period from October to March. As the farm income in this territory is fairly regular, reaching a high point in the fall and winter months, a year-round selling program is desirable with an increase of intensity beginning in August and September, and extending through January.

TABLE VI—MISCELLANEOUS ITEMS (U. S. Census of Agriculture: 1925)

	Farm Power		Number of Creameries	Number of Silos	Concrete or Brick Road	Macadam Road	Kind of Road Farms Located On		Unimproved Dirt Road	All Other
	Number of Tractors	No. of Horses and Mules					Gravel Road	Improved Dirt Road		
FARGO DIVISION	1 746	49 989	16	775	11	--	514	4 244	2 431	168
Becker, Minn.	241	10 584	12	251	10	--	207	1 444	1 148	58
Clay, "	455	14 490	4	311	1	--	247	1 085	682	17
Cass, "	1 050	24 915	*	213	--	--	60	1 715	601	93
SOUTHWESTERN DIVISION	3 713	95 586	58	2 386	2	--	6 203	5 987	3 238	466
Chippewa, Minn.	336	10 439	4	215	--	--	457	898	204	9
Lyon, "	454	13 269	8	370	--	--	498	793	449	109
McLeod, "	482	10 602	14	507	1	--	1 650	382	416	15
Redwood, "	644	17 027	6	440	--	--	899	853	628	245
Renville, "	699	18 181	10	423	1	--	1 028	1 072	871	44
Sibley, "	531	11 461	9	174	--	--	1 212	678	272	33
Yellow Medicine.	567	14 607	7	257	--	--	459	1 311	398	11

*Not Reported.

PROMOTIONAL RATES

General

An examination of a large number of rates in cities throughout the country indicates a rather definite movement toward the establishment of follow-on rate schedules to encourage use. The data available from various sources indicates that the consumption of electricity for residential users where there is no electrical cooking and water heating, amounts to about 460 kw-hr. per annum or a little more than 1 kw-hr. per day. The necessity of increasing the number of kilowatt-hours used by residential customers need no argument.

Electricity in the home is such a small portion of the family budget as compared with many other minor expenditures of the family that an increase in the amount of electricity used in the home would only have beneficial results.

The essential point is that the rate for electricity used in addition to normal use must be low.

The primary use of electricity in the home has been for lighting purposes. The increasing use of adequate, as well as ornamental lighting, is desired by the householder, and in using a promotional or follow-on rate the charges for the first block of energy never vary, so that when the householder desires to use appliances of any description, such a schedule encourages the use of these devices at prices the customer can easily afford to pay. When the customer once understands the relatively small portion of the bill included in the first or first and second steps, it is easy to show him that further use of electricity is at the lower rate, and only moderately increases the total cost, whereas with the straight line meter rate in effect the customer notices that adding appliances of any description makes a definite and proportionate increase in his monthly bill. The effect of this is to discourage the rapid acquisition of appliances for convenience and labor saving.

The practice of some companies of reducing maximum rates where they are already relatively low is deplored. Every time this is done it merely passes more of the burden to the customer who desires full use of electricity in his home.

From the company's point of view the follow-on rate is a reduction not in the price for the normal amount of electricity that the customer would use and pay for anyway. The follow-on rate is not a reduction in the company's income. The follow-on rate is a lower rate for some kilowatt-hours that the customer would not otherwise use. We know of no more constructive work for central station companies than increasing the use of electrical appliances in the home. There is nothing that will add more to the ease and pleasure of living than making it possible for the householder to use more electricity at a lower average rate.

Examining the rates printed in the N. E. L. A. Rate Book gives a definite picture to anyone interested as to the general situation in the industry, and we think emphasizes the desirability of more standardization of form.

Various Types of Rates

Straight Line Meter Rate

The term "straight line" indicates that the price charged per unit is constant; that is, does not vary on account of an increase or decrease in the number of units. This is the simplest of all rates.

This rate is based on a flat rate per kilowatt-hour, and under no circumstances could it be considered as encouraging the use of electricity, unless the rate were so low that it is out of line with the usual charges in such rates, as expressed in the N. E. L. A. Rate Book.

There are some cities having a flat rate of 5 cents per kw-hr. which show a comparatively satisfactory use of electricity per residential customer; but even in such instances we believe a follow-on type of rate would have decided advantages because if at 5 cents per kw-hr. the customer in these cities will use 600 kw-hr. per annum, it would seem almost certain that a rate of 3 cents per kw-hr. for additional use would sell even more kilowatt-hours.

Even in places having a low straight line meter rate there is no reason why an alternative follow-on rate should not be used to take care of those customers who desire to use greater quantities of electricity. In many instances the average rate in cities having a follow-on form is lower than even the low types of straight line meter rates enjoyed in certain cities.

Step Meter Rate

The term "step" indicates that a certain specified price per unit is charged for the entire consumption, the rate depending on the particular step within which the total consumption falls each month.

It seems to your committee that the disadvantages of the step meter rate are so outstanding that step rates should not be encouraged. It is an irritation to a customer to realize that he can never pre-determine his rate, and in many instances this form of rate is practically equivalent to a straight line meter rate, as the top step is frequently so high that ordinary uses of electricity in the home would not bring the customer outside of this block.

Block Meter Rate

The term "block" indicates that a certain specified price per unit is charged for all or any part of a block of such units, and reduced prices per unit are charged for all or any part of succeeding blocks of units, each such reduced price per unit applying only to a particular block, or portion thereof.

An examination of the N. E. L. A. Rate Book has brought out the fact that out of approximately

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300 companies listing residential rates, half of them are practically straight line meter rates, although many of them are classed as "block" rates. Study of many of these schedules indicates that the first step of a block rate is so broad that it is impossible for a residential customer to secure a lower rate for even what is now considered large use. For instance, there are few cities, except where electric cooking and water heating are included, which use to exceed an average of 50 kw-hr. per month, and the average is nearer 30 kw-hr. So that in using a rate of the block type, which has wide first and second steps, it does not appear that there is any advantage in that kind of a set-up. It might just as well be a straight line meter rate.

Flat Demand Rate

The term "flat demand" applies to a charge for electric service based upon the customer's installation of energy-consuming devices. This is usually so much per watt or per kilowatt per month or per year. Sometimes this type of rate is nominally so much per customer per year or per month, for each of the various classes of customers. Several years ago it was believed that the flat demand rate should not be used, but recently this type of rate has come into use for small residence customers in some sections of the country.

Service Charge Rate

For quite a number of years the "service charge" rate was looked upon as a disturbing form of rate, particularly where the charge per month per customer was called a "service charge." In some parts of the country this form of rate has come into use as an alternative form with considerable success, notably in northern Indiana, where such rates have been used as alternative to straight line meter rates. Such rates are being recommended by some commissions, for instance, Massachusetts.

This form of rate also has the advantage of being able with proper working out of follow-on blocks after the service charge to permit serving all classes of customers, including those using electricity for cooking and water heating, refrigeration, etc.

Example:

$1 per month per customer, or $12 per customer per year, followed by block steps of—

7c. per kw-hr. for the first 30 kw-hr., and in some instances further steps at lower charges.

Wright Demand Rate

The term "Wright Demand" applies to that method of charge in which a maximum price per unit is charged for a certain amount of energy, depending on the number of rooms, floor area, or maximum demand or connected load, etc., and one or more reduced prices per unit, or charge for the balance of the electricity used.

Examples:

10c. per kw-hr. for electricity used equivalent to, or less than, the first 30 hr. use per month of the maximum demand,

5c. per kw-hr. for additional electricity used equivalent to, or less than, the next 30 hr. use per month of the maximum demand,

3c. per kw-hr. for electricity used per month in excess of the equivalent of 60 hr. use of the maximum demand.

The Wright Demand rate served its purpose well over a long period of years, and so long as lighting was the principal use for electricity in the home, this type of rate did a good job. The difficulty came when appliances appeared in larger numbers in the home, and the question of continuing to determine the demand by demand meters made the costs so heavy that the meter measurement of demand was discarded. The result was the establishment in some places of a percentage of the connected load, based only on the lighting installation. But even here difficulty was found from the fact that modern use of electricity occasioned rapid changes in the lamp installation in the home, which upset the company records and changed the basis of the charges month in and month out, making it a very expensive form of rate to apply.

Many of the companies formerly using the Wright Demand form of rate have gone to the floor area or room basis for the primary charge, establishing these as alternative rates until the time when all of the customers can be put over on the new rate, with increasing uses of electricity. These forms can also be considered as in the Wright Demand rate class.

Block Hopkinson Demand Rate

A demand charge based on a maximum demand per kilowatt-hour, plus a follow-on block rate.

Examples:

$2.40 per month per kw. for the first 50 kw. of the maximum demand in the month.

$2 per month per kw. for the excess of the maximum demand over 50 kw., plus an energy charge of 5c. per kw-hr. for the first 1000 kw-hr. used per month, and

3c. for the next 4000 kw-hr. used per month, and further block steps where desired.

This form of rate can be built to home use, but it has had very little, if any, acceptance.

The difficulty in the use of this form of rate is the necessity for installing a demand meter (which is expensive) if a proper record of the customers demand is to be kept. It is obvious that it would be difficult to assume a demand based on any predetermined factor. So that it is not likely that this form of rate will have very much acceptance for domestic applications.

Three Charge or "Doherty" Rate

Any of the foregoing types of rates may be modified by the addition of a customer charge. When such a charge is introduced in the Hopkinson Demand Rate, it becomes a Three Charge Rate or "Doherty" rate, which consists of a customer, or meter, charge, plus a demand charge, plus an energy charge.

Many people consider that, theoretically, this is an ideal type of rate.

The principal objections to it are that the charges are in three classes—customer charge, demand charge and energy charge.

Floor Area Rate

A flat charge based upon the square foot of floor area in the house plus a block rate per kilowatt-hour. This is, in principle, the same as the Hopkinson Rate except that the demand is determined from the floor area instead of by a demand meter.

Examples:
- $1 per month for the first 1000 sq. ft. of floor area 4c. per 100 sq. ft. in excess of 1000 sq. ft., plus an energy charge of—
- 7c. per kw-hr. per month for the first 40 kw-hr., and follow-on blocks at lower charges per block, depending on the circumstances.

or
- 9c. for the first 3 kw-hr. per 100 sq. ft. of floor area,
- 5c. for the next 6 kw-hr. per 100 sq. ft. of floor area, and
- 3c. for the excess.

In the application of this rate in most instances, basements, pantries, closets, hallways and bathrooms are not counted in the floor area.

Room Rate Charge

- Blank kw-hr. per active room for the top rate per kw-hr.
- Blank kw-hr. per room for the next block rate per kw-hr.
- and following blocks where it seems desirable.

Example:
- 10c. per kw-hr. per month for the first 3 kw-hr. per counted room.
- 7c. per kw-hr. per month for the next 3 kw-hr. per counted room.
- 4c. per kw-hr. per month for the excess over 6 kw-hr. per counted room.

A modification of this rate can be as follows:
- 20c. per month per counted room plus a block rate with several steps for the energy charge, or a further modification of—
- 12c. per kw-hr. for 3 kw-hr. per room for the first 2 rooms, and 2 kw-hr. per room for the excess over 2 rooms, with follow-on rates of 8c. and 5c. per kw-hr.

This room rate form is also having increasing acceptance because of its follow-on feature. It is superseding in many locations the older forms of rates. It is particularly advantageous in large cities, where people live in apartments, because the real estate rating established by the local real estate boards are used as the criterion of the number of rooms, upon which the primary charge is based.

Both the floor area form of rate and the room basis present possibilities for accomplishing this result satisfactorily for all concerned. Practically no trouble is found with either, once it has been adopted and used for a year or so. In cities and towns where the people live in individual homes the floor area basis is practical. While it is not so practical in large cities where people live in apartments, the same general results can be obtained by the proper application of any of these forms of rates in accomplishing the results desired.

The floor area is usually obtained by making deductions from the outside dimensions of the building, and this procedure is sometimes difficult in the case of apartment buildings.

The room basis charge is a stabilized method of determining the primary charge to the customer, as it is very seldom that rooms are added to existing occupancies. The regular real estate rating of the number of rooms in a home is acceptable as the proper basis for room count. These methods of basing residential rates do not interfere with the use of any of the electrical devices commonly used in the home, and these rates can also be modified to include electrical cooking and water heating where desirable.

A detailed examination of the Rate Book of the National Electric Light Association indicates a great many rates in addition to those above outlined. Most of these are quite apparently based on the individual ideas of some employee of a company who has been asked to give some attention to the rate subject.

The committee has no quarrel with the development of individual ideas. If individual ideas were to be forbidden and no experiments tried, our industry would come to a dead stop. Compulsory standardization is another form of saying: "You must not progress any further." Standardization and simplification are apt to be evils in themselves, and are justifiable only when what is adopted as a standard is better than what is non-standard, and only when what is simple is better than what is not so simple.

Simple Forms Recommended

But on the other hand it seems to your committee that it would be for the advantage of the industry if it should abandon some of the more complicated forms now in use in different cities, and more generally adopt some of the simpler forms that have been found practically successful, but without any idea of stopping progress in case any better form still shall be discovered.

Your committee holds no brief for any particular type of follow-on rate. It merely points out to the best of its ability the advantages and disadvantages of the various forms. However, if we could get down to two, or three at the most, forms of rates for residential service, it would be a distinct advantage to all concerned, and we strongly recommend consideration of the suggestion by all companies.

A change of this character can be made over a period of a few years, by the adoption of the plan of alternative or optional rate. While it is usually impossible to develop a new follow-on schedule which will show a reduction to all classes of customers with one rate change, over a period of a few years, this result can be satisfactorily accomplished.

Some of the companies fear that to change to a follow-on rate would involve a lot of trouble. Of course, nothing can be accomplished without some trouble, but the experience of companies that have changed is comparatively little and temporary in any case.

When the follow-on rate will not be an advantage to every customer, it can be put out as an optional rate, and if it is expected that most of the customers will benefit by it, they can all be changed to the new rate, provided it is made clear to them that they can change back in case it should not prove to their advantage.

The matter is largely one of psychology and of proper wording of the notices and advertisements, and so on.

Determining Principal Rate

An important point in connection with the following of alternative rates is the policy to be applied in determining which is to be considered the principal rate. That is usually determined by the statistical information secured, which would indicate under which of the two rates the majority of the customers would be benefited. It has been the experience of several companies that calling the rate that applies to the largest number of customers the principal rate, and considering the other the alternative rate, and making public a statement to the effect that the customer is to be placed on the principal rate, but that if he so desires he can be transferred to the alternative (the rate applying to the smaller number of customers), is the best policy. And that when these new rates are put into effect, which apply more favorably to the larger number of customers, it should agree with the Commission, where there is one, that all customers should be billed on this rate, and that those desiring to make a change shall indicate such desire to the utility company. Several companies have also adopted the practice, when such new rates have been put into effect, of printing on the monthly bills for a period of six months, a statement that there is another form of rate, and that if it seems beneficial the company will be glad to change the customer over to that form after examination of a year's bills. As time goes on, these rate differentials will disappear, and one rate will result.

Your committee does not consider that any attempt on the part of the company to select one or the other of the two rates for the customer would meet with any degree of success; that the changing conditions of the customer in his use of electricity from month to month make it practically impossible to pre-determine the best rate in many instances. So that your committee is emphasizing the great desirability of establishing a principal rate, and putting it up to the customer to select the other form if he deems it is more beneficial to him.

An attempt to select each month either one of two rates for a large number of customers would make an almost impossible situation and should be avoided. A full year's use of the service in one location is the only safe way to determine the *better* rate *of the two.* The differential in cents per month per customer between two such rates is so very small in many cases where the customer is on the dividing line between the two rates that very little criticism arises from the public when such a rate is put into effect, which does not affect every customer by a reduction. In the long run all customers would be benefited by the rate having the follow-on feature.

A Commission ruling on this point may be of value here. The Alabama Commission in the case of the Alabama Power Co. (P. U. R. 1929A, 458) stated as follows:

> "However, it is the opinion of the Commission that the standard rate prescribed in this order will prove of very great advantage to all customers of this utility, and we will, therefore, make the new rate applicable to all customers, unless the individual customer shall elect in writing, within a limited time, prescribed in the order, to return to the old rate."

In large cities another factor comes into the picture, and that is the tendency on the part of the customer to move.

In one large city the average number of changes in occupancy per year is about 25 per cent of the total number of residential customers. We point out that this is another reason why a principal rate should be determined upon, because there is no possible means of making comparisons between one residential customer and another, as the habits of people occupying the same premises consecutively are frequently entirely different; and furthermore, a customer moving from one premises to another sometimes changes his entire mode of living, due to adverse financial conditions or the reverse.

All of these factors make it seem very important that when two rates are in effect on residential occupancies, the principal rate be known, and that this rate be applied by the company at all times, unless the customer specifically requests a change to the alternative rate.

In numerous instances coming to the attention of the Committee, in cities where the older forms of rates have been in force for many years, the companies put into effect an alternative rate based on the floor area or room basis, which has had the effect of putting over on the new form a very large percentage of the customers in a very short time and has resulted in an appreciable increase in kw-hr. sold per customer. The advantage of having optional rates in effect is the development of a new follow-on rate system, which in time automatically eliminates the old form of rate. Confusion in bookkeeping has not been found a serious matter in the billing department, and this practice adopted by any company has been looked upon with favor by the public and the commissions.

In the case of the Hartford Electric Co., where the floor area basis of rates has been in effect for some time, the kw-hr. per annum have gradually

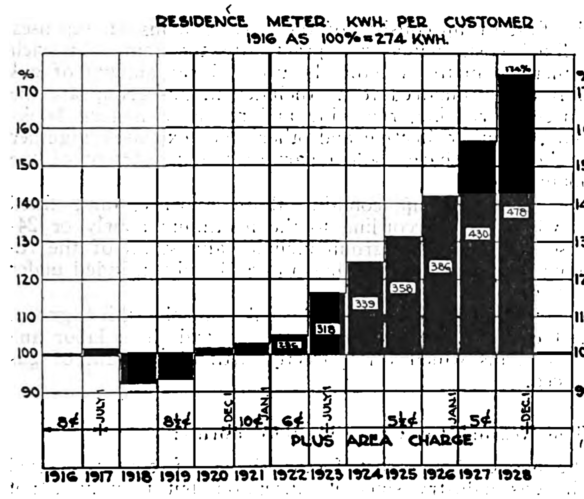

FIG. 1.

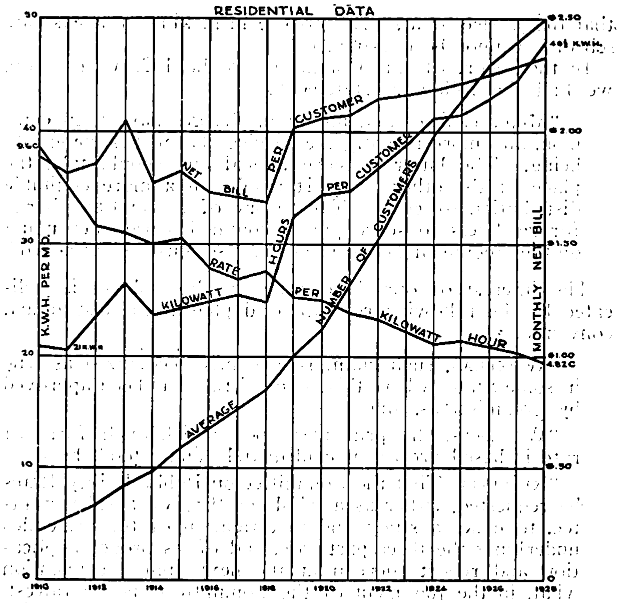

FIG. 2.

mounted year by year, until now we find the average to be 478 kw-hr. annually in 1928. Companies in the same section of the country using forms of rates without follow-on features show no increase in kw-hr. use.

The graphs shown in Fig. 1 and 2 illustrated what may be accomplished through the use of follow-on rates with reductions over a period of years, a most important indication of what can be accomplished with the proper form of rate in not only giving the customer many more kw-hr. at a decreasing rate, but also improving the company's revenue in a satisfactory manner.

Rural Residential Schedules

In most instances successful rates are based on a monthly service charge, plus a relatively low energy charge. The service charge may be entirely distinct from the charge for energy consumed, or it may include a small block of energy. The important thing is to have an energy charge that will encourage the use of electricity. The service charge itself may be based on transformer capacity, number of rooms, floor area, or any other standard. The important feature is that the service charge should be designed so as not to discourage the installation, or use, of any service that the company can profitably supply.

As an example of the way some commissions are thinking, we quote the following:

The Alabama Commission, in rendering a recent decision, said:

> "A 'promotional' rate for utilities service has been defined as a rate which successfully develops an increasing volume of profitable business. This end is attained when each customer is offered an opportunity to use additional service at a low follow-on rate for energy consumed. In order that a really low energy rate may be offered to each customer, it becomes necessary to establish a relatively high charge for an initial small block of energy to partially cover the fixed cost of service. The problem of the rate-maker centers generally around the method of assessing such initial charge to the individuals or groups of customers."

NATIONAL ASSOCIATION OF RAILROAD AND UTILITIES COMMISSIONERS

Report of Committee on Public Utility Rates 1927

The following quotation from the "Report of Committee on Public Utility Rates" of the National Association of Railroad and Utilities Commissioners gives an idea of the way other commissions are thinking on this subject. While the subject matter refers to gas rates, the same arguments might well apply to electricity rates.

To the National Association of Railroad and Utilities Commissioners:

The Committee on Public Utility Rates has in past years given considerable attention to the subject of scientific rate structure. These reports have discussed the principles of cost allocation and the necessity for the application of these principles of cost allocation have been more apparent for more than twenty-five years in electric power rates, and with the greatly increased use of major electric appliances in the home, such as the range, the water heater and the refrigerator, the application of demand principles in domestic electric rate making is rapidly coming to the front.

In its report to the 35th Convention in 1923 this Committee called attention to the alarming condition of the smaller gas utilities of the country and the necessity for the application of the rate schedules for these utilities, which would more equitably distribute the cost of service. Previously Hon. Carl D. Jackson when President had stated in an address to the Association that rate schedules based primarily upon the cost of service are a necessity to permit the possibility of the increased use of gas in fields where it has not as yet been used to any large extent. In 1923 this Committee closed its report with the statement that the justice of a service charge in making up a gas rate schedule cannot be questioned.

In the report of this Committee to the 1925 Convention, we find the following statement:

> "Meter charges and minimum charges have been common, and more recently the service charge has come into being. The latter is more logical and should take the place of the other two. It results in a more equitable distribution of costs. The theory of a stand-by charge for readiness to serve plus a commodity rate depending on the amount of actual use cannot seriously be attacked."

The interest of our Association in this subject is indicated by the following resolution adopted at the last annual convention:

> "WHEREAS, such claim is evidently recognized as true in some States where this form of rate has been approved by Commissions, and
>
> "WHEREAS, the principles upon which such form of rate is based are often inadequately understood, be it
>
> "RESOLVED, That the Committee on Public Utility Rates be requested, either as a whole or through a subcommittee, to make a study and investigation of the principles underlying the three-part rate, and of its proper application and report thereon at the next annual convention what, in the judgment of the Committeee, is the fairest, most accurate and most equitable method of charges for gas service."

Investigation as to Gas Schedules

Your Committee, therefore, in accordance with your request has made an investigation of the methods of determining the forms of rates for gas.

A review of the gas rates throughout the United States and possessions, as published in the Rate List of the American Gas Association and in the Rate Sheets of the Natural Gas Association of America, reveal the existence even at this day of straight meter rates, and also show many forms of sliding scales, block rates and special rates applicable to classes of customers, varying conditions of demand, and to specific purposes of utilization.

However this may be, it seems to your Committee that constructive and statesmanlike regulation demands that the Commissions should aid in every way possible, through encouragement of reasonable and businesslike forms of rates, the full development of public utilities in their service to the people. Nothing could put State regulation on a more useful and firmer basis.

The total gross or net revenues which may be collected by any gas company under any form of rate is not an issue in this discussion, since in the last analysis the amount of such earnings is regulated by our Commissions. The question is rather with the *forms* of rates which good management will prescribe to give the maximum public service and yield no more than the proper aggregate net revenues. It is with fair, accurate and constructive forms of rates that we are here concerned.

Your Committee feels, therefore, that an investigation of the subject matter of the Association's above quoted resolution could conveniently be divided into the following questions, which method was followed by us:

A. What are the principles underlying the so-called three-part form of rate?

B. Why should there be any occasion to change the methods of charging for gas to conform to these principles?

C. How should the principles be applied?

D. What are the relative merits of the various rate forms as to fairness, accuracy and equity?

A. The Underlying Principles:

The expenses and fixed costs incident to operating a gas company may be classified into three groups:

1. Customer Costs.
2. Demand Costs.
3. Commodity Costs.

The first group consists of the various items of expenses and fixed costs which are practically the same for each customer, no matter whether he uses a large amount of gas or only a few hundred feet. Included in this group are the expenses of reading, removing and repairing meters, bookkeeping, billing, collecting and other office expenses, together with the fixed charges on a part of the investment of the company.

The second group contains those expenses and fixed costs which vary according to the maximum hourly or 24-hr. use of gas. This group includes almost all of the remaining fixed costs, other than those already included under customer costs.

The commodity costs, which make up the third group, consist of coal, oil and other supplies, and those labor and expense items which vary directly with the amount of gas produced.

B. The Reasons for Changing Rate Forms:

The above shown cost factors have, of course, existed in the gas industry since its inception, but they have not been given general recognition in the making of rates for several reasons:

(1) As long as the major part of the gas supply was used for lighting, the use of gas was about the same for all classes of customers, and a close adherence to cost analyses was not necessary.

(2) Changes in rate forms are generally viewed with suspicion by the public. Conservative gas companies hesitated to stir up trouble as long as they could make a fairly adequate return on the old basis.

With a straight meter rate of so much per 1000 cu. ft., about one-third of the customers of a gas company are served at a loss, in that they fail to pay the bare operating expenses chargeable against them, without consideration of any return on the investment. For instance, on a rate of $1.50 per 1000 cu. ft. a customer who uses only 500 cu. ft. in a month will pay 75 cents. The customer cost to serve this customer will be more than $1.00 per month, the minimum demand cost 20 or 30 cents. This makes a total of more than $1.70, with which the customer should be charged if he is to pay a full fair return upon the investment necessary to serve him. He, therefore, lacks more than $1.00 per month of paying his way, which dollar or more must be made up by some other customer if the company is to make a fair return.

There is another approximate one-third of the customers who, while paying the operating costs necessary to serve them, do not pay a full fair return. The remaining third of the customers not only pay all of their own costs, but if the company is receiving a fair return, this group must also pay all of the losses incident to serving the other two-thirds of the customers. For example, in a recent case an official of a large company testified that one group of his customers not only paid their own way, including a full fair return, but contributed $3,000,000 a year in order to make up the deficits caused by other customers.

By reason of their rate structures, many companies get the bulk of their net earnings from their most competitive classes of service. This is an unsound condition, and it naturally hampers the growth of the industry.

C. The Application of the Principles:

The three-part principles can be expressed outright as shown in the following example:

(1)	A customer charge per meter, per month.... Plus	$1.00
(2)	A demand charge per cubic foot of maximum hourly demand, per month .... Plus	.02
(3)	A commodity charge per 1000 cu. ft. of gas sold	.60

The rate can be simplified by grouping the first two charges as per the following:

(1) A fixed charge	
For the first 25 cu. ft. or less of maximum hourly demand, per month	1.50
For all additional demand, per cu. ft. of gas sold	.60
Plus	
(2) A commodity charge per 1000 cu. ft. of gas sold	.60

The form in which the rate is expressed will depend to a large extent upon the nature of the business to be served. If the rate is to be used as an optional schedule, available only to certain classes of service, the three parts may be expressed outright or the first two grouped together, as shown above, without encountering difficulties, since the rate is to be made applicable to all customers, consideration must be given to the choosing of the method which is least expensive. The measurement of the demand of a customer, either by a demand meter or by use of a demand limiting device, is an expensive procedure, and so should not be used until absolutely necessary. In selling natural gas, where the early morning peak on an extremely cold day plays such an active part in the rendering of service, some such means may be necessary, but for most manufactured gas companies it should prove less expensive to estimate the demand of at least the bulk of the domestic users. The results arrived at may be accurate enough for all practical purposes.

In estimating the demand, some companies rate all domestic customers at the same figure and make more exact calculation for only the large industrial customers. Others rate customers according to the size of meter required. Ratings according to number of rooms and the floor area of the house have also been considered.

The principles of the three-part rate need not necessarily be stated in three parts. They are often put in force without any fixed charge, by using a high variable charge for the first few hundred feet. However, if this simplification process were carried to the extreme of distributing customer costs and demand costs at so much per 1000 cu. ft. of gas sold, the results will in all probability no longer accord with sound allocation of the actualities of the costs.

D. A Comparison of Rate Forms

A useful method of judging the merits of various rate forms is to set up several rates, each of which, when applied to the sales of a sample company, will yield the same gross revenue.

Suppose we assume a company with average sales of 2500 cu. ft. per month and a straight meter rate of $1.40 per 1000. The monthly revenue per customer would, therefore, be $3.50.

A block rate, to yield the same money, would require a slightly greater charge per thousand for the first block, and we would, therefore, have something along the following lines:

RATE No. 2

For the first 5000 cu. ft. per month, per 1000 cu. ft.	$1.45
For the next 5000 cu. ft., per 1000 cu. ft.	1.25
For all over 10,000 cu. ft., per 1000 cu. ft.	1.00

If the blocks are made shorter, the initial price will necessarily have to be larger, unless the company is willing to make a decrease in revenue in order to encourage sales. These comparisons being based on equal revenue, we would require something along the following lines:

RATE No. 3

For the first 3000 cu. ft. used per month, per 1000.	$1.50
For all additional gas, per 1000 cu. ft.	1.10

If a service charge is used of, say, $1.00 per month, the commodity charge could be lowered to $1.00 per 1000 for all customers, the rate and revenue being as follows:

RATE No. 4

(1) Service charge per meter per month	$1.00
Plus	
(2) Commodity charge per 1000 cu. ft. of gas	1.00

Revenue on this:

2500 cu. ft. at $1.00	$2.50
Service charge, per meter per month	1.00
Total	$3.50

The rate could also be put in a more popular form by quoting it as follows:

RATE No. 4 (Optional Form)

For the first 200 cu. ft. or less of gas used each month	$1.20
For all additional gas, per 100 cu. ft.	.10

The revenue on this basis would be:

200 cu. ft. at $1.20	$1.20
2,300 cu. ft. at .10	2.30
Total	$3.50

To calculate a three-part rate, we must first choose a method of measuring the demand. In the following rate, the room basis is used merely as an example, without any intention of recommending this basis for adoption by any commission or company. It is merely an illustration.

RATE No. 5

(1) Customer charge per meter, per month	$0.95
Plus	
(2) Demand charge per active room, per month (with a minimum of three active rooms)	.10
Plus	
(3) Commodity charge per 1000 cu. ft. of gas	.80

Assuming an average of 5½ rooms per customer, this rate would yield the following revenue on present sales:

Customer charge	$.95
Demand charge, 5½ rooms at 10 cents	.55
2500 cu. ft. at 80 cents	2.00
Total	$3.50

If the number of rooms is more or less than 5½, the above charge will require slight changes. This rate can also be quoted in the following form, eliminating the complexity:

For customers with 3 or less active rooms, for the first 200 cu. ft. or less of gas used each month	$1.41
For all additional gas, per 100 cu. ft.	.09

For customers with more than 3 active rooms, the above charge of $1.41 for the first 200 cu. ft. shall be increased 10 cents for each additional room.

Having thus calculated the rates, it may next be in order to compare them, and an easy method is to show the bills of representative customers on each, as follows:

Gas Bill on Various Rates

Gas Used	No. 1 Meter Rate	No. 2 Block Rate	No. 3 Block Rate	No. 4 Service Charge	No. 5 3 Rooms	Three-Part Rate 3 Rooms	Three-Part Rate 8 Rooms
10,000	$14.00	$13.50	$12.20	$11.00	$9.25	$9.45	$9.75
9,000	12.60	12.25	11.10	10.00	8.45	8.65	8.95
8,000	11.20	11.00	10.00	9.00	7.65	7.85	8.15
7,000	9.80	9.75	8.90	8.00	6.85	7.05	7.35
6,000	8.40	8.50	7.80	7.00	6.05	6.25	6.55
5,000	7.00	7.25	6.70	6.00	5.25	5.45	5.75
4,000	5.60	5.80	5.60	5.00	4.45	4.65	4.95
3,500	4.90	5.07	5.05	4.50	4.05	4.25	4.55
3,000	4.20	4.35	4.50	4.00	3.65	3.85	4.15
2,500	3.50	3.62	3.75	3.50	3.25	3.45	3.75
2,000	2.80	2.90	3.00	3.00	2.85	3.05	3.35
1,500	2.10	2.17	2.25	2.50	2.45	2.65	2.95
1,000	1.40	1.45	1.50	2.00	2.05	2.25	2.55
500	.70	.72	.75	1.50	1.65	1.85	2.15
0	0	0	0	1.00	1.25	1.45	1.75

Three Part Rate Fairest

Except for one consideration (that it tends to increase the bills of all casual and irregular or "convenience" customers), the three-part rate shown in the last three columns of the above table immediately becomes apparent as the fairest, most accurate and most equitable of the rates shown. It comes closest to charging each customer with the cost of serving him. It appears to be as accurate as is possible without the expense of additional meters to actually measure or limit the demand.

Technically speaking, gas rates should be judged only by the standards of fairness, equity and sound business judgment. However, in order to cultivate that valuable asset of public utilities, namely, good public relations, it is necessary to consider rates from that angle also. When the rates in the above table are so viewed, the decision is again in favor of the three-part rate. It will be noted that winter and summer bills will be equalized, thus minimizing the danger from that prolific source of complaints, high bills. It will also be noted that 80-cent gas is offered to every customer, thus permitting the substitution of a clean convenient fuel at a reasonable cost in the homes of the workingmen as well as in those of the well-to-do citizens. The initial charge is not excessive for any customer, and it is quoted in language easily understood by that customer. Although appearing somewhat complicated on paper, it can be easily explained to the customer, since for each customer, it consists of a meter rate of 80 cents per 1000, with a definite fixed charge or charge for the first 200 cu. ft. It is easy to see that the three-part rate will tend more than any of the others to encourage the use of gas, develop the industry and result in future economies and lower unit prices.

There remains for comment the first point mentioned above the increases to the small customers, as a talking point against the installation of rates embodying the three-cost principles. The small customer is often referred to as the poor man. Such is not commonly the case. It should not require any detailed examination or calculation to convince anyone that the workingman or clerk, whose wife cooks meals for the good sized family, whose laundry is done at home, and who cannot afford to eat out at restaurants, is naturally a larger user of gas than the well-to-do man who lives in a high priced apartment, where heat and hot water are furnished by the landlord, where few meals are cooked and where there is little use for gas, except as an occasional convenience. Technically speaking, we should not take into consideration the financial condition of the customers in determining gas rates and charges. However, even if this is done, we are forced to conclude that there is no reason why the small convenience user should not be asked to pay his own way, rather than remain a burden upon the customer who really uses gas service. The three-part rate can well be stated as the best rate for the poor man.

Any change in conditions to which people are accustomed causes opposition. Examples of this occur daily. For instance, violent opposition is offered in some cities to the installation of water meters, customers preferring the flat rate. This is the direct opposite of conditions in the gas industry, where companies are endeavoring to change from meter rates to something approximating a flat rate. A number of gas companies have had unfortunate experience with the installation of service charges, but this we believe was due to the installation of these charges as increases in rates, without enough of a reduction in the accompanying meter rate to demonstrate to the customers the benefits of the rate form.

The installation of proper rate forms for selling gas is a matter which will require extensive educational efforts on the part of the gas companies. They may best install new rate forms either to yield the same revenues they are now getting, or in connection with a decrease in their present revenue. If the lack of sales of any gas company is due to the rate form, the company may not advisably, in our judgment and experience, attempt to install a change in form at the same time, as it increases its average rate. It might well try first a change in form of rate and determine if this will not bring about the necessary improvement in financial results.

Your Committee, while not recommending to regulatory commissions or to gas companies any rigid uniformity or standardized method of rates and charges for gas, which should remain a matter for the best business judgment in each individual case in accordance with the local situation, does, however, heartily approve methods of charges for gas based on allocation of costs of service, so as to permit the gas industry of the country to develop its maximum possibilities in more extensive and more economical service to the public.

Respectfully submitted,

A. G. PATTERSON, *Chairman,*

Committee of Public Utility Rates of the
National Association of Railroad and
Utility Commissioners.

It will be noted that the last two paragraphs of the Commissioners' report says that the charges for gas should be based on allocation of costs of service so as to permit the gas industry to develop its maximum possibilities in more extensive and more economical service to the public.

The report points out that after the rate expert has allocated costs by one method and arrived at a set of rates, the rate expert should try another method of allocation of costs, and if the second method will result in more extensive and more economical service to the public, the second method of allocation of costs is better than the first method.

REPORTS OF ENGINEERING NATIONAL SECTION COMMITTEES 1928-1929

(For Personnel of Committees see Appendix 4)

Executive Committee

C E Stone, *Chairman*

Convention Address by Chairman Stone (see p. 28)

Accident Prevention Committee

C R Beardsley, *Chairman*

Serial Report, Publication No. 289-112, Suggestion Systems (see p. 446)

Electrical Apparatus Committee

J Allen Johnson, *Chairman*

Serial Reports

Pub. No.	
289-37	Progress in Generator Design and Practice (see p. 469).
289-48	Storage, Handling, Treatment, Inspecting and Testing of Insulating Oils (see p. 493).
289-52	Uniform Records of Electrical Operation of Power System (see p. 627).
289-60	Outline of Fundamentals of System Interconnection (see p. 536).
289-82	D-C Substation Design Practice (see p. 541).

Engineering Administration Committee

H P Liversidge, *Chairman*

No Serial Report

Hydraulic Power Committee

Byron E White, *Chairman*

Serial Reports

Pub. No.	
289-66	The Use of Hydro-Electric Units as Synchronous Condensers (see p. 640).
289-68	Mechanical Reliability of Hydro-Electric Units—1927 (see p. 649).
289-72	Penstock Valves (see p. 662).
289-84	Spillway Gates On Or Adjacent to Dam (see p. 683).
289-86	Hydro-Electric Bibliography and Manufacturers' Statements (see p. 712).

Inductive Coordination Committee

H L Wills, *Chairman*

Serial Report, Publication No. 289-95, Automatic Train Control—Installations and Description of the Code System (see p. 731)

Meter Committee

E E Hill, *Chairman*

Serial Reports

Pub. No.	
289-7	State Laws Relating to Theft of Electric Current (see p. 747).
289-39	Low Tension Metering Installation (see p. 773).
289-40	Summary of Public Utility Commission Rules and Regulations for Electricity Meters (see p. 777).
289-47	New Developments in Electrical Measuring Devices (see p. 797).
289-57	New Developments in Auxiliary Testing Equipment (see p. 829).

Overhead Systems Committee

Harold Cole, *Chairman*

Serial Reports

Pub. No.	
289-6	Practical Uses of Steel and Concrete Poles (see p. 862).
289-16	Recommended Practices for Design and Construction of Rural Lines (see p. 884).
289-42	Patrol and Inspection of Transmission Lines (see p. 906).
289-45	Suggested Specifications for Overhead Line Materials and Methods of Construction on Low and Medium Voltage Lines (see p. 939).
289-46	Types of Distribution Systems and Methods of Effecting Changeover (see p. 916).

Power Systems Engineering Committee

L W W Morrow, *Chairman*

No Serial Report

Prime Movers Committee

E B Ricketts, *Chairman*

Serial Reports

Pub. No.	
289-28	Power Station Chemistry—Part I (see p. 1005).
289-114	Power Station Chemistry—Part II (see p. 1025).
289-43	Coal and Ash Handling (see p. 1064).
289-49	Specifications (see p. 1085).
289-50	Standards for Use in Design and Operation of Mechanical Power Plant Equipment (see p. 1103).
289-53	Treatment of Feed Water (see p. 1118).
289-58	Operating Code Manual (see p. 1131).
289-59	Boiler and Turbine Room Instruments (see p. 1152).
289-64	Foreign Developments (see p. 1228).
289-69	Distillation Products of Coal (see p. 1177).
289-71	Stoker Equipment and Furnaces (see p. 1423).
289-73	Higher Steam Pressures and Temperatures (see p. 1193).
289-75	Boilers, Superheaters and Economizers (see p. 1259).
289-98	Turbines (see p. 1333).
289-111	Condensing Equipment (see p. 1458).

Special Engineering Research Committee

C F Hirshfeld, *Chairman*

No Serial Report

Underground Systems Committee

J W Sylvester, *Chairman*

Serial Report, Publication No. 289-87, Rate of Deterioration of Impregnated, Wood-Pulp Cable Paper Subjected to Heat Only (see p. 1493)

SUGGESTION SYSTEMS

Preface

Upon noting a subject such as suggestion systems on the list of those discussed by an Accident Prevention Committee, the first thought is to feel that such lies rather outside of its immediate scope. Further inquiry, however, among those who have to do with a suggestion system will develop the fact that there is no medium better than it to bring accident hazards to light, as well as valuable items along many other lines.

Moreover, no channel has yet been devised equal to it for obtaining the opinions of a large group of employees, and obtaining their accumulated experience which is far better than an equal amount of theorizing.

Introduction

A suggestion system is an orderly method for encouraging, receiving and rewarding helpful ideas of employees relative to the business of the employing firms or corporations.

That it is effective in producing the results desired is attested by the fact that several universities among them the University of Pennsylvania and the University of Michigan, offering courses in business administration and financial training, have made intensive studies of this phase of business. One university in a recent report states:

> "The number of American and British concerns having definite systems appears to include more than 300 companies employing more than a million workers."

Insurance companies also, through their service bureaus, have issued pamphlets commending the advantages of a suggestion system.

In the United States the first system apparently was introduced in 1888. In July, 1912, the United States Congress passed an Act providing that employees of the Ordnance Department not specifically charged with originating improvement and efficiency be suitably rewarded by cash payment for efforts resulting in improvements. Similar arrangements were introduced in the Post Office Department in 1913-1914, and again in 1924. The latest addition to the list of large corporations adopting such a plan is the Pennsylvania Railroad Company, as announced in December, 1927.

Other firms are displaying interest by making frequent requests for data from those who have successful systems in operation.

The reports of studies made by the two universities mentioned include certain statistics as shown in Tables I, II, III and IV.

TABLE I

(University of Pennsylvania)

NATURE OF THE COMPANIES

Nature of Business	*Companies Having Sugg. System*	*Number of Eligible Employees*
Industrial concerns	63	227,881
Public utilities	7	37,922
Department stores	6	28,900
Banks and insurance companies	6	14,071
Miscellaneous	4	1,520
	86	310,294

General

The successful operation of a suggestion system depends primarily on the management and the supervisory staff being sympathetic; if not, it is a mere waste of time to install a system.

Of almost equal importance are the methods of

TABLE II

(University of Michigan)

SIZE OF COMPANIES

Number of Employees	*Companies Having Suggestion System*
1 to 200	11
201 to 500	44
501 to 1,000	49
1,001 to 1,500	24
1,501 to 2,500	30
2,501 to 5,000	16
5,001 to 10,000	11
10,001 to 15,000	10
15,001 to 25,000	5
25,001 to 50,000	3
Over 50,000	4
	207

TABLE III

(University of Pennsylvania)

NATURE OF SUGGESTIONS
(First Group)

Topics	*Companies Reporting Topics* Number	Per Cent
Improvement of methods and processes	55	26.4
Safety practices and devices	36	17.3
Improvement of working conditions and industrial relations	31	14.9
Improvement of tools, jigs and equipment	29	14.4
Elimination of waste	15	7.2
New products or improvement of old	11	5.2
Improvement of design	9	4.3
Labor saving devices	5	2.4
Improvement of marketing methods	4	1.8
Advertising suggestions	4	1.8
Miscellaneous	9	4.3
	208	100.0

Publication No. 289-112. Serial Report, Accident Prevention Committee.

TABLE IV

(University of Pennsylvania)

NATURE OF SUGGESTIONS

(Second Group)

Topics	Companies Reporting Topics Number	Per Cent
Improvement of methods, routine, system and maintenance of office, store or shop	23	24.5
New forms, signs, tools or equipment	17	18.1
Improvement of working conditions and industrial relations	12	12.8
Improvement of selling methods and advertising suggestions	7	7.4
Health and safety	7	7.4
Improvement of service	3	3.2
Elimination of waste	3	3.2
New business	2	2.1
Publicity	2	2.1
Miscellaneous	15	16.0
	94	100.0

handling, for in a large concern highly organized, systematic procedure must be followed in order that proper consideration may be given each idea offered. Promptness and despatch are also essential and have much to do with keeping up interest and giving assurance that all ideas will be treated with the same facility and judgment given to other items of business.

With employees numbering thousands a relatively large volume of suggestions is certain to ensue, but these will come usually from 10 to 15 per cent of the force and about 25 to 30 per cent will be adopted. The figures, however, apply more to a large concern than to a small one and there will be exceptions where the percentage of employees participating and the volume of suggestions submitted and adopted will be very much greater.

Aside from the obvious purposes of a suggestion system there will be provided an additional point of contact between employer and employee, a feature which should appeal more particularly to the larger concerns. This will enable matters of all kinds to reach the management, and also permit the management to express itself to the employees, even individually.

Still another feature which should not be overlooked is that certain items can be handled by a suggestion system which can hardly be covered or provided for by any other channel, among these being matters pertaining to apparatus, such as quality and cost, or to factory and office-conditions as health and prevention of accident, or to miscellaneous items such as systems and methods, etc.

All systems include either a representative delegated by the management, or a committee consisting of management and employees appointed to handle the details of recording, investigating, answering and rewarding. The forms in vogue vary widely, but the most satisfactory seems to be that in which the committee acts as "attorney" for the suggestor, presenting his "case" to the proper "court" or branch of the organization most concerned. General knowledge of plant, policy, personnel and product is thus required of the committee in order that subjects may be referred to proper authorities for verdicts. The committee thus becomes the medium in transmitting proposals to the management and their verdicts to the suggestors. This method of procedure seems to be especially suited to large organizations, a better plan than for the suggestion committee itself to attempt to pass upon the merits of any suggestions.

After studying systems in operation in various concerns it is felt that the matter of eligibility and restrictions should not be overemphasized, though recognition must be given to these factors and perhaps certain employees excluded from participation. The majority of concerns favor cash awards for every suggestion, although some only pay for the very best and give honorable mention to others, some offer merit certificates while still others offer gift articles.

In the majority of instances it will not be possible to figure savings effected by the adoption of a suggestion; but, where it can be done the amount of the award should be a given percentage of the saving of a certain period, say one or two years. For the reason, however, that generally no clean-cut estimate of savings can be made, it is customary to consider awards simply as prizes, though some plan even here must be followed of which several are outlined in the appendix.

Of the suggestions submitted, it should not be expected that more than 25 to 30 per cent can be adopted, but, in order to maintain and increase interest in a system, an additional award may be offered. For example, when five suggestions have been accepted and paid for, an additional award of $5 may be made; when a total of ten suggestions have been accepted an additional award of $10 may be made and so on.

Suggestions involving patents usually require a long time before awards can be made. A quick way to handle these, however, is to decide on a minimum award of $25 in every instance where a patent seems to be worth trying for. If ultimately a patent is obtained and the claims allowed warrant, an additional award can then be made.

Details of a Suggestion System

Notices should be posted throughout the various departments of a plant outlining the system. Suggestion blanks on which statements may be written should also be available. These may either be deposited in special boxes, or dropped in the shop mail.

The advantages of the system may be held before employees by the posting of card "reminders" varying in style and form, and changed at regular intervals.

A revolving committee of not less than three persons to serve for a year should be appointed by the management with a permanent chairman and a secretary. Two of these members may be selected from the supervisory staff and one from among the hourly paid workers. The chairman and the secretary can handle all the routine work, somewhat as follows:

1. Suggestions, submitted on suggestion blanks or even on ordinary paper, are sent by mail to the committee.
2. Subjects are assigned, suggestions acknowledged on printed form, carbon copies of the form used are filed, both by subject and by name of employee.
3. Suggestions by typewritten letter are sent to the department or person most competent to answer, soliciting an opinion of the idea offered. Occasionally personal interviews are arranged.
4. When the reply is favorable (i.e., suggestions acceptable), the suggestion is listed with others accepted and all are evaluated by the secretary.

   When the reply is unfavorable, a copy of the opinion is forwarded to suggestor.
5. The chairman calls the committee into conference to discuss the list further, including awards; the approved list is signed by each member and forwarded to the manager of works or another officer, for final approval.
6. Notifications of acceptance and award are forwarded to suggestors.
7. Checks are delivered by the secretary or mailed to the suggestors who sign receipt cards. Cards serve as a record of the individual whose suggestions are adopted.
8. Prominent mention is given in the monthly plant paper to the "Best Suggestions."

Conclusion

The subcommittee has only aimed to present a condensed report, as observation and long experience with the operation of suggestion systems indicate their success rests upon simple, commonplace foundations, namely desire for improvement, good faith and sincerity of purpose. As the system becomes better understood by all, it furnishes a very distinct and effective agency for the collection of ideas, otherwise lost.

Acknowledgment is made herewith to the institutions quoted above, to the authors and publishers named in the appended bibliography, as well as to the members of our Accident Prevention Committee who have contributed details of their systems.

Bibliography

Booklets—Leaflets

Title	*Author*
Michigan Business Studies Suggestions from Employees	Z. Clark Dickson, University of Michigan
Suggestion Systems Safe Practices Pamphlet No. 40	National Safety Council, Chicago, Ill.
The Observing Employee	Metropolitan Life Insurance Company, New York
Employees Suggestion Systems (Report to Wharton School)	Prof. W. E. Fisher, University of Pennsylvania
Business Suggestions from Employees (Survey Report No. 13)	American Management Association, New York
Employee Suggestion Systems Management Bulletin—Kardex Institute	Herman Feldman, Dartmouth College

Publishers of Books

Ronald Press Company, New York
McGraw-Hill Company, New York
A. W. Shaw Company, Chicago

Magazine Articles

	Date of Issue
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Factory	April, 1925
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Factory	April, 1926
System	September, 1919
System	October, 1920
System	March, 1926
System	October, 1926
Manufacturing Industries	April, 1928

Plant Magazines Giving Prominent Mention to Suggestions

Westinghouse Magazine	Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
G. E. Works News	General Electric Co., Schenectady, N. Y.
The Kodak	Eastman Kodak Co., Rochester, N. Y.
The Bulletin	Youngstown Sheet & Tube Co., Youngstown, Ohio.
Public Service	Philadelphia Co., Pittsburgh, Pa.
The Reflector	Oakland Motor Car Co., Pontiac, Mich.

OPERATING COMPANIES' STATEMENTS

THE EDISON ELECTRIC ILLUMINATING COMPANY OF BOSTON

Subcommittee Report on One-Dollar Awards

This Committee has considered the various phases of the question of making a cash award of one dollar to employees calling attention to hazards to persons, property or service. The records of the Accident Prevention Committee since the inception of the one-dollar-award idea, and the correspondence between the Committee and the various Bureau and Department heads, have been reviewed. The Committee also has obtained the views of the most interested Department heads. With this information, together with Committee members' experience on the Committee as a background, the following recommendations are submitted:

1. It is believed there is merit in the idea of a cash award for suggestions because of the incentive which an award holds for most individuals. It is recommended that the practice be continued in a somewhat modified form of procedure and under slightly more restricted rules.

   It is realized that it might be argued that an employee should report all such conditions observed because of his sense of loyalty to the company. However, it is a psychological fact that human beings old and young require some motivation for the accomplishment of good works. A small cash incentive will cause the average employee to see more and report more than if such incentive were lacking.

   It seems to the Committee that the one-dollar award is a reasonable and economical means of accomplishing a desirable objective.

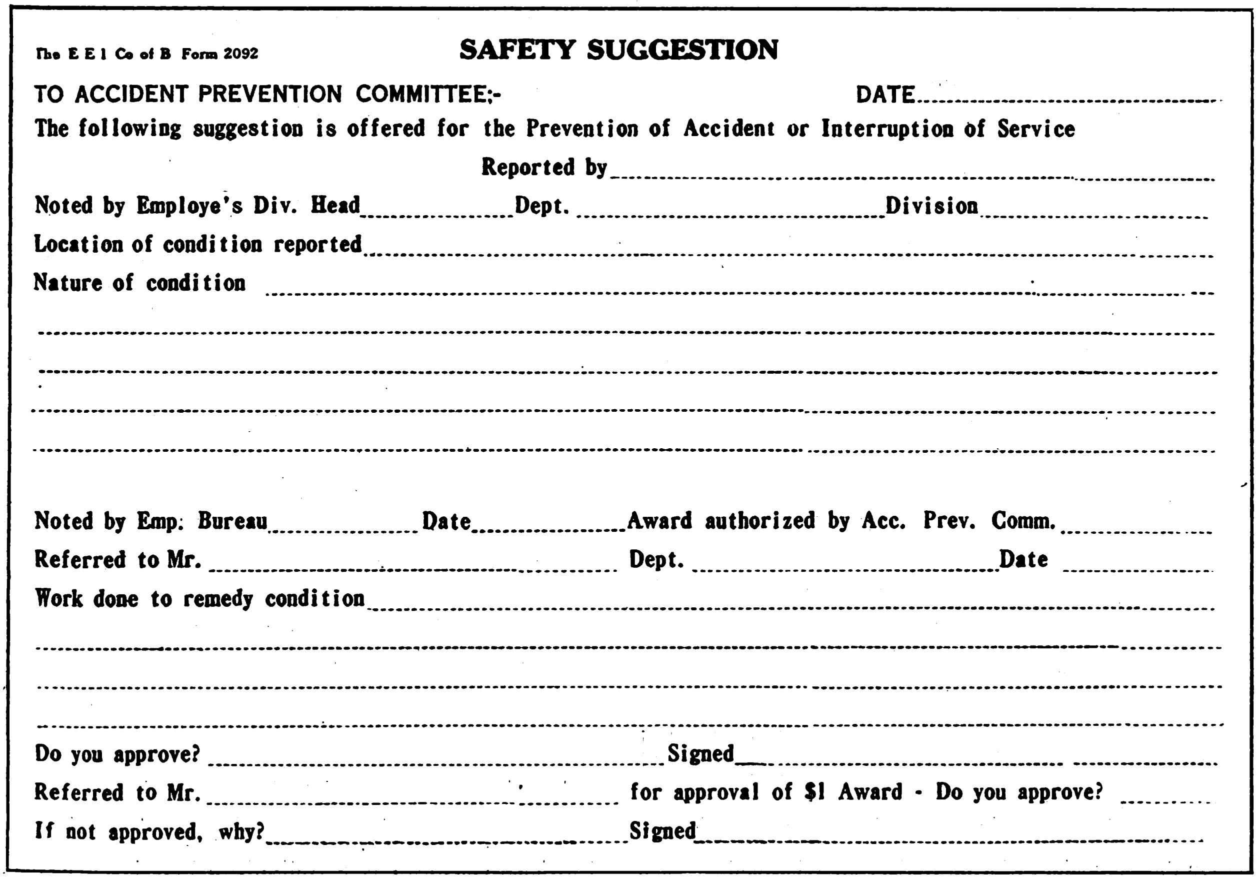
   The question of allowing awards by conducting a competition has been considered; that is, each month making an award to the two or three employees turning in the largest number of approved suggestions. It is realized, however, that while this might reduce the total amount of money spent for suggestions, it would automatically disbar the person who might make one suggestion per year which would be more valuable to the company than all of the suggestions of the prize winners. Therefore, this idea has been rejected.

2. The following specific procedure is recommended. It is believed that in most cases it conforms with present procedure, but as present procedure has never been made a matter of record, it seems that it is well to make the record now.

   (a) Suggestions shall be made in duplicate by the individual and submitted through his Division head to the Clerk of the Accident Prevention Committee.

   (b) The Clerk of the Committee should retain the copy of the suggestion and forward the original to the Department head having jurisdiction over the condition referred to. The Department head after investigation shall either approve or disapprove the suggestions giving reasons, and forward it to the head of the Department from which the suggestion emanated.

   (c) The head of the Department in which the suggestion originated may make any comments he may wish, approve or disapprove, and return to the Clerk of the Accident Prevention Committee.



The E E I Co of B Form 2092

SAFETY SUGGESTION

TO ACCIDENT PREVENTION COMMITTEE:- DATE..........

The following suggestion is offered for the Prevention of Accident or Interruption of Service

Reported by..........

Noted by Employe's Div. Head.......... Dept. .... Division..........

Location of condition reported..........

Nature of condition ....

Noted by Emp. Bureau.......... Date.......... Award authorized by Acc. Prev. Comm. ....

Referred to Mr. .... Dept. .... Date ....

Work done to remedy condition..........

Do you approve? .... Signed..........

Referred to Mr. .... for approval of $1 Award - Do you approve? ....

If not approved, why?.......... Signed..........

FIG. 1—SAFETY SUGGESTION FORM—EDISON ELECTRIC ILLUMINATING COMPANY OF BOSTON.

(d) Those suggestions which have been approved by both Department heads will be approved by the Accident Prevention Committee for the award. Those suggestions which have been disallowed by Department heads will be reviewed by the Accident Prevention Committee. If in the opinion of the Committee there is a question as to the merits of the suggestion from accident viewpoint, they may resubmit it to the Department heads having jurisdiction for further investigation and report.

(e) All suggestions will be acknowledged either by the award of one dollar or by a memorandum advising that the award has been disallowed, thanking the employee, and requesting his continued interest in submitting suggestions.

3. There are, of course, a great variety of suggestions, and it is impossible to define them all. However, experience has shown that a majority of awards in the past have been made on suggestions covering a few types of conditions, and the following definitions will apply to most cases which arise.

(a) Suggestions calling attention to undesirable conditions on or near primary wires, such as radio antennae crossings, broken insulators, wires off insulators, wires chafing in trees without protection, wires in proximity to houses or where they may be reached by persons, crossings with other circuits, etc., are well worth while and should be rewarded.

(b) Suggestions calling attention to secondary wires need more careful scrutiny. In general, broken or detached house irons are a potential hazard and suggestions calling attention to such cases should be rewarded. Twisted service wires may or may not constitute a hazard and the question of the award must be left to the judgment of the Department head. Contact with trees, chipped insulators, wires or pins, etc., are not generally a hazard and should not be awarded.

(c) The fact that a condition that has been called to the attention of a department is corrected, does not necessarily entitle the suggestor to the one-dollar award. It is recognized that a condition which is not in any way hazardous might be corrected because of the presence of a crew of men at the scene for investigation. No appreciable expense would be involved, the expense having been incurred in going to the location.

(d) The miscellaneous suggestions which may be sent in not covered in the above, must be dealt with individually and treated justly according to their merits.

(e) Those who are eligible to receive the one-dollar award shall be all persons who are employees of the Edison company below the rank of the assistant division heads, except the members of the Accident Prevention Committee of the company.

BROOKLYN EDISON COMPANY

General Instructions to Safety Subcommittee Members

Safety subcommittee members are appointed for a period of four weeks by the supervisors of their respective bureaus. While serving in this capacity they are expected to cooperate with the Safety Engineering Bureau in an endeavor to prevent accidents to employees through the elimination of hazardous conditions and unsafe methods of conducting work.

One day per week is to be devoted to this work. It is called to the attention of the subcommittee members that this time is charged to the account of the Safety Engineering Bureau and that this time will be profitably spent only if their duties are discharged in an intelligent and conscientious manner.

On the day assigned for inspection, the subcommittee members will meet for a short conference with a representative of the Safety Engineering Bureau and with their Bureau head or a representative of their Bureau, who will offer such special instructions and assignments as he deems advisable and necessary. The remainder of the day will be devoted to an inspection of the activities of their Bureau employees and the physical property of their Bureau.

As a general guide to the intelligent discharge of their duties the following activities are suggested to the subcommittee members:

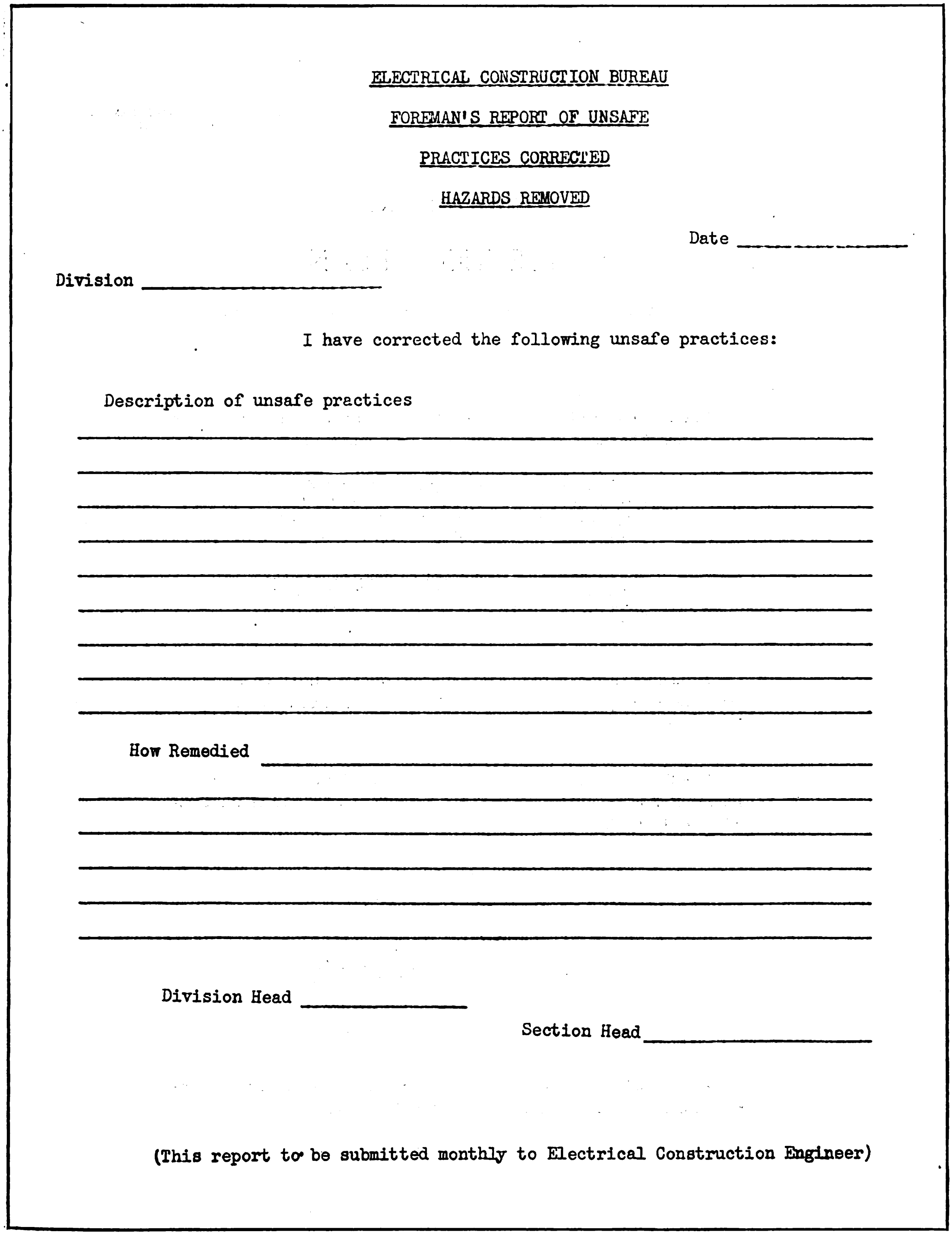
1. Inspection of the physical properties of their Bureau. Where this applies only to offices, particular attention should be given to all office equipment, noting any defects in desks, chairs, cabinets, inkwells, etc.
2. Inspection of the physical property of the Bureau in the field both mobile and stationary, for defects and hazardous conditions.
3. Inspection of tools and equipment used by the Bureau employees. This is very important because many accidents are caused by defective tools and the lack of necessary tools and equipment.
4. Particular attention should be paid to the manner of conducting work on the part of the Bureau employees. Accidents are certain to result when safety precautions are not observed. The subcommittee members should be familiar with the safety rules in order that they may correct their abuse or infraction in the field.
5. The safety subcommittee should secure safety suggestions from their fellow workers in the Bureau. These safety suggestions play an important part in the prevention of accidents and in creating safer working conditions for the employees. The men in the field should therefore submit suggestions to the subcommittee members freely. The number of suggestions submitted constitutes a very good indication of the zeal of the members of the subcommittee in the discharge of their duties.
6. A report of the results of the day's activities and the safety suggestions submitted should be made out on forms provided for that purpose by the Safety Engineering Bureau.
7. The subcommittee is charged with the classification of accident reports for their Bureau. This duty should be performed in a conscientious manner in order to avoid injustice to the injured employee by a wrong classification. These classifications should be settled upon only after a personal consultation with the injured employee. The purpose of this classification of accidents is two-fold. First, to get more details concerning the facts of the accident and the circumstances surrounding it at the time, and secondly, to obtain the opinion of fellow employees working in the same lines of work concerning the cause of the accident for the benefit of the Safety Engineering Bureau and the company. It should be recognized by the subcommittee members that in applying this code to the accident reports it becomes apparent that accidents do not happen, they are caused. Every accident is an indication of inefficiency either on the part of the injured employee, his fellow employee or in the manner of conducting the work in the process of which the accident occurred.

Special Work Assignments to Subcommittees

These special work assignments are to be agreed upon jointly by the Bureau supervisor and representative of the Safety Engineering Bureau for the purpose of attending to particular situations which may exist in the field. Particular attention should be given to these by the subcommittee members as they may be most productive of good for the employees themselves.

Educational Aspects of Safety Committee Work

The purpose of these subcommittees and especially the rotation of subcommittee members is also to educate the individual employees to a realization of the importance and necessity for intelligent effort to prevent accidents.



ELECTRICAL CONSTRUCTION BUREAU

FOREMAN'S REPORT OF UNSAFE

PRACTICES CORRECTED

HAZARDS REMOVED

Date ____________

Division ____________

I have corrected the following unsafe practices:

Description of unsafe practices

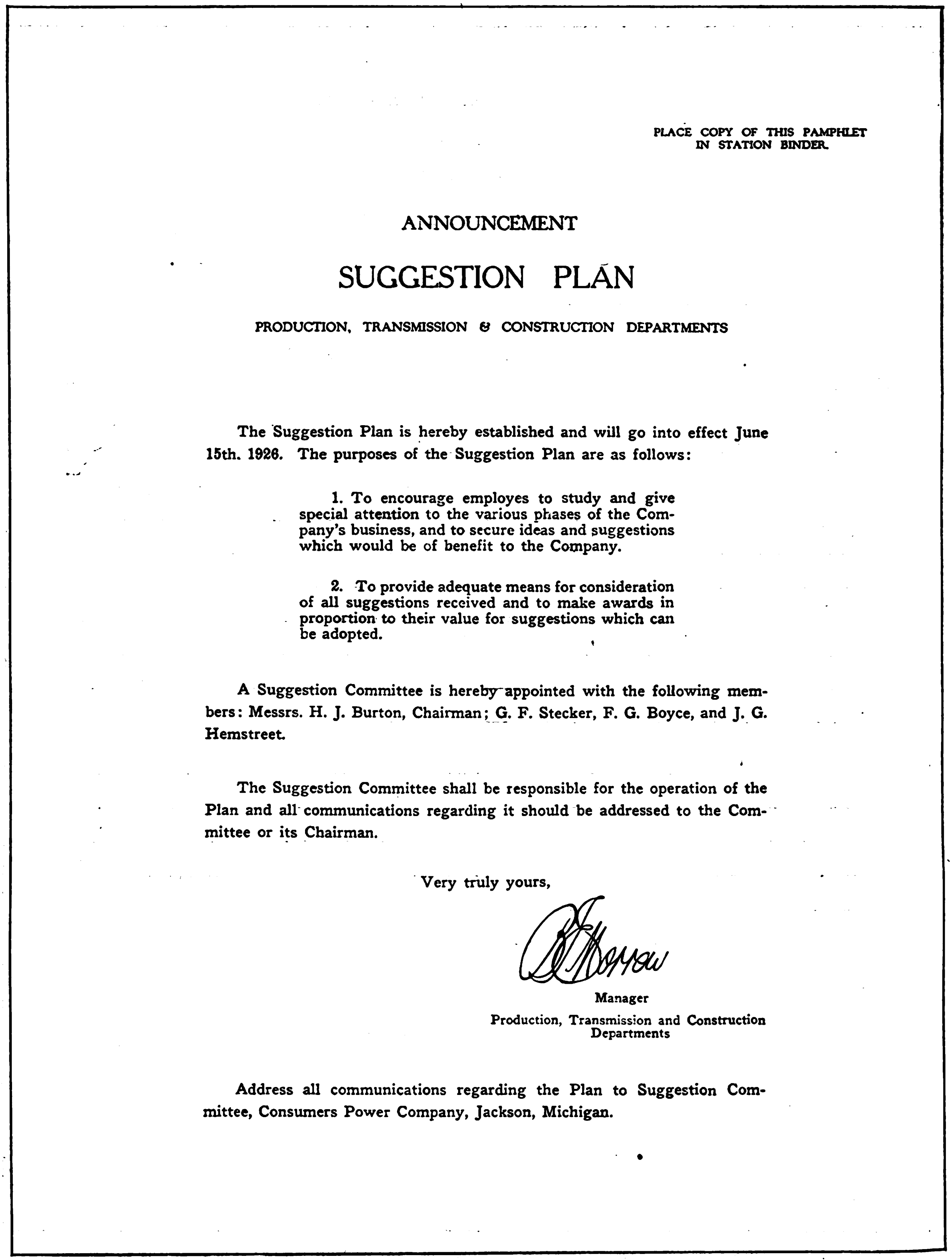
How Remedied ____________

Division Head ____________

Section Head ____________

(This report to be submitted monthly to Electrical Construction Engineer)

FIG. 2—Form of Foreman's Report on Removal of Hazards—Brooklyn Edison Company.



PLACE COPY OF THIS PAMPHLET
IN STATION BINDER.

ANNOUNCEMENT

SUGGESTION PLAN

PRODUCTION, TRANSMISSION & CONSTRUCTION DEPARTMENTS

The Suggestion Plan is hereby established and will go into effect June 15th. 1926. The purposes of the Suggestion Plan are as follows:

1. To encourage employes to study and give special attention to the various phases of the Company's business, and to secure ideas and suggestions which would be of benefit to the Company.

2. To provide adequate means for consideration of all suggestions received and to make awards in proportion to their value for suggestions which can be adopted.

A Suggestion Committee is hereby appointed with the following members: Messrs. H. J. Burton, Chairman; G. F. Stecker, F. G. Boyce, and J. G. Hemstreet.

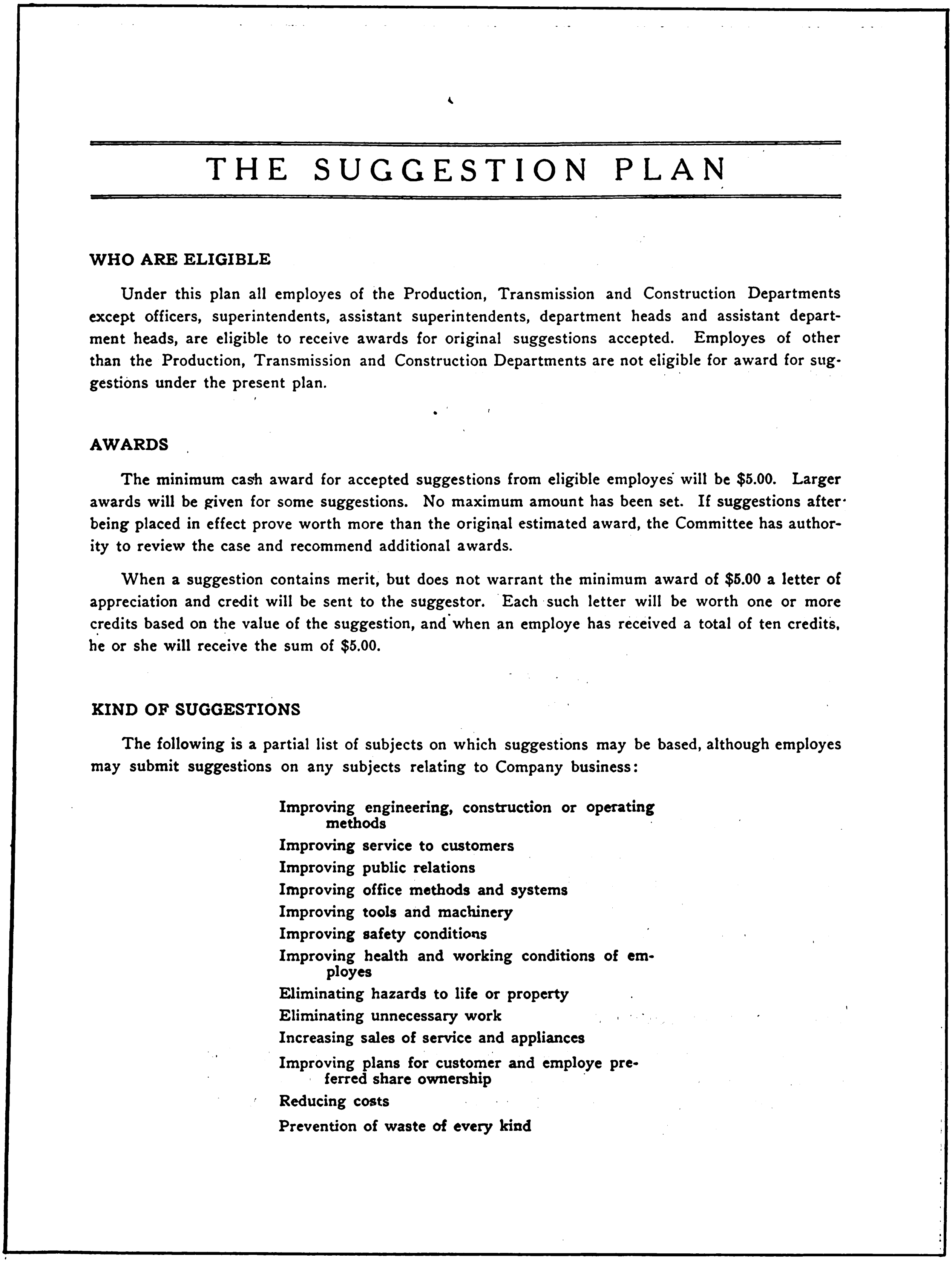
The Suggestion Committee shall be responsible for the operation of the Plan and all communications regarding it should be addressed to the Committee or its Chairman.

Very truly yours,

Manager
Production, Transmission and Construction
Departments

Address all communications regarding the Plan to Suggestion Committee, Consumers Power Company, Jackson, Michigan.

FIG. 3—PAGE 1—SUGGESTION PLAN ANNOUNCEMENT—CONSUMERS POWER COMPANY.



THE SUGGESTION PLAN

WHO ARE ELIGIBLE

Under this plan all employes of the Production, Transmission and Construction Departments except officers, superintendents, assistant superintendents, department heads and assistant department heads, are eligible to receive awards for original suggestions accepted. Employes of other than the Production, Transmission and Construction Departments are not eligible for award for suggestions under the present plan.

AWARDS

The minimum cash award for accepted suggestions from eligible employes will be $5.00. Larger awards will be given for some suggestions. No maximum amount has been set. If suggestions after being placed in effect prove worth more than the original estimated award, the Committee has authority to review the case and recommend additional awards.

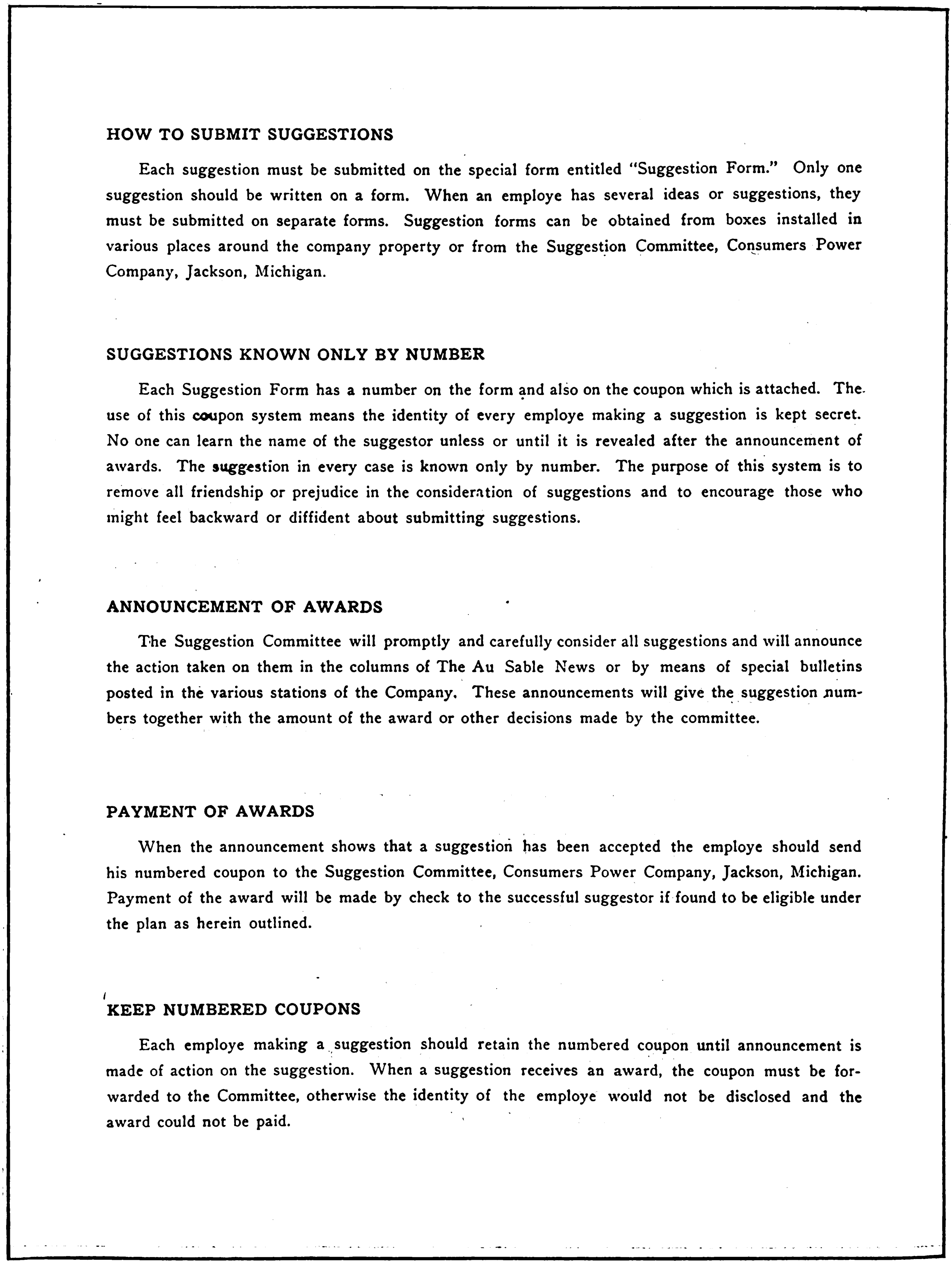
When a suggestion contains merit, but does not warrant the minimum award of $5.00 a letter of appreciation and credit will be sent to the suggestor. Each such letter will be worth one or more credits based on the value of the suggestion, and when an employe has received a total of ten credits, he or she will receive the sum of $5.00.

KIND OF SUGGESTIONS

The following is a partial list of subjects on which suggestions may be based, although employes may submit suggestions on any subjects relating to Company business:

Improving engineering, construction or operating methods
Improving service to customers
Improving public relations
Improving office methods and systems
Improving tools and machinery
Improving safety conditions
Improving health and working conditions of employes
Eliminating hazards to life or property
Eliminating unnecessary work
Increasing sales of service and appliances
Improving plans for customer and employe preferred share ownership
Reducing costs
Prevention of waste of every kind

FIG. 4—PAGE 2—SUGGESTION PLAN ANNOUNCEMENT—CONSUMERS POWER COMPANY.



HOW TO SUBMIT SUGGESTIONS

Each suggestion must be submitted on the special form entitled "Suggestion Form." Only one suggestion should be written on a form. When an employe has several ideas or suggestions, they must be submitted on separate forms. Suggestion forms can be obtained from boxes installed in various places around the company property or from the Suggestion Committee, Consumers Power Company, Jackson, Michigan.

SUGGESTIONS KNOWN ONLY BY NUMBER

Each Suggestion Form has a number on the form and also on the coupon which is attached. The use of this coupon system means the identity of every employe making a suggestion is kept secret. No one can learn the name of the suggestor unless or until it is revealed after the announcement of awards. The suggestion in every case is known only by number. The purpose of this system is to remove all friendship or prejudice in the consideration of suggestions and to encourage those who might feel backward or diffident about submitting suggestions.

ANNOUNCEMENT OF AWARDS

The Suggestion Committee will promptly and carefully consider all suggestions and will announce the action taken on them in the columns of The Au Sable News or by means of special bulletins posted in the various stations of the Company. These announcements will give the suggestion numbers together with the amount of the award or other decisions made by the committee.

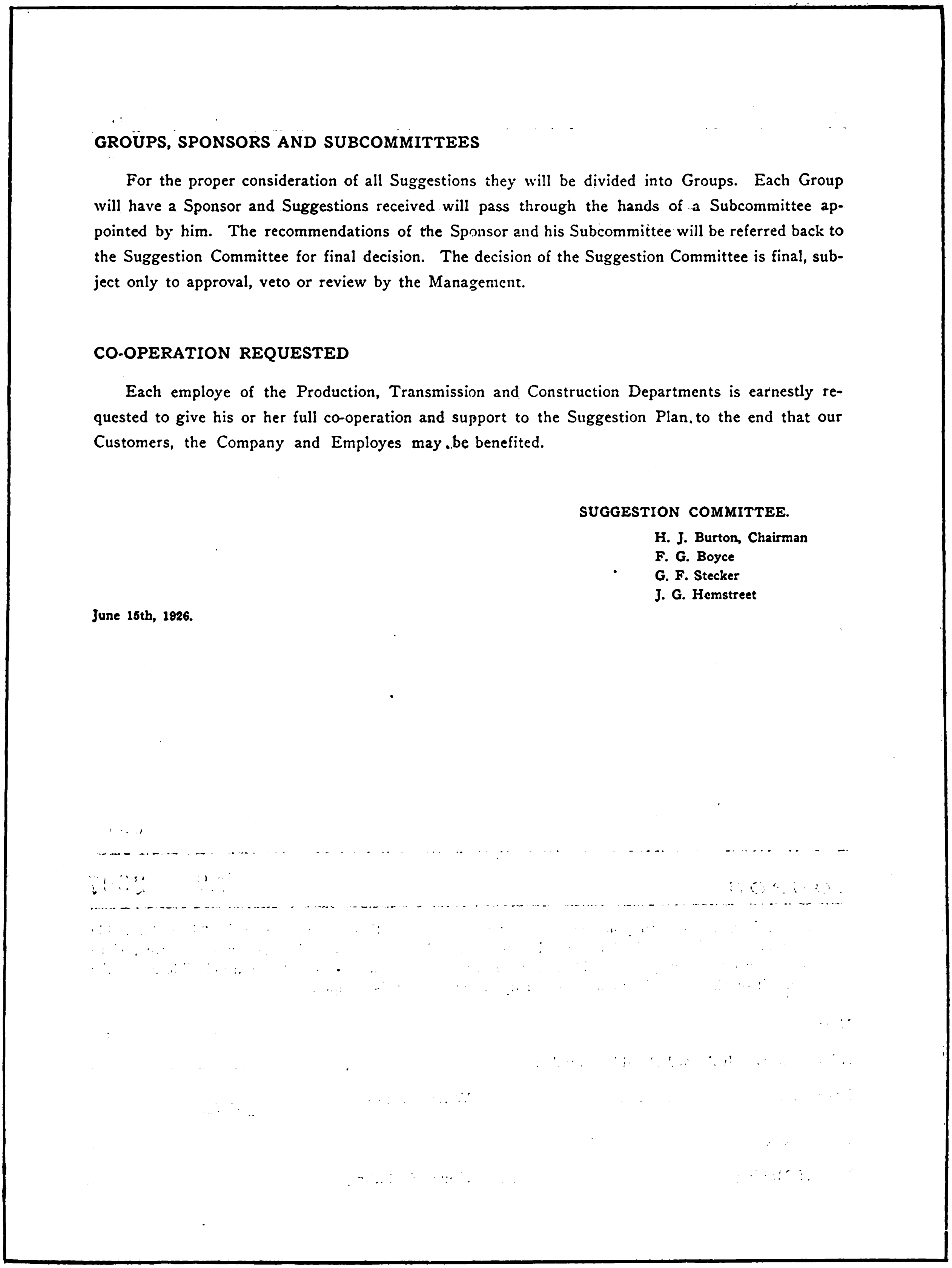
PAYMENT OF AWARDS

When the announcement shows that a suggestion has been accepted the employe should send his numbered coupon to the Suggestion Committee, Consumers Power Company, Jackson, Michigan. Payment of the award will be made by check to the successful suggestor if found to be eligible under the plan as herein outlined.

KEEP NUMBERED COUPONS

Each employe making a suggestion should retain the numbered coupon until announcement is made of action on the suggestion. When a suggestion receives an award, the coupon must be forwarded to the Committee, otherwise the identity of the employe would not be disclosed and the award could not be paid.

FIG. 5—PAGE 3—SUGGESTION PLAN ANNOUNCEMENT—CONSUMERS POWER COMPANY.



GROUPS, SPONSORS AND SUBCOMMITTEES

For the proper consideration of all Suggestions they will be divided into Groups. Each Group will have a Sponsor and Suggestions received will pass through the hands of a Subcommittee appointed by him. The recommendations of the Sponsor and his Subcommittee will be referred back to the Suggestion Committee for final decision. The decision of the Suggestion Committee is final, subject only to approval, veto or review by the Management.

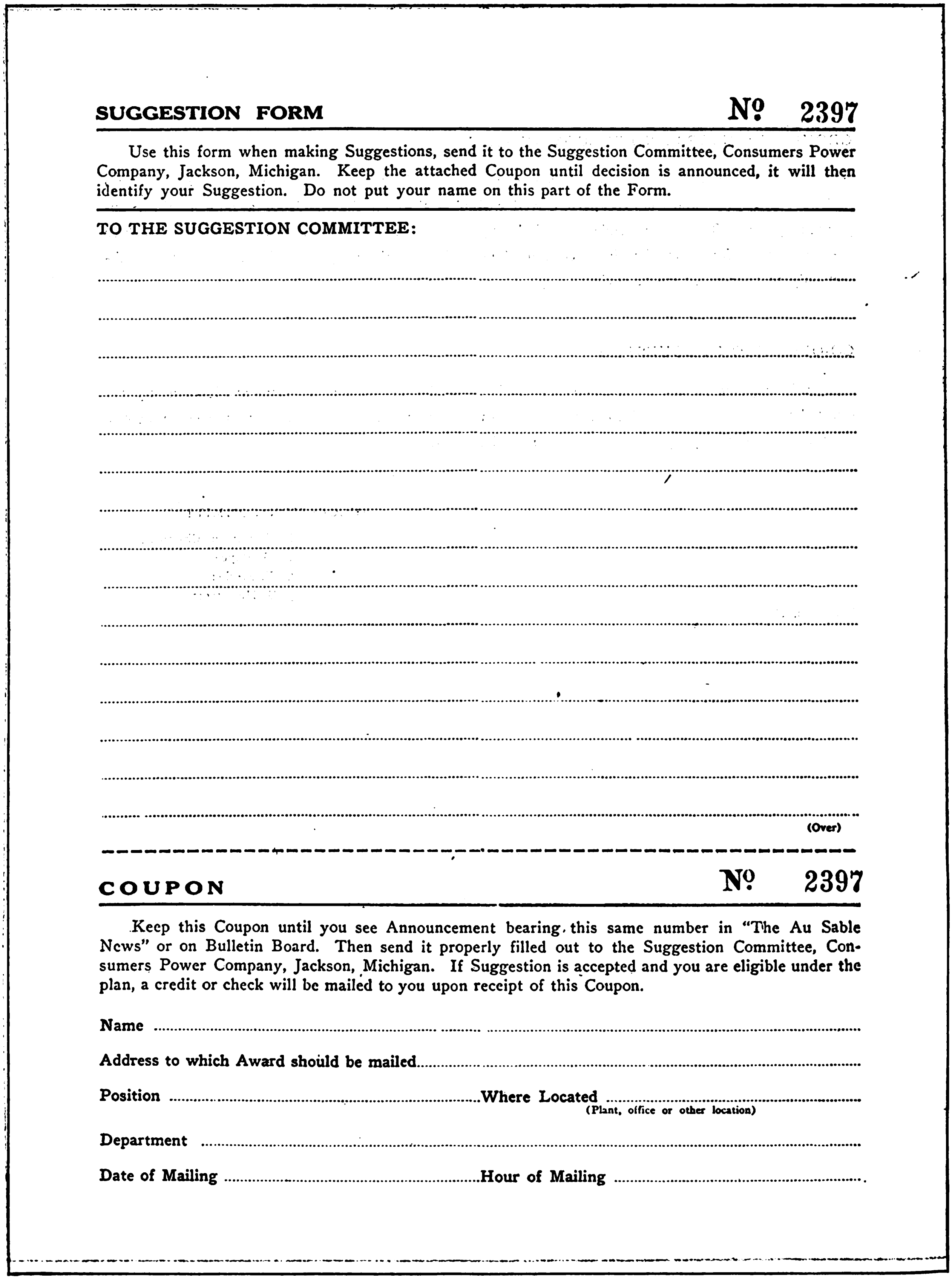
CO-OPERATION REQUESTED

Each employe of the Production, Transmission and Construction Departments is earnestly requested to give his or her full co-operation and support to the Suggestion Plan to the end that our Customers, the Company and Employes may be benefited.

SUGGESTION COMMITTEE.
H. J. Burton, Chairman
F. G. Boyce
G. F. Stecker
J. G. Hemstreet

June 15th, 1926.

FIG. 6—PAGE 4—SUGGESTION PLAN ANNOUNCEMENT—CONSUMERS POWER COMPANY.



SUGGESTION FORM **Nº 2397**

Use this form when making Suggestions, send it to the Suggestion Committee, Consumers Power Company, Jackson, Michigan. Keep the attached Coupon until decision is announced, it will then identify your Suggestion. Do not put your name on this part of the Form.

TO THE SUGGESTION COMMITTEE:

(Over)

COUPON **Nº 2397**

Keep this Coupon until you see Announcement bearing this same number in "The Au Sable News" or on Bulletin Board. Then send it properly filled out to the Suggestion Committee, Consumers Power Company, Jackson, Michigan. If Suggestion is accepted and you are eligible under the plan, a credit or check will be mailed to you upon receipt of this Coupon.

Name ....

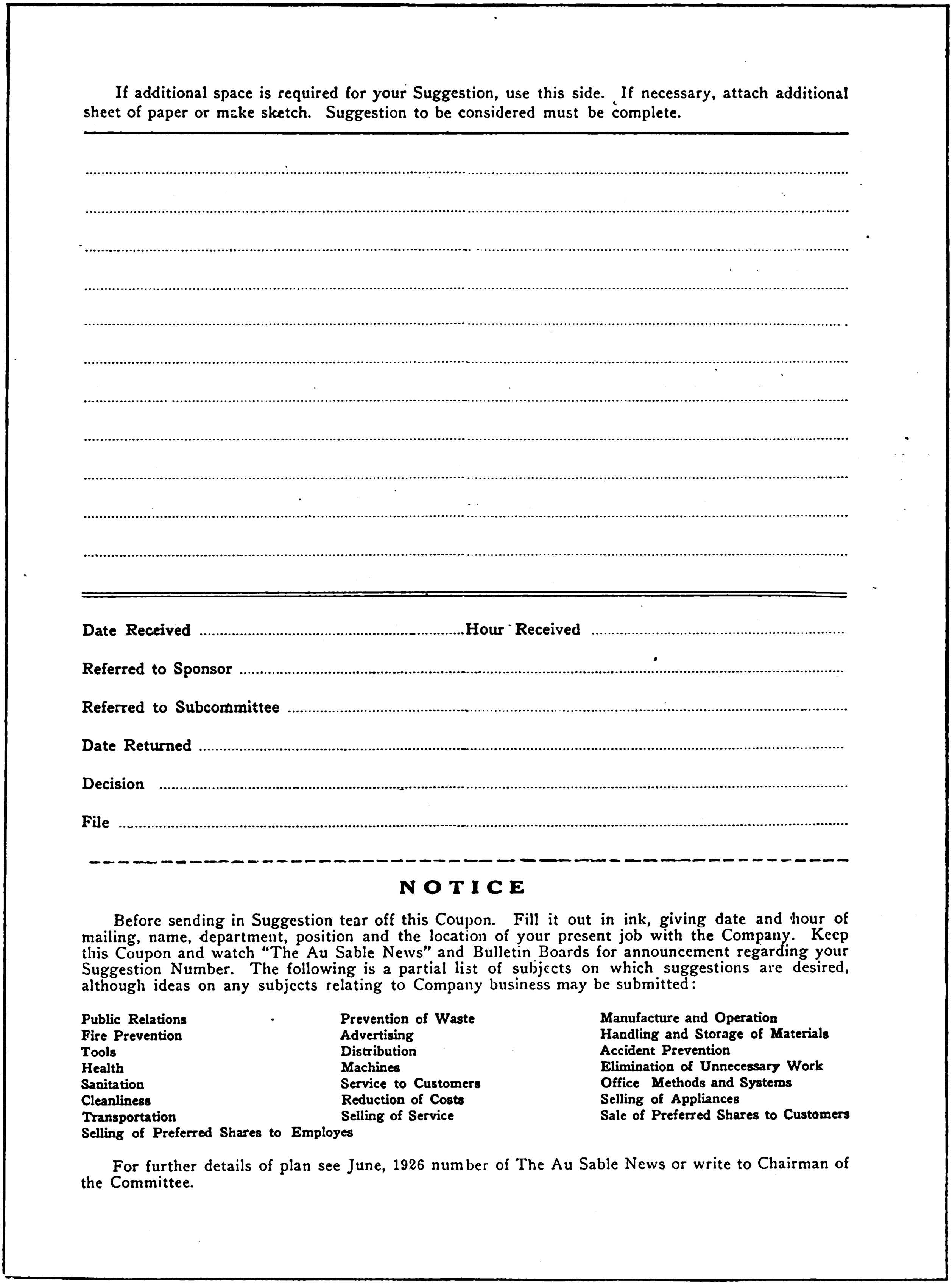
Address to which Award should be mailed..............................

Position ....**Where Located** ....
(Plant, office or other location)

Department ....

Date of Mailing ....**Hour of Mailing** ....

FIG. 7—PAGE 1—SUGGESTION FORM—CONSUMERS POWER COMPANY.



If additional space is required for your Suggestion, use this side. If necessary, attach additional sheet of paper or make sketch. Suggestion to be considered must be complete.

Date Received .... Hour Received ....

Referred to Sponsor ....

Referred to Subcommittee ....

Date Returned ....

Decision ....

File ....

NOTICE

Before sending in Suggestion tear off this Coupon. Fill it out in ink, giving date and hour of mailing, name, department, position and the location of your present job with the Company. Keep this Coupon and watch "The Au Sable News" and Bulletin Boards for announcement regarding your Suggestion Number. The following is a partial list of subjects on which suggestions are desired, although ideas on any subjects relating to Company business may be submitted:

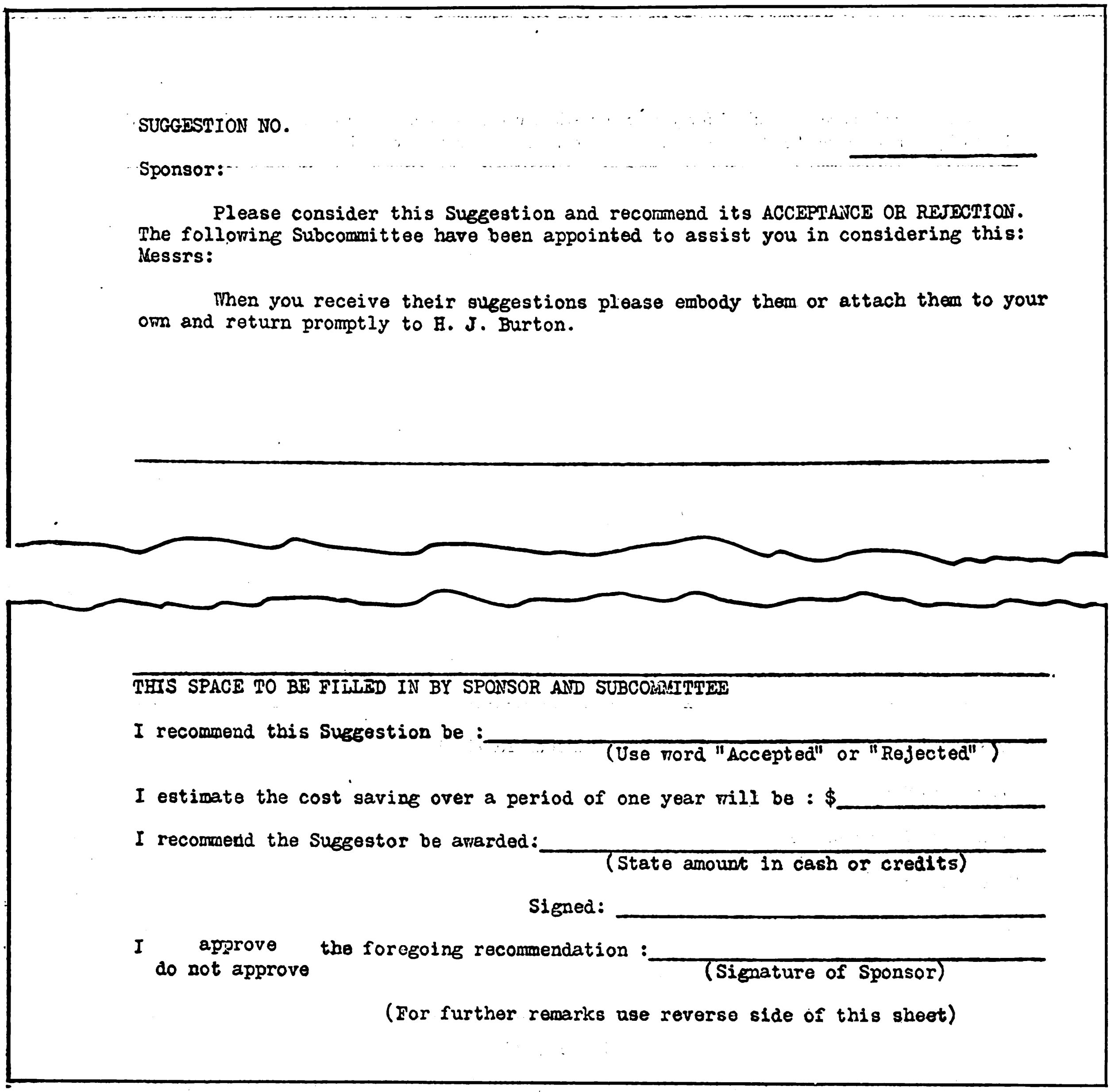
Public Relations
Fire Prevention
Tools
Health
Sanitation
Cleanliness
Transportation
Selling of Preferred Shares to Employes

Prevention of Waste
Advertising
Distribution
Machines
Service to Customers
Reduction of Costs
Selling of Service

Manufacture and Operation
Handling and Storage of Materials
Accident Prevention
Elimination of Unnecessary Work
Office Methods and Systems
Selling of Appliances
Sale of Preferred Shares to Customers

For further details of plan see June, 1926 number of The Au Sable News or write to Chairman of the Committee.

FIG. 8—PAGE 2—SUGGESTION FORM—CONSUMERS POWER COMPANY.



SUGGESTION NO.

Sponsor:

Please consider this Suggestion and recommend its ACCEPTANCE OR REJECTION. The following Subcommittee have been appointed to assist you in considering this: Messrs:

When you receive their suggestions please embody them or attach them to your own and return promptly to H. J. Burton.

THIS SPACE TO BE FILLED IN BY SPONSOR AND SUBCOMMITTEE

I recommend this Suggestion be :______ (Use word "Accepted" or "Rejected")

I estimate the cost saving over a period of one year will be : $______

I recommend the Suggestor be awarded:______ (State amount in cash or credits)

Signed: ______

I approve / do not approve the foregoing recommendation :______ (Signature of Sponsor)

(For further remarks use reverse side of this sheet)

FIG. 9—RECOMMENDATION FORM FOR USE BY SPONSOR AND SUBCOMMITTEE—CONSUMERS POWER COMPANY.

THE GENERAL ELECTRIC COMPANY

Suggestion System

In discussing the General Electric suggestion system it might be well to go into the history of the system somewhat, in order to give an idea of the reasons for its origination and to convey some idea of its background.

The first suggestion committee of the General Electric Company was appointed at Schenectady to take care of ideas originated by the men which formerly had gone directly to the manager or to his staff. These things went there because the men originating them were not satisfied with having anyone of less importance consider them. Taking care of this work was a burden and the manager, in order to relieve himself of this necessity, created the suggestion committee. When it first began to function it was a job assigned to various individuals who were to devote part of their time to the work. The meetings were irregular, sometimes months passing between meetings. It was looked upon by everyone as a sort of nuisance to be tolerated but not encouraged. A great deal of dissatisfaction was caused among the men due to the fact that no effective check was made on the reports rendered by the superintendents to the committee. Their word was practically final.

The committee was not very well known among the men, no advertising being used in order to sell the idea and no very definite stamp of approval was placed upon it by the management. Therefore all opposition to the suggestion system was quite open and active.

The changes which were made in order to bring the system into respect and make it effective were not changes of principle so much as changes of routine and personnel. The management gave its whole-souled support and chose men for work on the committee who were particularly suited for duties of that sort, and an advertising campaign was started to make the system well known and to encourage the men to use it. Meetings were held regularly, occurring once each week whether there was much business to be done or not; and an effective check was made on the reports of final decisions of the committee. With these changes and a general increase in the efficiency of handling suggestions, renewed interest on the part of the men was manifest, and from then on, the growth of the suggestion system has been gradual and normal.

It should be borne in mind that the above conditions prevailed as recently as six or seven years ago. The present "new" system, therefore, is not very many years old.

So much for the early history of the suggestion system—it is but a short step to present conditions.

To begin with, it should be noted that the company does not follow a standard practice in all its different works. Unification of this work has recently been undertaken and satisfactory progress is being made toward standardization along the lines which, from this company's experience, appear to represent the best practice. The outline which follows covers the general principles upon which the General Electric system as a whole is based, but special reference is made to Schenectady practice since it is the largest works.

Suggestion Boxes

In the first place, suggestion boxes are installed at convenient points throughout the factory and offices. At first they were located in out-of-the-way places on the supposition that employees were rather sheepish about offering suggestions. This was not found to be the case, however. Placing the boxes near exits, time clocks, bulletin boards and drinking fountains has been found to be more effective. The number of boxes provided approximates one for every 200 employees in our large plants, and one for every 100 employees in our small plants. The type of box recently adopted as standard is shown in the accompanying illustration, the dimensions of the bulletin board behind the box being about 18 in. wide with the other dimensions in proportion, as shown. (See Fig. 10.)

A great variety of boxes was tried out, ranging from the familiar metal rural delivery box to a simple wooden box of about the size and shape of the box proper, as shown in the illustration. The most satisfactory form is that shown in which the box is mounted on a back board which provides a rack for display of advertising cards, one for envelopes already addressed to the suggestion committee, another for cards requesting a personal interview (for use by suggestors who can not express themselves well in writing) and another for a pad of suggestion blanks upon which suggestions may be written.

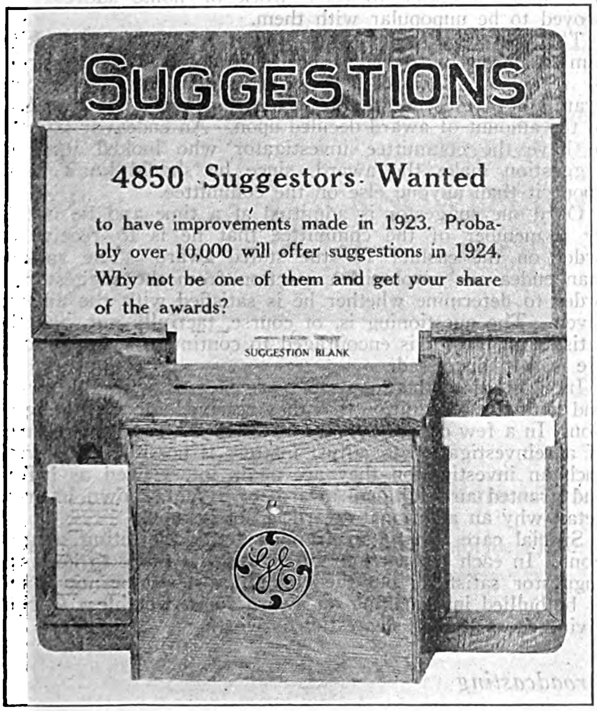

SUGGESTIONS
4850 Suggestors Wanted
to have improvements made in 1923. Probably over 10,000 will offer suggestions in 1924.
Why not be one of them and get your share of the awards?
SUGGESTION BLANK

FIG. 10—SUGGESTION BOX—GENERAL ELECTRIC COMPANY.

Advertising

Too much emphasis can not be placed upon the value of the advertising posters which are placed on the boxes. These have been found so valuable in stimulating interest in the suggestion system that the company has arranged a standardized service to provide uniform cards to all works with a monthly change of copy. In these cards an endeavor is made to avoid sermonizing and dry reading. To provide conspicuous cards which will agreeably contrast with the general run of shop notices use is made of colored cards, employing catchy illustrations and type treatment along the same lines as the street car cards. Interest in the system is also maintained by publishing suggestion news in the several works' papers and by talks on this subject by company officials.

Advertising pressure is kept up constantly and the problem must be tackled from every possible angle in order to break down prejudice, overcome supervisory opposition and most of all, overcome inertia and indifference. The object of advertising is not merely to obtain suggestions, but to obtain *good* suggestions. The committee desires to avoid being swamped with a large number of trivial suggestions.

Collections

In the Schenectady works, members of the patrol department make semi-weekly visits to the various boxes to gather the accumulated suggestions which they turn over to the suggestion committee secretary. In some other plants these collections are made by some member of the committee. In no case are collections made less frequently than once a week.

Classifications

When suggestions are received from the collector by the suggestion committee secretary he classifies them according to his filing system. This is generally straight numerical filing in which the suggestions are consecutively numbered in the order in which they are received. Each suggestion is also stamped with the date of its receipt, is recorded by number, name of suggestor and sometimes by title of suggestion, and is then turned over to the department concerned for investigation.

Investigation

The department head appoints a man to investigate the suggestion, who is usually a member of his own staff. In the investigation this man always makes an effort to interview the suggestor in order to make sure that he understands what the suggestor has in mind. The report which he renders states whether or not it will be adopted and if it is possible to estimate savings, a savings figure is given. If not, he recommends an award to be given. From the department, the suggestion goes back to the committee secretary, who then refers it to one of his own investigators for reinvestigating and reporting to the committee. If the committee investigator finds the recommendation of the department adequate and fair, he disposes of the rejections courteously and with great care by a personal interview with the suggestor; those adopted he brings before the committee with a full description of all details and a recommendation of the size of the award. If the committee investigator deos not find sufficient reason for rejection, he takes the matter up with the department investigator. He likewise does the same thing in the event that the saving or the recommended award is not adequate. In all cases the suggestion committee and the department come to an agreement in regard to a suggestion. One always convinces the other.

From this it will be readily appreciated that the ability and personality of the secretary and investigators is a great factor in the success of the system. A great deal of responsibility is placed on their shoulders. It is their duty to keep the men satisfied and inspire their confidence. They give the system its personality in the eyes of the men. A good secretary and efficient investigators are probably the biggest single factors in its success.

Antagonism from some of the men in supervisory positions was at first experienced. This has been largely overcome by repeated declarations from the management that suggestions are desirable and regarded as an indication of a department's progressiveness. Employees are encouraged to have faith in their superiors and to enlist their cooperation in attempting to make their suggestions successful.

When possible the investigator obtains samples embodying the suggestion. Savings figures are obtained from the cost department whenever possible, since the awards granted for adopted suggestions are always based upon estimated savings when these are determinable.

Many kinds of suggestions are received representing improvements in design, convenience, safeguards, and improvements in manufacturing methods. Some of these suggestions effect a determinable saving by reducing the cost of manufactured parts; others by improving shop equipment for producing parts. Still other suggestions, such as those relating to safety appliances, conveniences of employees, improvement of products and the like, do not always permit the determination of their cash value. In such cases, the award is based upon an estimate of the importance of the suggestion.

Even where an actual saving can be determined, the award varies according to the ingenuity and effort required of the suggestor. Obviously, a suggestor who effects a saving of several thousand dollars a year by substituting a punched part for a molded one does not spend the effort required of the suggestor who on his own time and at his own expense produces an ingenious device upon which production is small.

It should be noted that the adoption of a suggestion, or rather the granting of an award, is not necessarily based upon the absolute originality of the idea. It does not have to be an invention or a startling innovation. The fact that not more than five out of the five thousand suggestions received at Schenectady in 1928 were patentable will serve to illustrate this point. It may even be a thing which has been suggested before but, due to negligence on the part of supervisors, has not been applied wherever possible.

At this point it will be well to explain that obviously impractical suggestions are rejected by the secretary without being referred to the department concerned. It should also be noted that the usual practice is to exclude salaried executives, engineers and draftsmen when making awards. Their suggestions are received and acted upon and then called to the attention of the heads of their departments or their supervisors.

Committee

As stated, the adopted suggestions are turned over to the suggestion committee. This committee usually consists of a permanent secretary (who, in the larger plants, devotes his entire time to this work), a permanent chairman, or a chairmanship rotated among the committee members, and four or more additional members generally taken from the manufacturing organization.

The committee membership generally comprises manufacturing executives, such as the electrical and mechanical superintendents, etc., together with any special investigators who devote their entire time to the suggestion work. It has been found good practice to include in the committee a member familiar with electrical engineering, one familiar with electrical operation or testing, one skilled in mechanical design and machine shop practice and possessing a good knowledge of machine tools, and a cost man to determine savings. In some of the General Electric Company's works, where there is an employee's council, the employees are permitted to select representatives to act with the suggestion committees in passing upon suggestions.

Meetings

Considerable importance is attached to the speed with which the suggestions are handled. Best results follow when a suggestion can be completely disposed of within one month. This time is always aimed at although there are many suggestions which require greater time for a verification of their worth. In order to keep the time at a minimum, however, most of the committees meet once each week on a specified day. The first business is to hear the secretary's report of the number of suggestions received during the week, number reported upon, number awaiting investigation and the number pending (awaiting test requiring time) in order to check operation or saving. Following this, the awards granted a year previously are reviewed to see whether the suggestor received a sufficient award as determined by the year's operation. Where it seems desirable, figures are obtained and a supplementary award is granted to adjust compensation to its proper value.

A report of the pending suggestions is then made if the time determined for them has elapsed. If complete information permits, their consideration follows, and the awards are determined for those which have been adopted. The committee then considers new suggestions. These are read by the secretary or some other member of the committee and each in turn passed upon and awarded upon its merits. The awards average approximately 10 per cent of the estimated savings for the first year.

Awards

The final act is to interview the successful suggestors of the preceding week and issue the awards in the form of cash orders, payable on presentation to the cashier. For large awards suggestors may choose to take Employee's Investment Bonds in multiples of $10. In this case their bonds are mailed to them, but the practice of mailing checks to employees either to their work or home address has proved to be unpopular with them.

The secretary writes each successful suggestor asking him to appear on a certain day the following week in order to receive his award. The notifications contain a congratulatory reference to the suggestion and a statement as to the amount of award decided upon. An endeavor is made to have the committee investigator who looked into the suggestion make the award, since he should know more about it than anyone else on the committee.

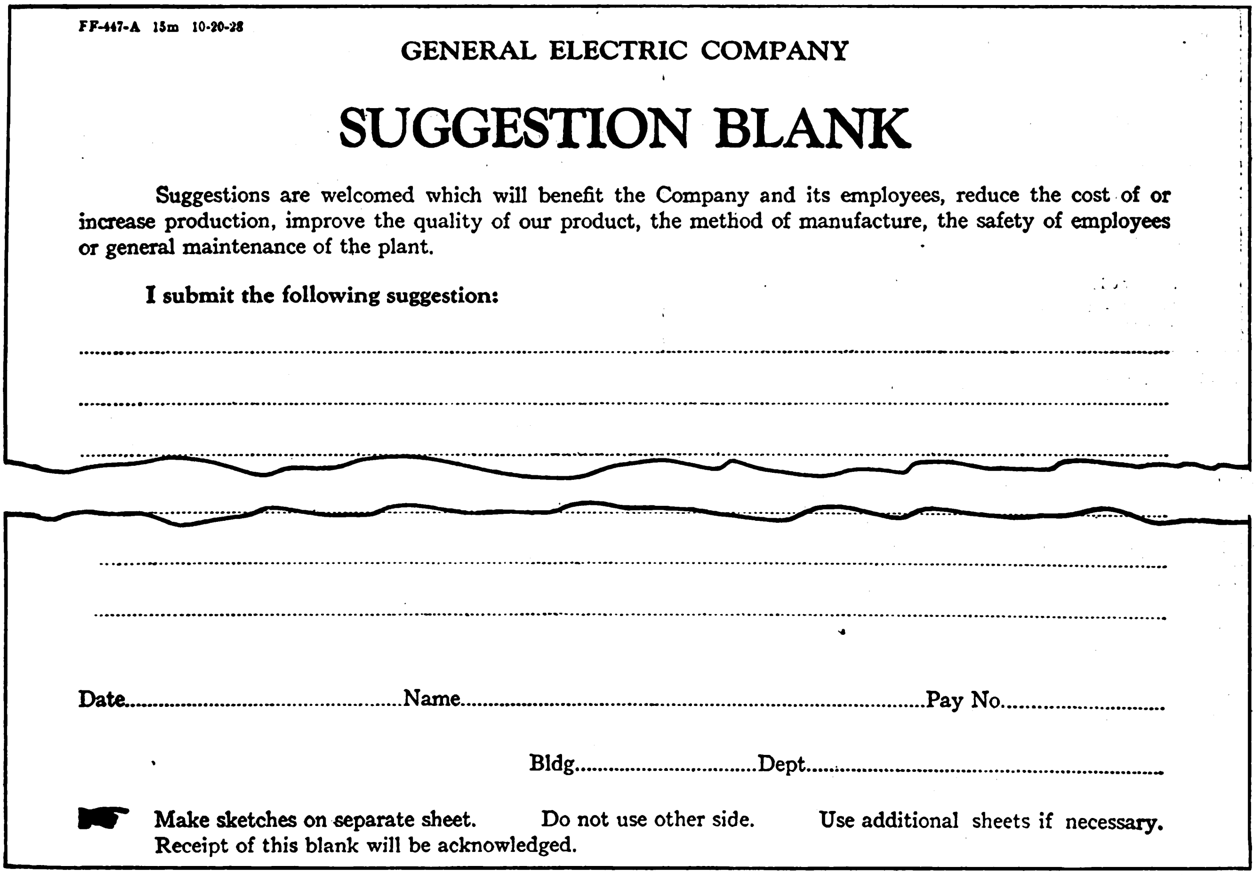
Only one suggestor is admitted at a time and he is told by a member of the committee that he is to receive an order on the cashier for the stated award. The spokesman endeavors to obtain a reaction from the suggestor in order to determine whether he is satisfied with the amount given. The questioning is, of course, tactfully put, and the satisfied suggestor is encouraged to continue the good work. He is then dismissed.

In most cases the suggestors are pleased with the award and with the recognition that they received for their suggestions. In a few cases, they are dissatisfied. These are assured of a reinvestigation to adjust matters if possible. Following such an investigation they are again interviewed as before and granted an additional award, or, if not, shown in great detail why an additional award is not granted.

Special care is used in framing letters rejecting suggestions. In each transaction, an endeavor is made to keep the suggestor satisfied; but the committee never permits itself to be bullied into making an award for a worthless idea or giving more than a suggestion is worth.

Broadcasting

In order that the suggestion committees may follow a more or less standardized practice, a man in the manufacturing



FF-447-A 15m 10-20-28

GENERAL ELECTRIC COMPANY

SUGGESTION BLANK

Suggestions are welcomed which will benefit the Company and its employees, reduce the cost of or increase production, improve the quality of our product, the method of manufacture, the safety of employees or general maintenance of the plant.

I submit the following suggestion:

....

....

....

....

....

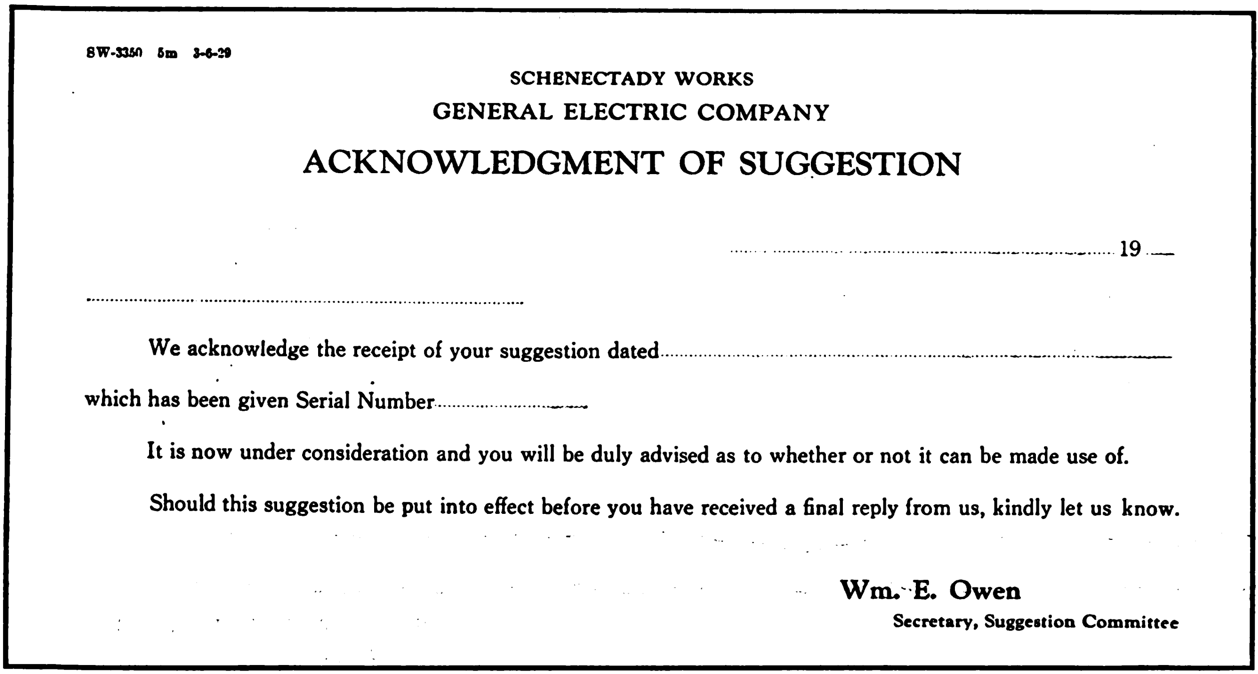
....

Date.............................Name..Pay No....................

Bldg.....................Dept...

☛ Make sketches on separate sheet. Do not use other side. Use additional sheets if necessary.
Receipt of this blank will be acknowledged.

FIG. 11—SUGGESTION FORM—GENERAL ELECTRIC COMPANY.



SW-3350 5m 3-6-29

SCHENECTADY WORKS
GENERAL ELECTRIC COMPANY
ACKNOWLEDGMENT OF SUGGESTION

....19....

....

We acknowledge the receipt of your suggestion dated..

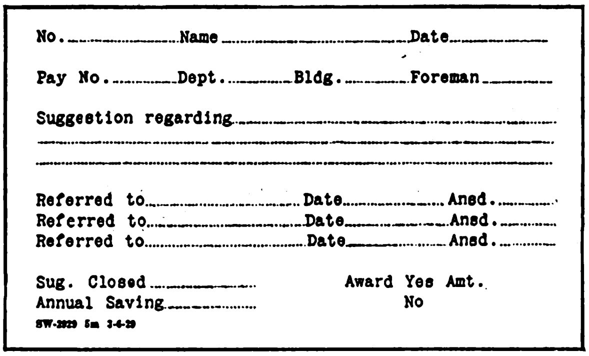
which has been given Serial Number....................

It is now under consideration and you will be duly advised as to whether or not it can be made use of.

Should this suggestion be put into effect before you have received a final reply from us, kindly let us know.

Wm. E. Owen
Secretary, Suggestion Committee

FIG. 12—ACKNOWLEDGMENT OF SUGGESTION FORM—GENERAL ELECTRIC COMPANY.


No. .... Name .... Date ....

Pay No. .... Dept. .... Bldg. .... Foreman ....

Suggestion regarding ....

Referred to .... Date .... Ansd. ....
Referred to .... Date .... Ansd. ....
Referred to .... Date .... Ansd. ....

Sug. Closed .... Award Yes Amt.
Annual Saving .... No
SW-3929 5m 3-4-29

FIG. 13—SUGGESTION CLASSIFICATION CARD—GENERAL ELECTRIC COMPANY.

general office is appointed, whose duties are those of a general secretary. He keeps in close contact with all committees by correspondence and by personal visits. It is his duty to do the general advertising and to lend assistance in helping individual committees out of their difficulties. Also, all suggestions of more than local interest are sent to his office for broadcasting to the other works in order that the greatest possible benefit may result from them.

If a suggestion which has been broadcast to all the works through these channels proves of considerable benefit, the suggestor is usually given an additional award based on these benefits.

Absolute fairness is the life of the system.

WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY

Suggestion System

The Westinghouse Electric & Manufacturing Company's suggestion scheme was put into effect about July 20, 1910. More than 32,500 suggestions have been received by all works of which number about 25 to 30 per cent have been adopted. A considerable number were vetoed, although meritorious, simply because the company was unable, for various reasons to make use of them. Details of the system are given in the accompanying illustrations showing form 3065, sketch C-7901 and shop-mail card. Fig. 16, 17 and 18.)

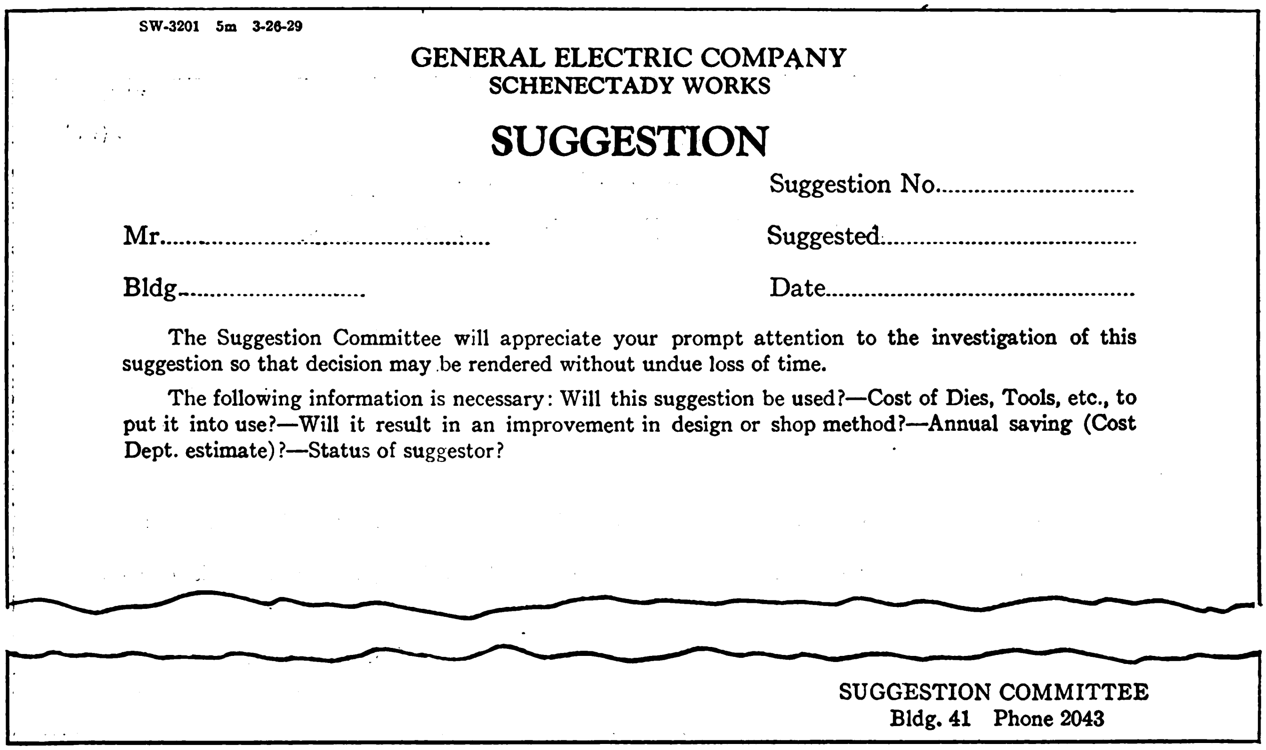
The estimated savings from individual suggestions have varied from zero to $20,000.00 per year, the awards being made on the basis shown in Table V. Many suggestions, however, while representing improvements involve an outlay of money so that payment on the basis of savings effected is not a practical scheme and the awards should accordingly be looked upon rather as prizes. The majority of the suggestions are small in value being in the $2.50 class; a lesser number in the $5.00 class, and so on.

It may be mentioned that the American Museum of Safety

TABLE V

Scale of Awards

$2.50	Suggestions which are neither original nor have appreciable money value yet which should be adopted, perhaps being modified before adoption, even when expense is involved.
$5.00	Suggestions which are not original but have appreciable money value difficult to estimate.
$10.00	Suggestions which are not original but have considerable money value estimated on an annual basis. Suggestions which are original but have no appreciable money value.
$15.00	Suggestions which are original and have considerable money value.
Above $15.00	Special.
$5.00	For first five suggestions accepted.
$10.00	For second five suggestions accepted.
$15.00	For third five suggestions accepted.
	And so on.


SW-3201 5m 3-26-29

GENERAL ELECTRIC COMPANY
SCHENECTADY WORKS

SUGGESTION

Suggestion No. ....

Mr. .... Suggested ....

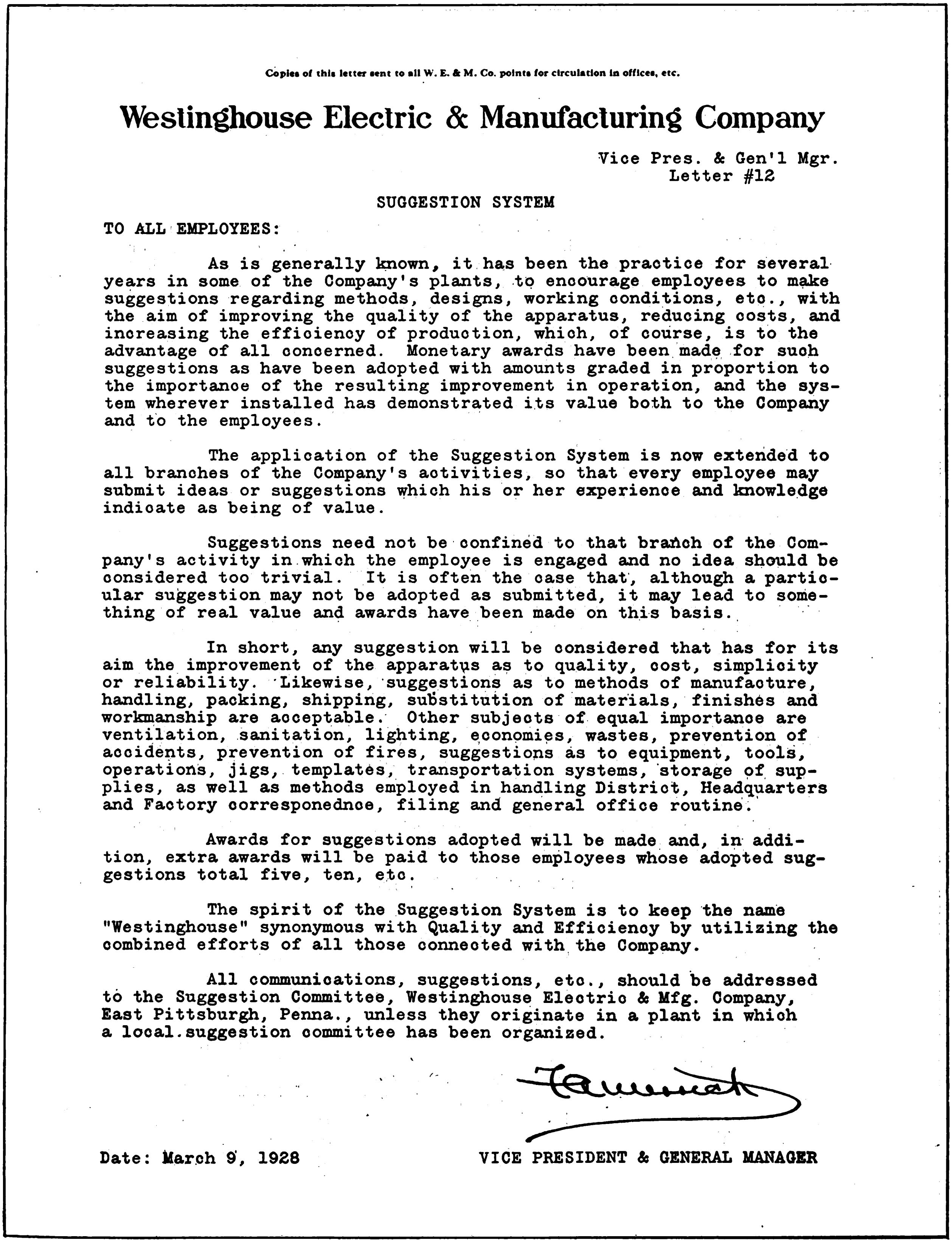
Bldg. .... Date ....

The Suggestion Committee will appreciate your prompt attention to the investigation of this suggestion so that decision may be rendered without undue loss of time.

The following information is necessary: Will this suggestion be used?—Cost of Dies, Tools, etc., to put it into use?—Will it result in an improvement in design or shop method?—Annual saving (Cost Dept. estimate)?—Status of suggestor?

SUGGESTION COMMITTEE
Bldg. 41 Phone 2043

FIG. 14—SUGGESTION INVESTIGATION FORM—GENERAL ELECTRIC COMPANY.



Copies of this letter sent to all W. E. & M. Co. points for circulation in offices, etc.

Westinghouse Electric & Manufacturing Company

Vice Pres. & Gen'l Mgr.
Letter #12

SUGGESTION SYSTEM

TO ALL EMPLOYEES:

As is generally known, it has been the practice for several years in some of the Company's plants, to encourage employees to make suggestions regarding methods, designs, working conditions, etc., with the aim of improving the quality of the apparatus, reducing costs, and increasing the efficiency of production, which, of course, is to the advantage of all concerned. Monetary awards have been made for such suggestions as have been adopted with amounts graded in proportion to the importance of the resulting improvement in operation, and the system wherever installed has demonstrated its value both to the Company and to the employees.

The application of the Suggestion System is now extended to all branches of the Company's activities, so that every employee may submit ideas or suggestions which his or her experience and knowledge indicate as being of value.

Suggestions need not be confined to that branch of the Company's activity in which the employee is engaged and no idea should be considered too trivial. It is often the case that, although a particular suggestion may not be adopted as submitted, it may lead to something of real value and awards have been made on this basis.

In short, any suggestion will be considered that has for its aim the improvement of the apparatus as to quality, cost, simplicity or reliability. Likewise, suggestions as to methods of manufacture, handling, packing, shipping, substitution of materials, finishes and workmanship are acceptable. Other subjects of equal importance are ventilation, sanitation, lighting, economies, wastes, prevention of accidents, prevention of fires, suggestions as to equipment, tools, operations, jigs, templates, transportation systems, storage of supplies, as well as methods employed in handling District, Headquarters and Factory corresponednce, filing and general office routine.

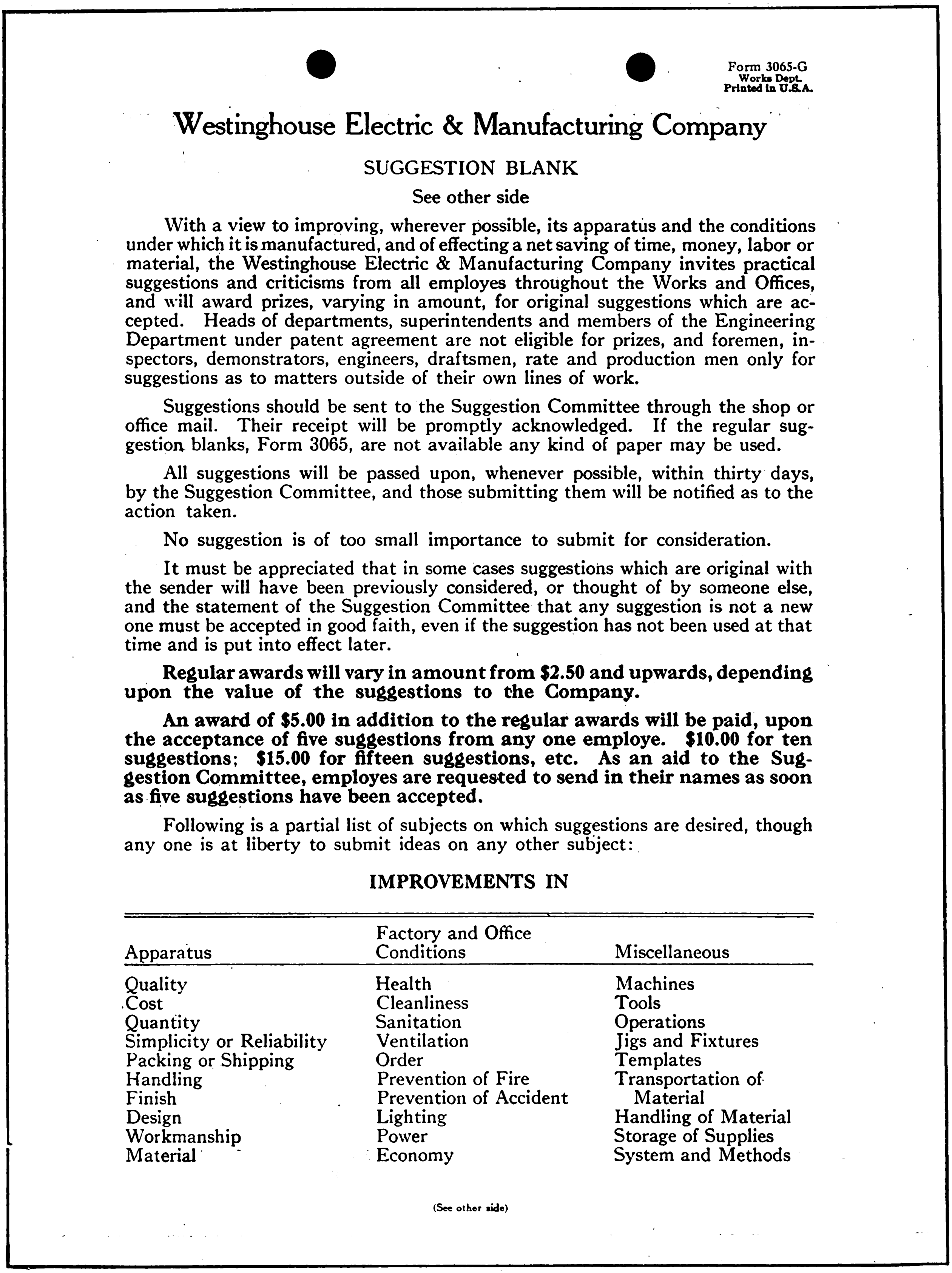
Awards for suggestions adopted will be made and, in addition, extra awards will be paid to those employees whose adopted suggestions total five, ten, etc.

The spirit of the Suggestion System is to keep the name "Westinghouse" synonymous with Quality and Efficiency by utilizing the combined efforts of all those connected with the Company.

All communications, suggestions, etc., should be addressed to the Suggestion Committee, Westinghouse Electric & Mfg. Company, East Pittsburgh, Penna., unless they originate in a plant in which a local suggestion committee has been organized.

Date: March 9, 1928 VICE PRESIDENT & GENERAL MANAGER

FIG. 15—SUGGESTION SYSTEM LETTER SENT TO ALL EMPLOYEES—WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY.



Form 3065-G
Works Dept.
Printed in U.S.A.

Westinghouse Electric & Manufacturing Company

SUGGESTION BLANK

See other side

With a view to improving, wherever possible, its apparatus and the conditions under which it is manufactured, and of effecting a net saving of time, money, labor or material, the Westinghouse Electric & Manufacturing Company invites practical suggestions and criticisms from all employes throughout the Works and Offices, and will award prizes, varying in amount, for original suggestions which are accepted. Heads of departments, superintendents and members of the Engineering Department under patent agreement are not eligible for prizes, and foremen, inspectors, demonstrators, engineers, draftsmen, rate and production men only for suggestions as to matters outside of their own lines of work.

Suggestions should be sent to the Suggestion Committee through the shop or office mail. Their receipt will be promptly acknowledged. If the regular suggestion blanks, Form 3065, are not available any kind of paper may be used.

All suggestions will be passed upon, whenever possible, within thirty days, by the Suggestion Committee, and those submitting them will be notified as to the action taken.

No suggestion is of too small importance to submit for consideration.

It must be appreciated that in some cases suggestions which are original with the sender will have been previously considered, or thought of by someone else, and the statement of the Suggestion Committee that any suggestion is not a new one must be accepted in good faith, even if the suggestion has not been used at that time and is put into effect later.

Regular awards will vary in amount from $2.50 and upwards, depending upon the value of the suggestions to the Company.

An award of $5.00 in addition to the regular awards will be paid, upon the acceptance of five suggestions from any one employe. $10.00 for ten suggestions; $15.00 for fifteen suggestions, etc. As an aid to the Suggestion Committee, employes are requested to send in their names as soon as five suggestions have been accepted.

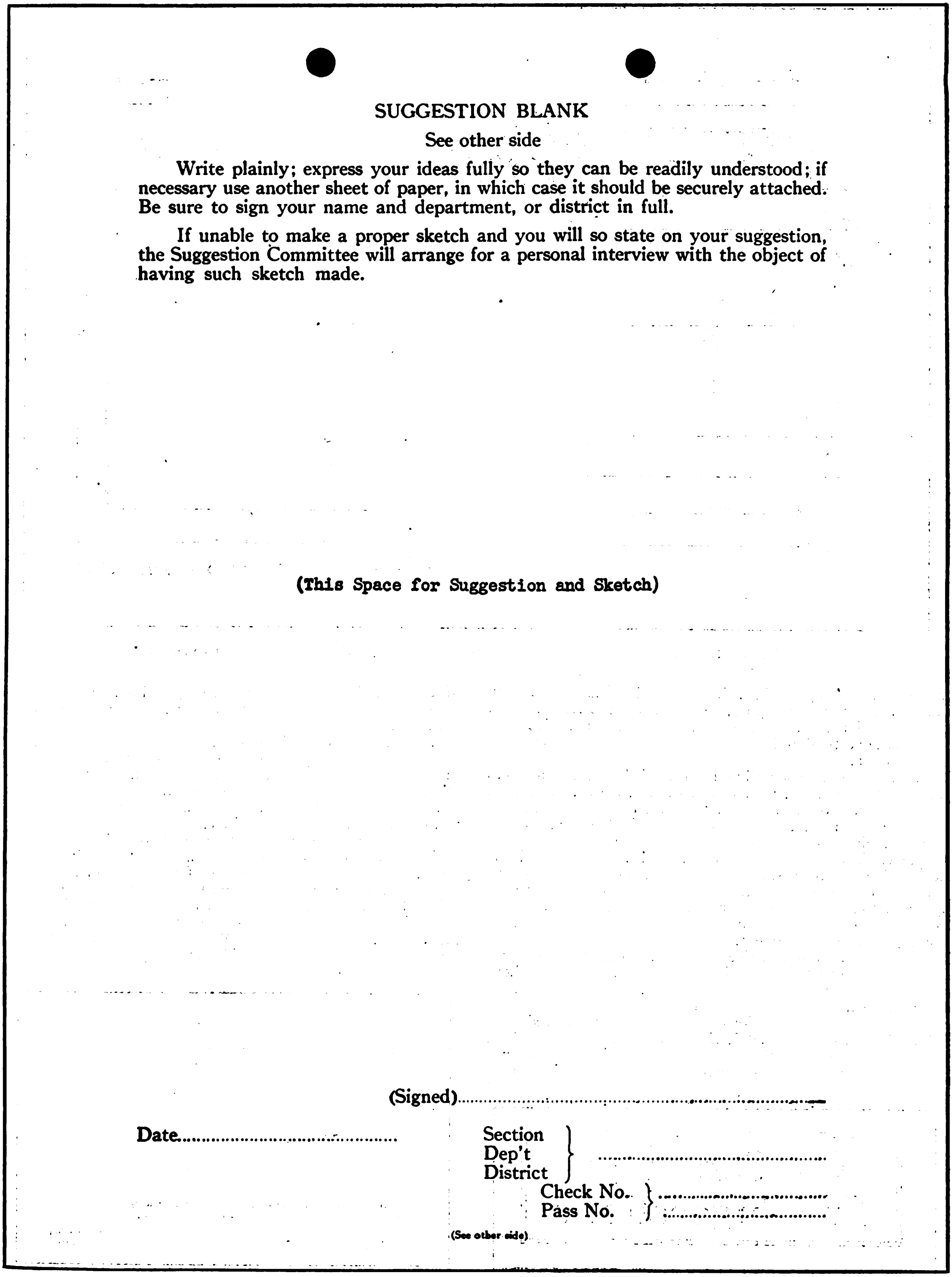
Following is a partial list of subjects on which suggestions are desired, though any one is at liberty to submit ideas on any other subject:

IMPROVEMENTS IN

Apparatus	Factory and Office Conditions	Miscellaneous
Quality	Health	Machines
Cost	Cleanliness	Tools
Quantity	Sanitation	Operations
Simplicity or Reliability	Ventilation	Jigs and Fixtures
Packing or Shipping	Order	Templates
Handling	Prevention of Fire	Transportation of Material
Finish	Prevention of Accident	
Design	Lighting	Handling of Material
Workmanship	Power	Storage of Supplies
Material	Economy	System and Methods

(See other side)

FIG. 16—PAGE 1—SUGGESTION BLANK—WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY.



SUGGESTION BLANK

See other side

Write plainly; express your ideas fully so they can be readily understood; if necessary use another sheet of paper, in which case it should be securely attached. Be sure to sign your name and department, or district in full.

If unable to make a proper sketch and you will so state on your suggestion, the Suggestion Committee will arrange for a personal interview with the object of having such sketch made.

(This Space for Suggestion and Sketch)

(Signed)..

Date..

Section } Dep't } District } ....

Check No. } ....

Pass No. } ....

(See other side)

FIG. 17—PAGE 2—SUGGESTION BLANK—WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY.

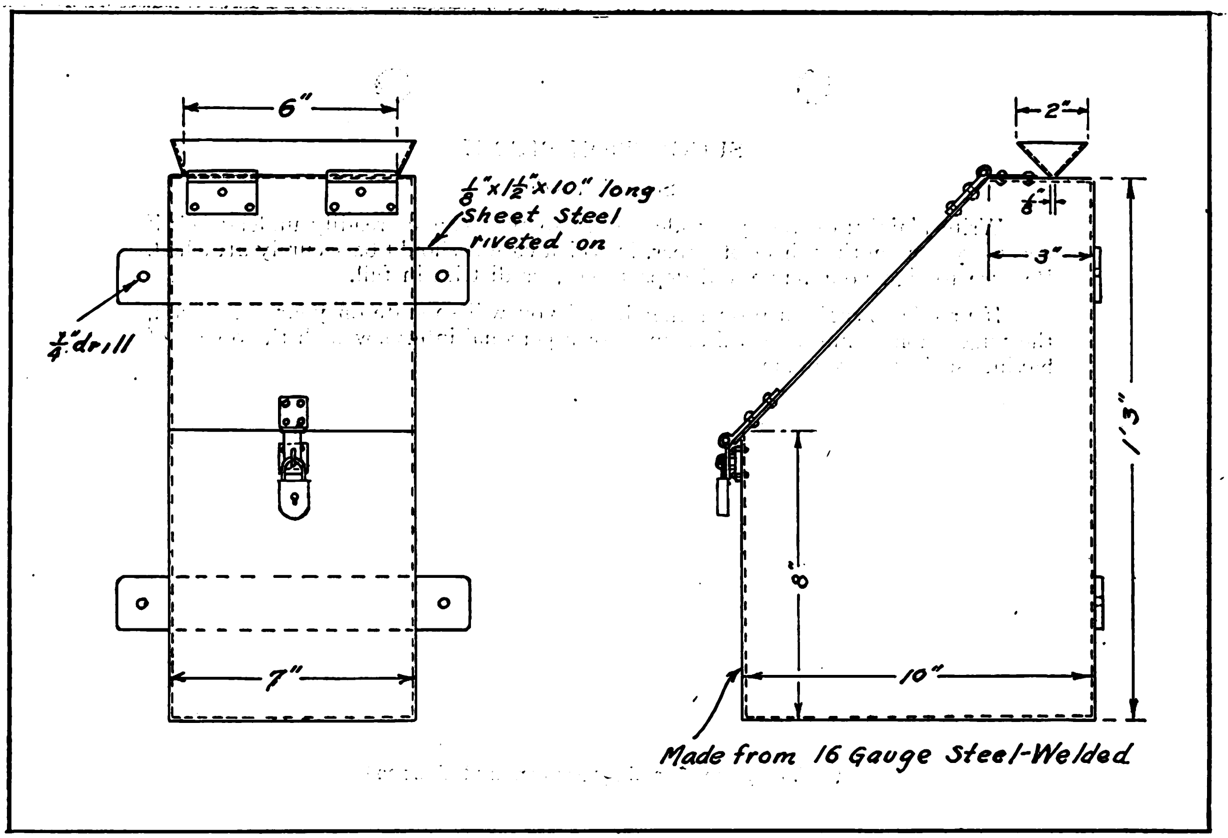


FIG. 18—Suggestion Box—Westinghouse Electric & Manufacturing Company.

awarded the company in 1913 a special medal for a very unique and original safety device which was received through our suggestion system. The Travelers Insurance Company also has advertised it in connection with its name throughout America.

The suggestion scheme has been applied to the employees throughout the shops, including workmen, clerks, inspectors, rate men and foremen, but in the case of foremen, inspectors and rate men, the suggestions must fall outside of the line of their regular duties.

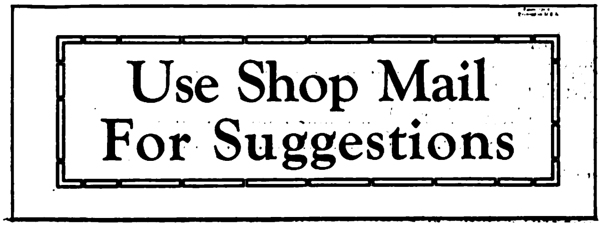
The engineering department (clerical force excepted) is not eligible for awards, although members of the department may and do enter suggestions; if adopted, they are sent a special letter of thanks accompanied by the statement that no award has been made on account of being connected with the engineering department.

It used to be our practice to collect every week all suggestions that had been deposited in locked boxes throughout the various departments of the works, but the shop mail has now been substituted. (See Fig. 19.)

Upon receipt, suggestions are serially numbered and acknowledged on form 3067, shown in Fig. 20, after which they are referred to the suggestion committee. All suggestions are indexed in two ways; (1) in alphabetical order of employees' names; (2) according to kind of suggestion. Carbon copies of this same form (3067) are used in making both of these indexes.

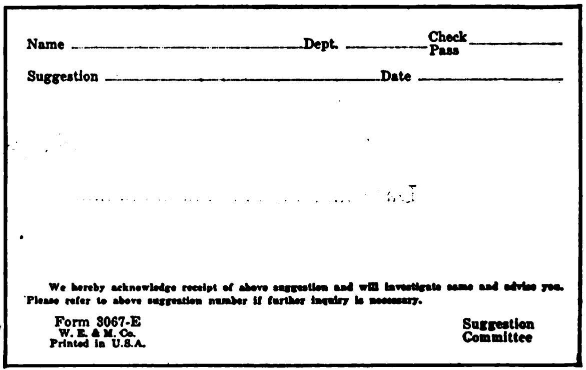
A suggestion committee of four members consisting of one permanent member (the chairman) and three others (rotating at periods of about twelve months) passes upon all suggestions. Of the members of the committee two are drawn from the heads of various manufacturing departments and one from the shop committee.

If the committee is, of its own knowledge, unable to decide on the merit of a suggestion, (and this is largely the case), it is referred to the head of the department directly concerned, the name of the party entering the suggestion being, however, withheld as a rule. If a favorable reply is received, the suggestion committee then determines upon the amount of the award. When a sufficient number of suggestions have been favorably acted upon, they are listed



Use Shop Mail
For Suggestions

FIG. 19—Shop-Mail Card—Westinghouse Electric & Manufacturing Company.



Name ______________ Dept. ________ Check / Pass ________

Suggestion ______________ Date ________

We hereby acknowledge receipt of above suggestion and will investigate same and advise you. Please refer to above suggestion number if further inquiry is necessary.

Form 3067-E
W. E. & M. Co.
Printed in U.S.A.

Suggestion
Committee

FIG. 20—Suggestion Acknowledgment Form—Westinghouse Electric & Manufacturing Company.

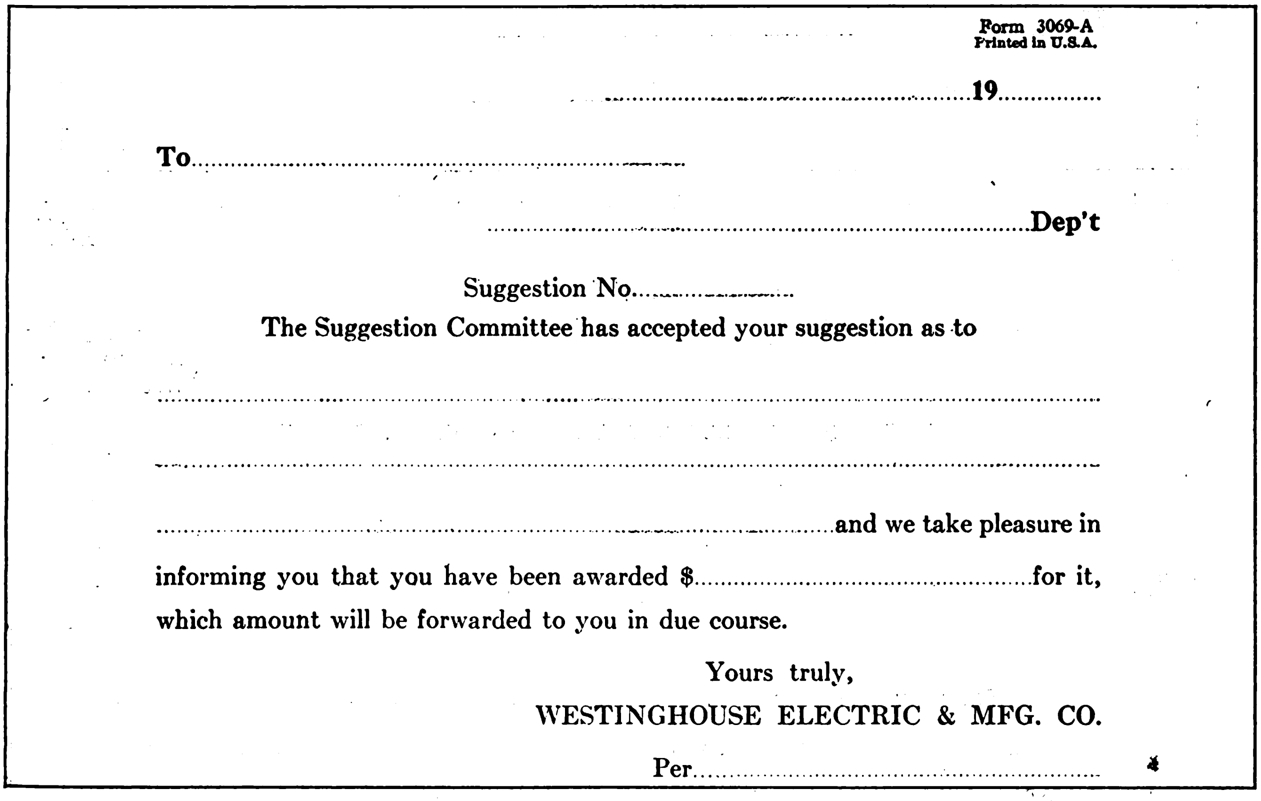
and presented usually semi-monthly to the works manager who, with the vice-president, either O.K.'s or modifies the award recommended.

When the first five suggestions have been accepted from any individual an extra award of $5.00 is paid; for the second five accepted suggestions an extra award of $10.00 is paid, and so on.

In the event of an award being made, the party entering the suggestion is notified on form 3069, illustrated in Fig. 21, and this notification is followed in due course by a check. A card, shown in Fig. 22, accompanies check whereon employee's signature is affixed acknowledging payment. Cards also are made out for each adopted suggestion and when filed serve as a record of the total number credited to any one employee toward an additional award. If, however, the suggestion is not accepted, a personal letter is sent to the employee giving the reason for being unable to make use of it. The stenographic work can be saved by the use of form 12383, illustrated in Fig. 23.

Reports on suggestions which are referred to other departments are made to the suggestion committee in triplicate. A copy of this report together with form mentioned is then forwarded to suggestor as final reply.

A list of suggestions adopted is posted in the monthly shop paper giving the title of the suggestion and the name of the employee who made it, but usually omitting the amount of the award although awards have been published as well on occasions. Occasionally the employee requests the omission of his or her name, in which case, when publishing the adopted suggestion, the statement is made that the name of the employee is omitted by request.



Form 3069-A
Printed in U.S.A.

....19..............

To..

....Dep't

Suggestion No.....................

The Suggestion Committee has accepted your suggestion as to

....

....

....and we take pleasure in

informing you that you have been awarded $.....................................for it,

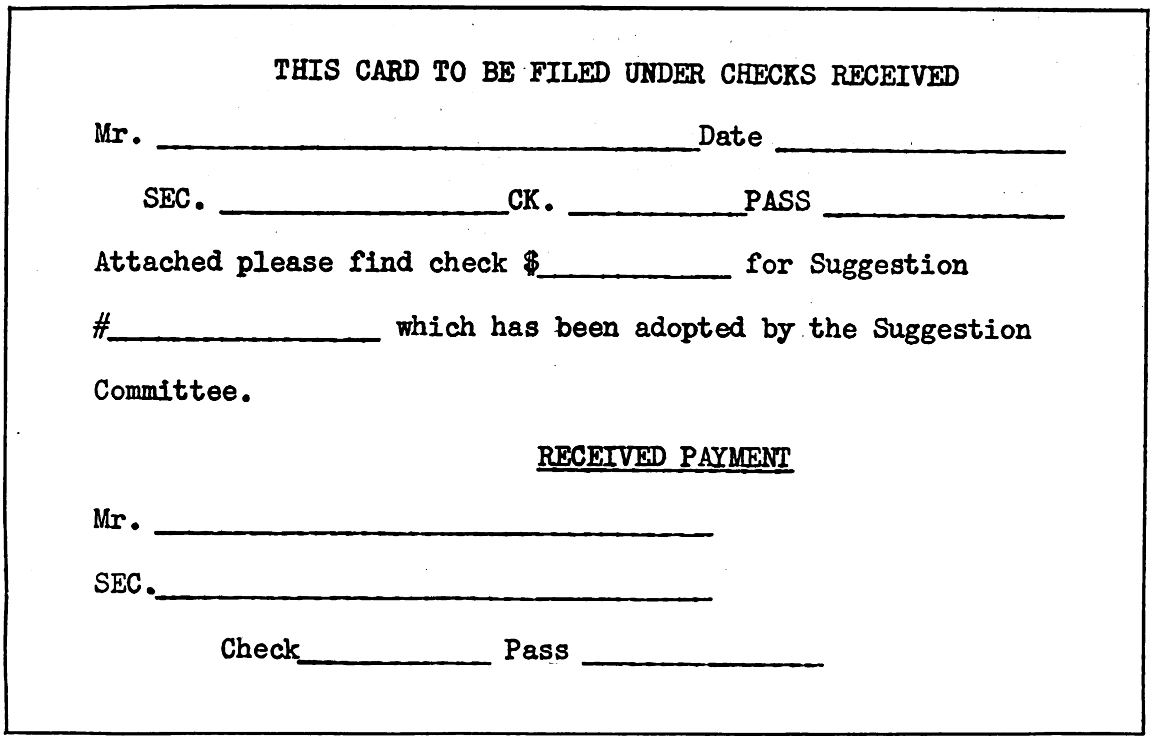
which amount will be forwarded to you in due course.

Yours truly,

WESTINGHOUSE ELECTRIC & MFG. CO.

Per...

FIG. 21—ACCEPTANCE NOTIFICATION FORM—WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY.



THIS CARD TO BE FILED UNDER CHECKS RECEIVED

Mr. ______________________________ Date ________________

SEC. ________________ CK. __________ PASS _____________

Attached please find check $__________ for Suggestion #______________ which has been adopted by the Suggestion Committee.

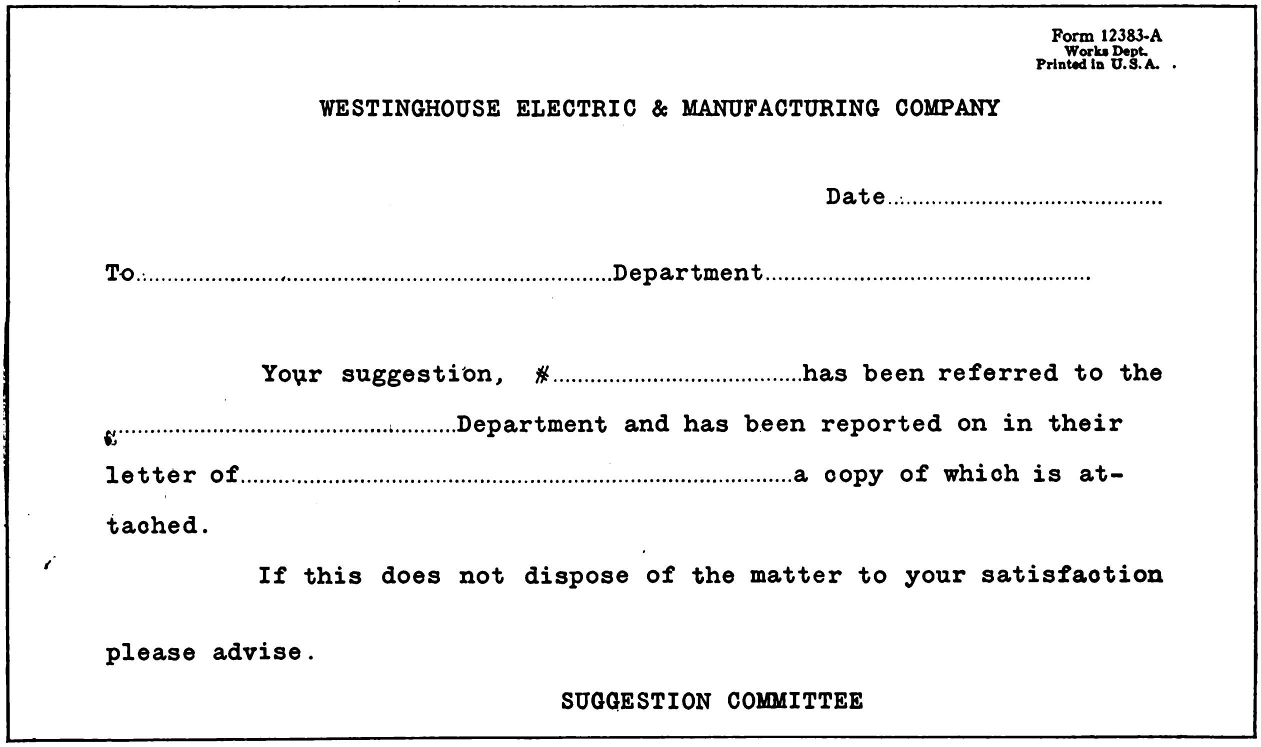
RECEIVED PAYMENT

Mr. ______________________________

SEC. ______________________________

Check__________ Pass _____________

FIG. 22—PAYMENT ACKNOWLEDGED CARD—WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY.



Form 12383-A
Works Dept.
Printed in U.S.A.

WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY

Date..

To..Department..

Your suggestion, #....................................has been referred to the ....Department and has been reported on in their letter of..a copy of which is attached.

If this does not dispose of the matter to your satisfaction please advise.

SUGGESTION COMMITTEE

FIG. 23—NON-ACCEPTANCE NOTIFICATION FORM—WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY.

PROGRESS IN GENERATOR DESIGN AND PRACTICE

During the last few years, due largely to revolutionary advances in the art of steel welding and cutting by flame and arc, great changes have occurred in the mechanical construction of electric generators.

Concurrently, the demand for generators of greater capacity, due largely to the advancing practice of system interconnection and the requirement for higher quality and longer life, has resulted in the development of new practices in the electrical design, construction and application of generators.

This report of the Electrical Apparatus Committee is intended as a concise, but comprehensive, digest of the present state and trend of the art, and is presented in the form of statements by four of the larger manufacturers.

MANUFACTURERS' STATEMENTS

STATEMENT BY THE ALLIS-CHALMERS MANUFACTURING COMPANY

Structural Steel and Welding

During the past year there has been built a number of generators and motors having parts such as stator yokes, bases, rotor spiders, and bearing pedestals for roller bearings constructed of electrically welded steel parts. There is at present under construction a 25,000-kw., 143-r.p.m. horizontal waterwheel generator, whose stator yoke will be electrically welded throughout. This yoke will have an outside diameter of 26 ft. and will weigh approximately 58,000 lb. Experience so far with welded frames and bases has been quite satisfactory, there being a considerable saving in pattern work and pattern storage, and it is expected that the use of this type of construction will undoubtedly become very general. Although the frames made from structural shape and steel plate have ample strength, there is danger, if care is not taken in the design, that sufficent stiffness and rigidity will not be obtained. In fact, cast iron has definite advantages from the point of view of rigidity, but there is no reason why welded frames cannot be so designed and braced that they will be equally good in this respect. Examples of the new type of construction are illustrated in Fig. 1, 2 and 3.

Other Mechanical Advances

During the past year there have been completed and put into operation three large hydro-electric generators, which are of interest in respect to their mechanical design. They are believed to be the largest machines in operation of the so-called umbrella type. Two of these machines are rated at 27,500 kv-a. and 90 r.p.m., and one is rated at 22,500 kv-a. and 75 r.p.m. One of the 22,500-kv-a. machines is shown in Fig. 4. These machines have only one guide bearing each, and both the thrust bearing and the guide bearing are mounted under the rotor. There being no upper bridge, the whole weight of the rotating parts is carried by the spider under the generator. Generators of this type are specially suitable for semi-outdoor power stations, and it is possible, by mounting the generators outdoors and covering them with sheet-steel enclosures, materially to reduce the cost of the power house. With this design it is also possible readily to obtain access to the stator winding merely by lifting the rotor off the shaft, with the bearings and other parts left in place. These machines operate fully as well mechanically as those of the conventional double-guide-bearing design. The single-guide-bearing design is best adapted for large moderate-speed units, which have rotors of large diameter. The design, however, is not suited to large high-speed generators, which have rotors of relatively small diameter and considerable axial length, since it is not possible to place the guide bearing sufficiently high to keep the overhang of the rotor with respect to the bearing within safe limits, and at the same time to have the thrust bearing in a readily accessible location.

Insulating Compounds

In large generators, and particularly in those operating at 6600 and higher voltages, "Class B" (mica) insulation is recommended for the stator coils, even if the operating temperature is within the limit for "Class A" (fabric) insulation. The longer life of the mica insulation and its ability to resist damage from corona make it desirable in large units regardless of temperature. Extensive tests have shown that an asphaltum-base varnish or binder is superior to shellac or linseed-oil varnish for stator coil insulation, and mica coils are now made with this type of varnish exclusively. Life tests have shown that the asphaltum-base material is not affected by corona to anywhere nearly the same extent as shellac, which, in the course of long-continued operation, is likely to disintegrate. Another advantage of the asphaltum material is that it retains its flexibility, not becoming as hard as shellac or linseed-oil varnishes.

Higher Voltages

Generators have not been built for voltages higher than 15,000. So far as generators themselves are concerned, higher voltages are not desirable, but, in order to limit the current handled by oil circuit breakers, there has been a demand for higher voltages in machines of very large capacity. Such machines can be built, although, of course, thicker insulation is necessary, and less efficient utilization can be made of the slot space. It is also necessary to take special precautions as regards corona. It would seem that more consideration might be given, in attempting to limit the current handled, to subdividing the output from large units by using windings of more than one circuit per phase and thereby reducing the current by half or more.

Transposed Windings

During the past two years a number of machines have been built with transposed armature conductors. Such an arrangement is advantageous for large units, and also for smaller units wound for low voltage and high current. In large four-pole machines where only four parallel circuits are available, the depth of conductor becomes so great that some form of transposition is desirable in order to reduce the eddy-current losses and heating, but it is not advisable to introduce the complication and expense of transposed conductors in the case of machines where the eddy-current loss can be kept within conservative limits by the use of multiple circuits, as can be done, for example, in most waterwheel generators. Another advantage of the transposed conductor is that it reduces the number of turns per coil and, therefore, the number of conductors per slot, thereby making the machine less liable to breakdown between turns.

Divided Circuits

As stated above, large generators can, if desired, be built with divided circuits, thereby reducing the output of any one winding. Where such divided circuits are used, it is necessary to employ protective means to insure against overloading any one of the circuits in case of trouble.

Publication No. 289-37, Serial Report, Electrical Apparatus Committee.

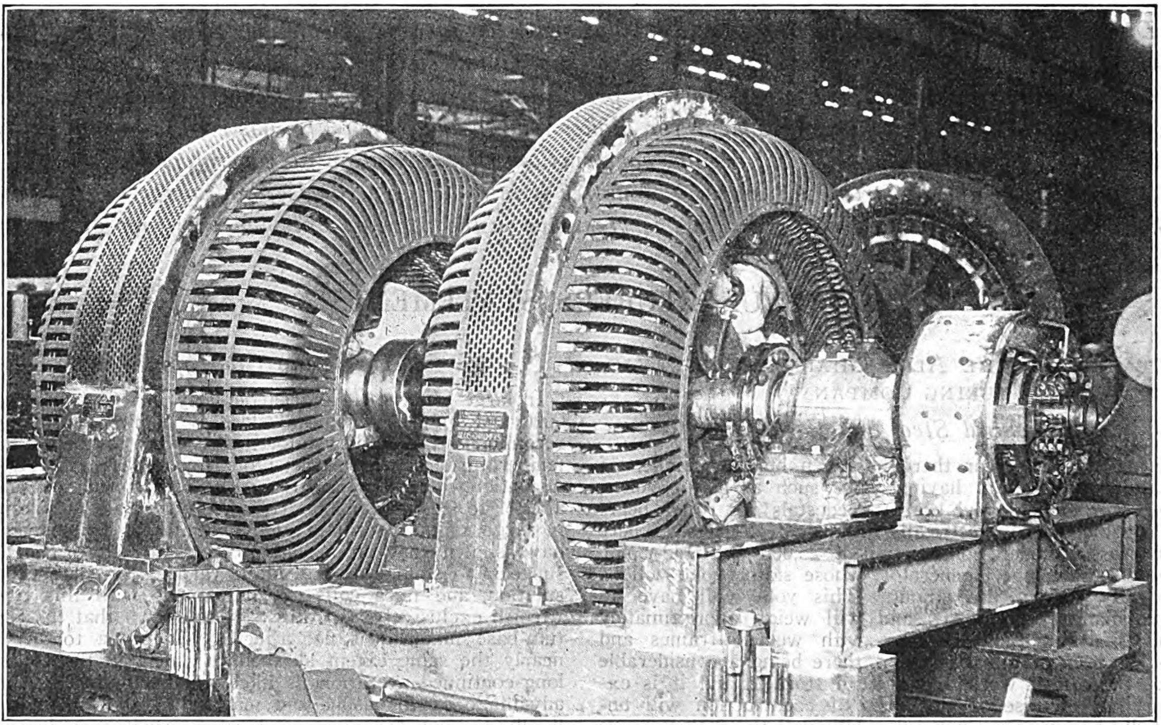


FIG. 1—1000-KW. ALLIS-CHALMERS FREQUENCY-CONVERTER SET FOR HONOLULU IRON-WORKS COMPANY.

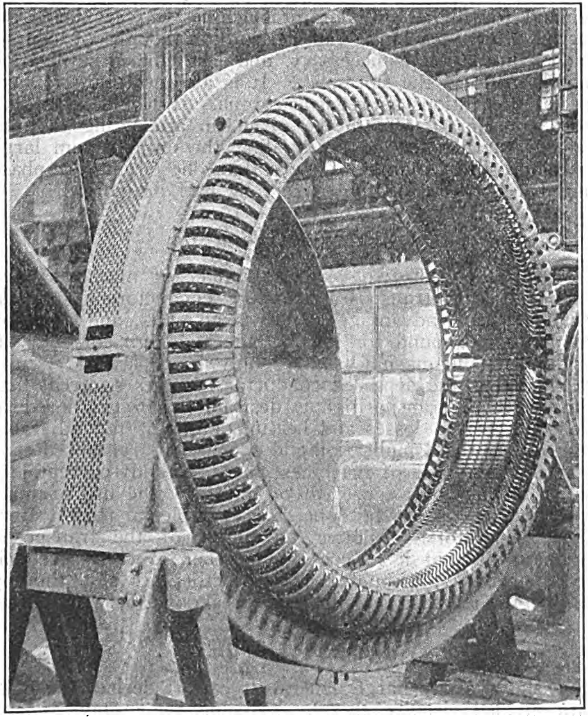


FIG. 2—SPLIT WELDED-STEEL YOKE OF 1100-H.P. ALLIS-CHALMERS SYNCHRONOUS MOTOR FOR WEST PENN CEMENT COMPANY.

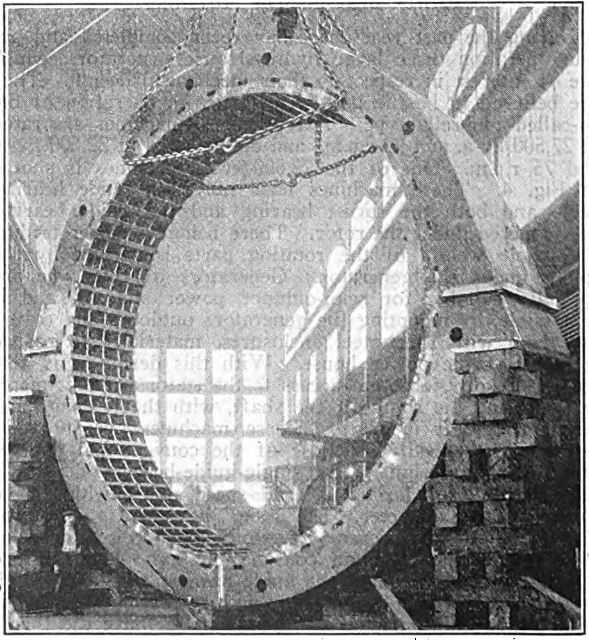


FIG. 3—WELDED PLATE YOKE OF 25,000-KV-A. ALLIS-CHALMERS WATERWHEEL GENERATOR FOR THE CITY OF LOS ANGELES.

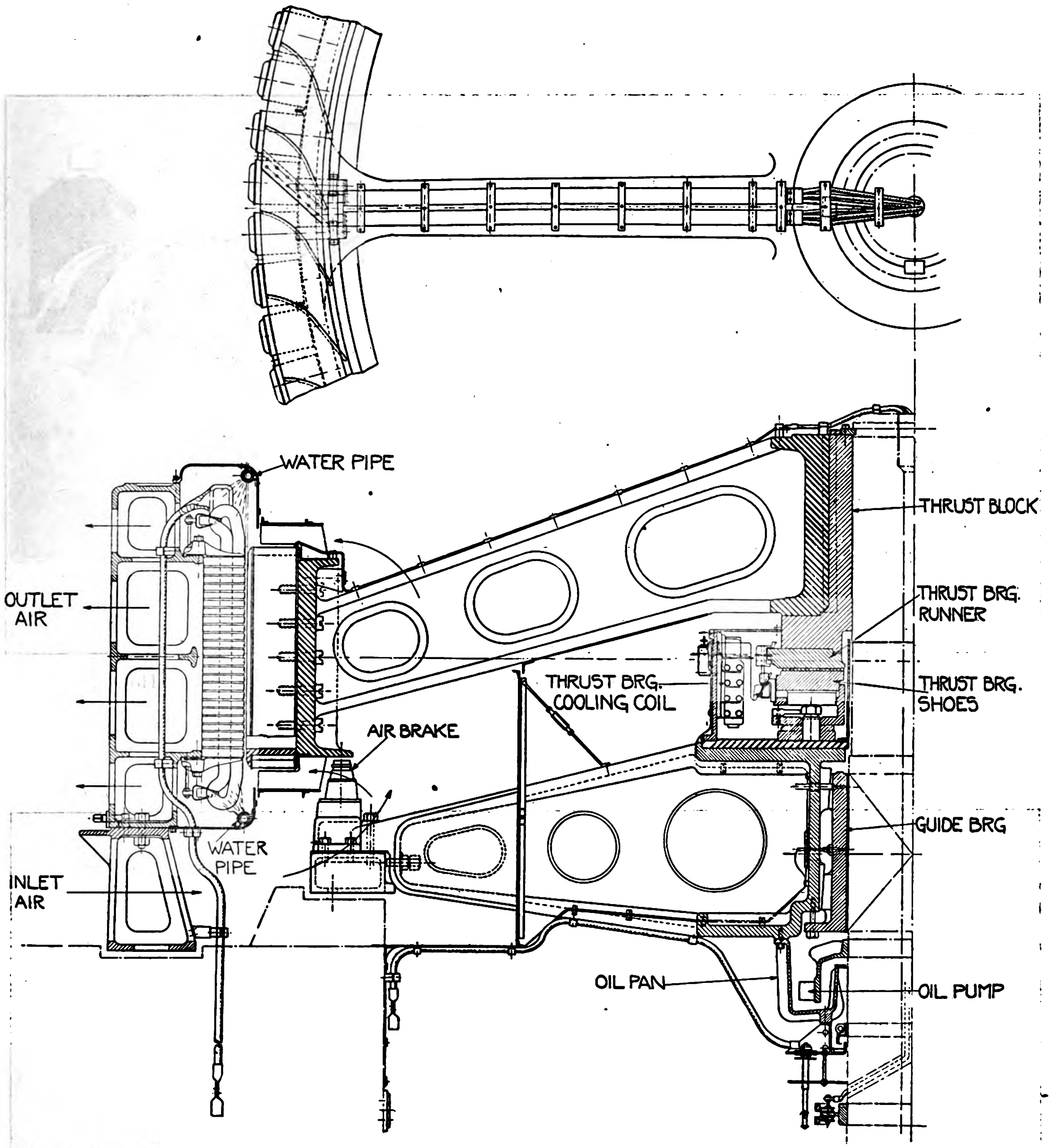


FIG. 4—CROSS-SECTION OF 22,500-KV-A. ALLIS-CHALMERS WATERWHEEL GENERATOR FOR THE NORWOOD HYDRO-ELECTRIC COMPANY.

STATEMENT BY THE AMERICAN BROWN-BOVERI ELECTRIC CORPORATION

Structural Steel and Welding

Up to the present time use has not been made of structural steel to any great extent.

Other Mechanical Advances

In the effort to minimize capital outlay for power stations, the tendency is always toward larger units and higher speeds, and the construction of alternators has been forced to keep pace with this progress.

Radical improvements in design have led to the development of high-speed, steam-driven turbo-generators of large capacity. A machine rated at 32,500 kv-a. and 3000 r.p.m. has been placed in operation, and two machines, each rated at 40,000 kv-a. and 3000 r.p.m., are now under construction.

Improvements have similarly led to the development of waterwheel generators of large capacity. Contrary to American practice, machines having horizontal shafts are often preferred to the vertical type in foreign countries. Three three-phase, 30,000-kv-a., 8000-volt, 42-cycle, 420-r.p.m. waterwheel generators, installed in an Italian power house, are shown in Fig. 5. The largest single-phase alternators ever built of such low frequency as is sometimes required for railway work have been constructed for the Swiss Federal Railways and installed in the Barberine Power Station. These units are rated at 10,000 kv-a., 15,000 volts, 16⅔ cycles per second and 333 r.p.m., and are illustrated in Fig. 6. Fig. 7 shows that the stator of one of these machines is supported on rollers in such a manner that it may be easily rotated for inspection or repairs.

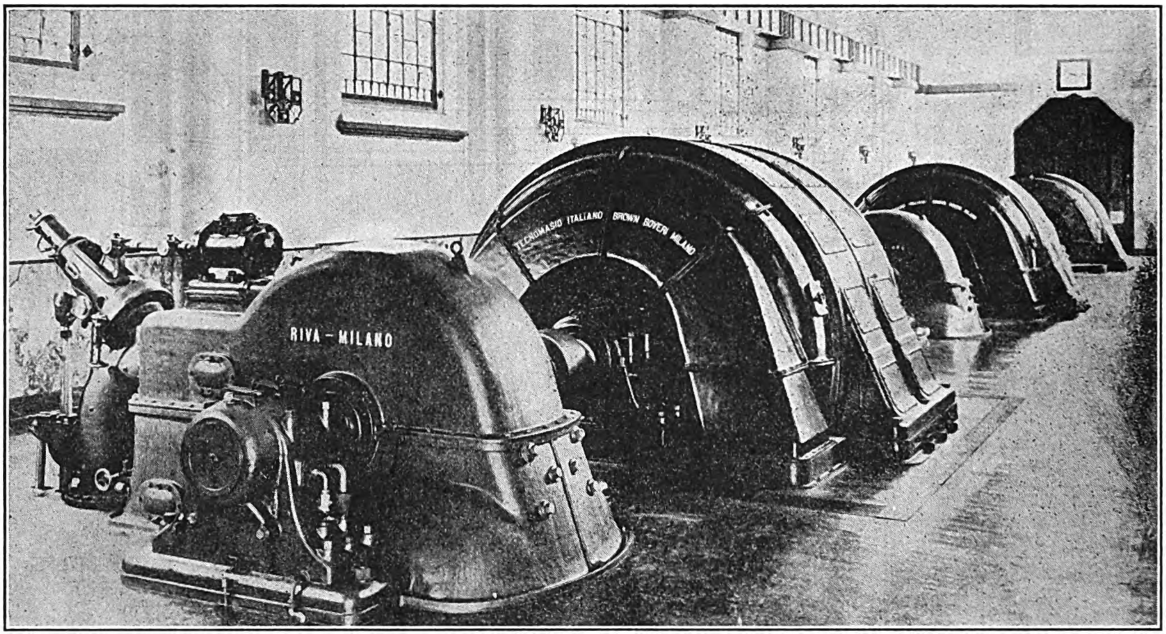

TECNOMASIO ITALIANO BROWN BOVERI MILANO
RIVA-MILANO

FIG. 5—30,000-KV-A. BROWN-BOVERI WATERWHEEL GENERATORS IN AN ITALIAN POWER HOUSE.

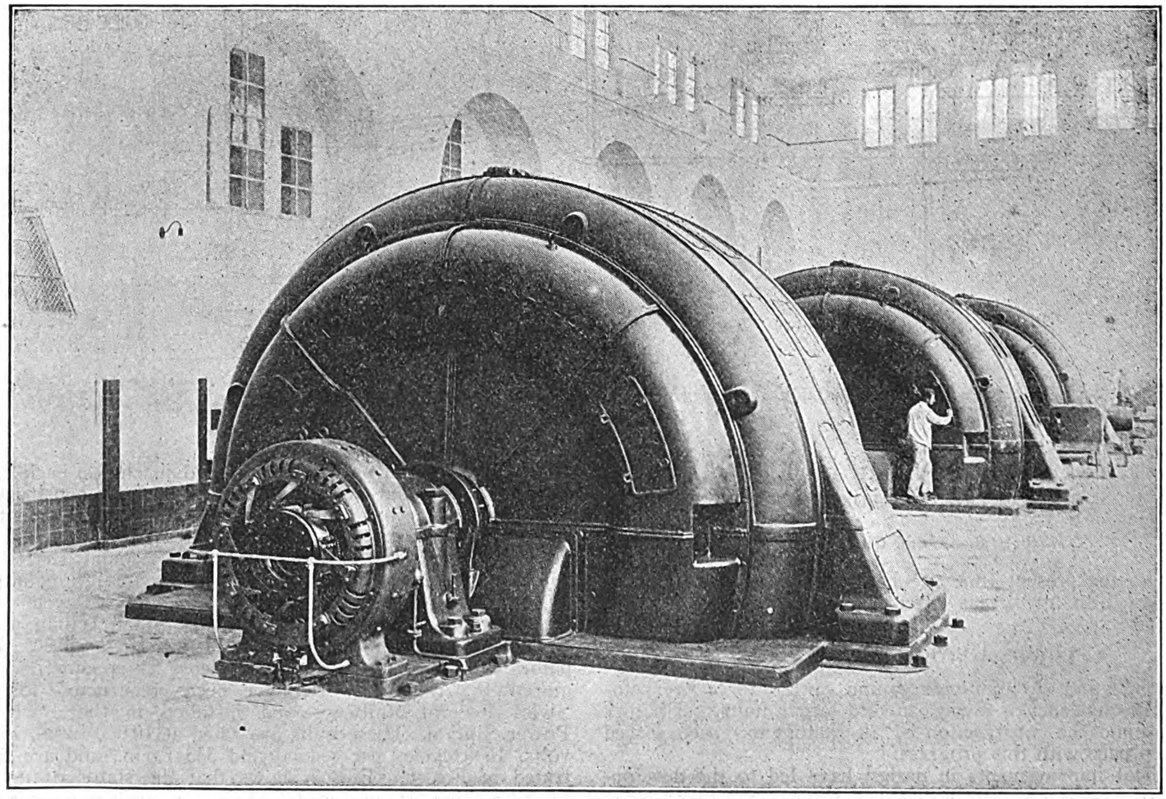


FIG. 6—10,000-KV-A. SINGLE-PHASE BROWN-BOVERI ALTERNATORS FOR THE SWISS FEDERAL RAILWAYS.

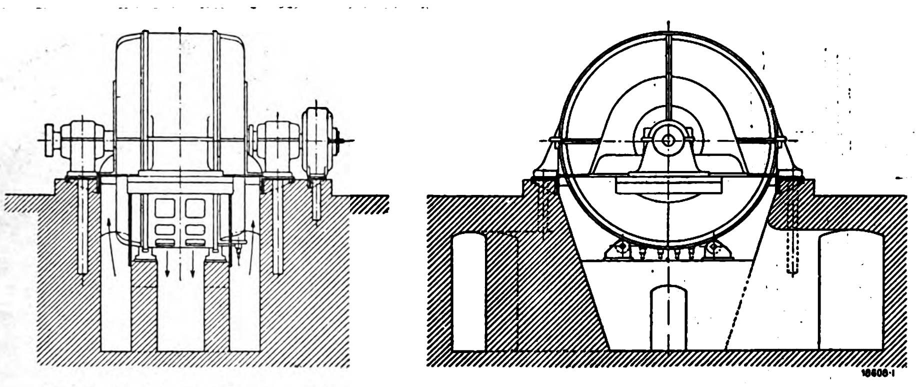


FIG. 7—THREE-PHASE BROWN-BOVERI ALTERNATOR WITH MOVABLE STATOR.

With respect to hydro-electric units with vertical shafts, one of the most important components is the thrust bearing, which has to carry the weight of the rotating parts of both alternator and turbine, together with the hydraulic thrust on the latter. Thrust bearings for this purpose are made of two types. For moderate loads and low speeds the design is suitable in which the running surfaces are of one piece and are spherically seated. For thrusts up to 500 tons and for high speeds the usual one-piece bearing surface is replaced by a number of separately pivoted segments. Such a bearing, for a pressure of 350 tons and 100 r.p.m., is shown in Fig. 8. The segments are supported somewhat eccentrically and, when the shaft is running, take up such a position that a wedge-shaped oil film forms between each segment and the surface of the thrust collar on the shaft. In this way contact of the surfaces is prevented and friction losses are made extremely small. The load is uniformly distributed between segments in a most effective manner by means of steel balls, as is also shown in Fig. 8. The lower bearing bracket is provided with supporting bolts, upon which the rotor can rest after it has been raised for inspection or repairs. Several different designs have proved that bearings of this type are completely reliable under the most unfavorable conditions, even at speeds as low as those which occur during starting and slowing down.

Under certain conditions, such as when the speed of the waterwheels is low and direct-coupled generators would be too costly or too large, it may be advantageous to employ geared drives. Modern spur gearing is suitable in such cases for very high powers and large ratios, but the application of bevel gears in this respect is very limited. It is possible, for example, to drive a generator at 1000 r.p.m. from a turbine running at 100 r.p.m. As the cost of the gearing is considerable, it must be carefully investigated in every case whether geared drive or direct coupling is the more advantageous. It has generally been found that gearing should be employed when the output exceeds 1000 to 2000 kw., and the turbine speed is as low as 80 to 100 r.p.m.

Insulating Compounds

The insulation used is the result of research and experience extending over many years, and insures the production of coils capable of meeting the strictest requirements, both electrically and mechanically. The impregnation process in particular prevents the ingress of all air and moisture, and thereby eliminates all danger of the formation of ozone. The solidarity obtained by the impregnation and pressing processes obviates any tendency of the individual conductors to become loose and consequently to vibrate.

The final layer of insulation consists of a micanite sheath on the straight portions and several wrappings of varnished tape on the coil heads. The former is made up of micafolium, a thick, tough paper faced with flakes of mica. Shellac is used only for the micafolium wrapper, the impregnation of the coil before the wrapper is put on being done with a bitumen-base insulating compound. This compound is also used for impregnating the coil heads.

Insulation of this type is used on all steam-driven turbogenerators, except low-speed units of low voltage, which are provided with "Class A" insulation. It is recommended for continuous service at all temperature rises up to 75 deg. cent. above an ambient temperature of 40 deg. cent., and has proved to have a very long life.

Higher Voltages

A great deal of experience has been had in the building of high-voltage generator windings. As early as 1910 five three-phase generators, each rated at 3000 kv-a. and 17,600 volts, were built for the Bernese Power Supply Company of Switzerland, and are still in satisfactory operation. Numerous generators for this voltage have since been built, a noticeable example being the single-phase railway alternators previously referred to. These machines have been in operation since 1920 at 16,000 volts, with one pole permanently grounded, and are subjected to all the voltage surges coming in over the contact line, which is fed directly from the power station without intermediary transformers.

In the case of high-voltage windings, particularly when one pole is earthed, and in the case of windings designed

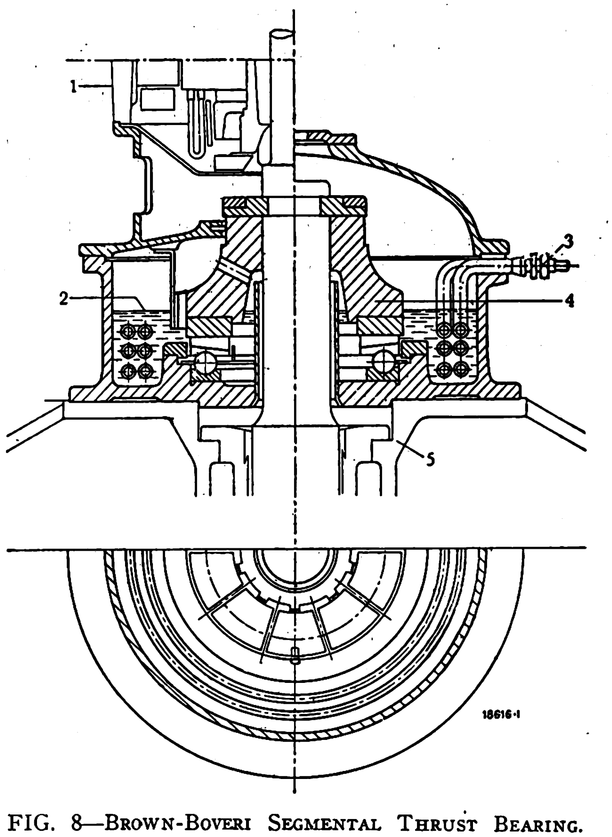


FIG. 8—BROWN-BOVERI SEGMENTAL THRUST BEARING.

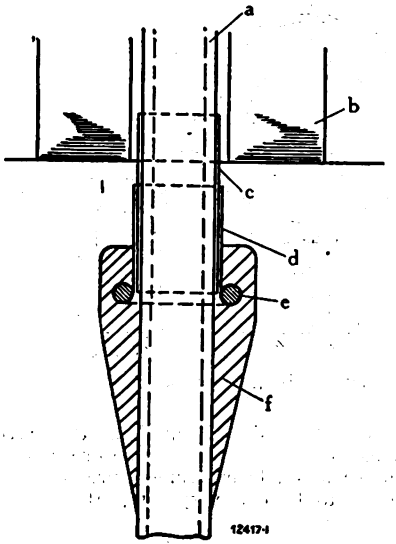


FIG. 9—CORONA-EFFECT PROTECTION USED ON HIGH-TENSION BROWN-BOVERI ALTERNATORS.

for a test voltage of three or more times the rated voltage, unless precautionary measures are taken, it is inevitable that the air dielectric in the slight spaces remaining between the coil insulation and the slots will be overstressed and will consequently be the source of discharge effects. By way of remedy, the insulating sheath of the coil is provided with a coat of conducting varnish, shunting the air space between coil insulation and stator iron. Conditions are particularly severe in the case of traction alternators, such as those previously mentioned, where, on account of the unfavorable flux distribution, discharges endangering the coil insulation are likely to occur at the edges and the corners of the teeth and the clamping plates in the neighborhood of the points where the conductors leave the iron. In order to prevent such discharges, the coils of the machines of this type are provided, at the points where they leave the core (Fig. 9), with a narrow conducting sheath (c) of tin-foil, over which a sleeve of conducting material (brass) is drawn. Due to the connections thus made between the iron core and the sleeve, the surface of the coil at this point is artificially brought to the potential of the core, i.e., to earth potential, and all discharge phenomena can be easily and effectively eliminated by covering this edge with a layer of insulating material after the edge has been rounded off.

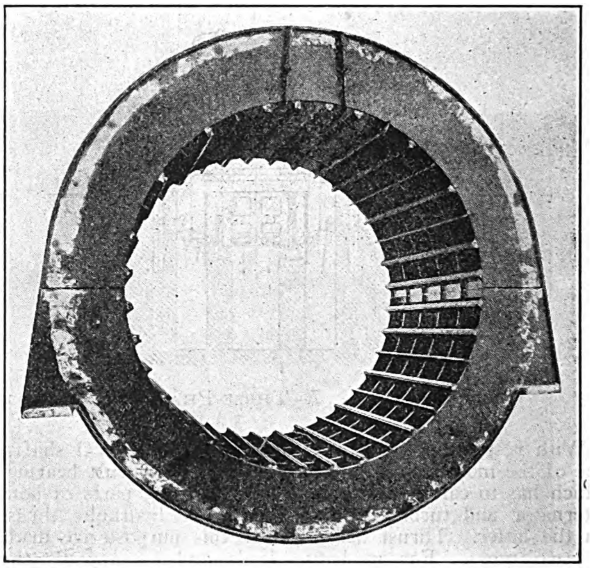


FIG. 10—STRUCTURAL-STEEL STATOR FRAME OF 50,000-KV-A. GENERAL ELECTRIC SYNCHRONOUS CONDENSER FOR SOUTHERN CALIFORNIA EDISON COMPANY.

Transposed Windings

The stator windings, being the most important part of alternators, demand the greatest care on the part of the designer. From the point of view of design, they are divided into two classes: coil windings and bar windings. Windings are considered to be of the latter type when each slot contains only one or two turns or bars, each bar being insulated for the full voltage. Such an arrangement is employed only when the current is in excess of 600 amperes.

When the bar becomes of considerable cross-section, it is advisable to employ some method of lessening to as great an extent as possible the eddy-current losses resulting from skin effect. The twisted-strand type of stator winding, in which the bars are built up of a number of strips and are transposed so that each strand occupies in turn every possible position in the cross-section of the slot, has proved to be the most satisfactory form of bar winding, and has the advantage of simplicity.

Divided Circuits

Divided circuits are frequently used in order to utilize the most suitable copper dimensions.

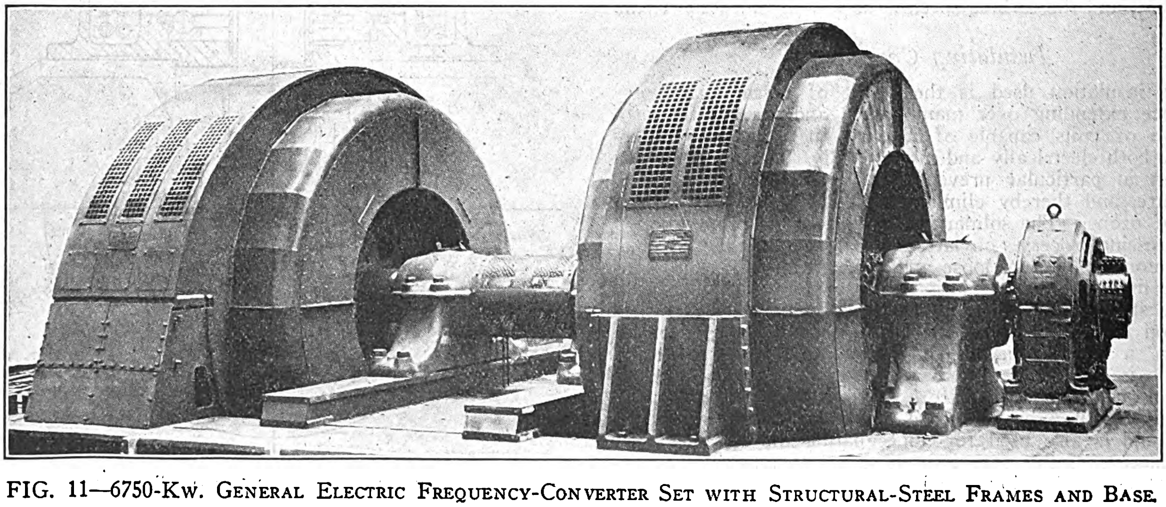


FIG. 11—6750-KW. GENERAL ELECTRIC FREQUENCY-CONVERTER SET WITH STRUCTURAL-STEEL FRAMES AND BASE.

STATEMENT BY THE GENERAL ELECTRIC COMPANY

Structural Steel and Welding

Salient-Pole Synchronous Machines

It is estimated that 90 per cent of the salient-pole synchronous machines as now designed are made of structural steel.

There are several reasons for the recent tremendous increase in the use of structural steel and welding as a substitute for the use of castings. The cost of constructing patterns and the expense of storing them, the loss occasioned by defects in the castings, and the likelihood of failure in service as a result of internal strains, blowholes and the like, are some of the disadvantages of the old method of construction. They have long been appreciated by the industry and have been tolerated only because of the fear that some other form of structure would give rise to other troubles of even more serious nature.

With the development of flame cutting of steel plate and with the increased knowledge of the art of welding, however, the designers have become convinced that steel plate will not only eliminate casting defects but will also produce better mechanical structures. In fact, factory tests have demonstrated that the new method of construction eliminates the disadvantages of castings, and produces a structure superior in strength and reliability to the cast structure, and one more able safely to withstand the shocks of handling and the stress of short circuits.

The welded-plate stator construction, as applied to horizontal units, is illustrated in Fig. 10 and 11, respectively. The side plates of horizontal units consist of segments cut from heavy rolled-steel plate, which are welded together by means of the hydrogen-enveloped arc. The use of this arc-welding process eliminates the necessity of scarfing the joints between segments and at the same time insures a ductile weld. The supporting feet of the units are cut out as part of the side plates, and a heavy foot plate is welded to these feet. The back plates are flame-cut, are rolled to the proper shape and are then welded to the side plates by an automatic arc-welding machine, which produces a practically perfect weld. The ribs for supporting the casting on which the stator laminations are stacked, are also welded to the side plates.

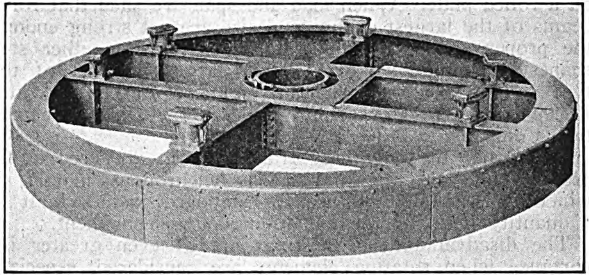


FIG. 12—TYPICAL GENERAL ELECTRIC LOWER-BEARING BRACKET OF STRUCTURAL STEEL.

With reference to vertical units the first application of structural steel to the lower guide bearing was made in 1921, in the case of the 20,000-kv-a. generators built for the Alabama Power Company. Since that time practically all vertical waterwheel generators of large diameter have been furnished with structural-steel lower guide brackets. Fig. 12 illustrates a typical lower guide bearing and bracket.

A typical upper-bearing bracket, carrying the thrust bearing for vertical waterwheel generators, is illustrated in Fig. 13. Standard rolled girder beams are employed in this design, and the appearance is improved by cutting off the ends of the beam in the form of an arc and by welding

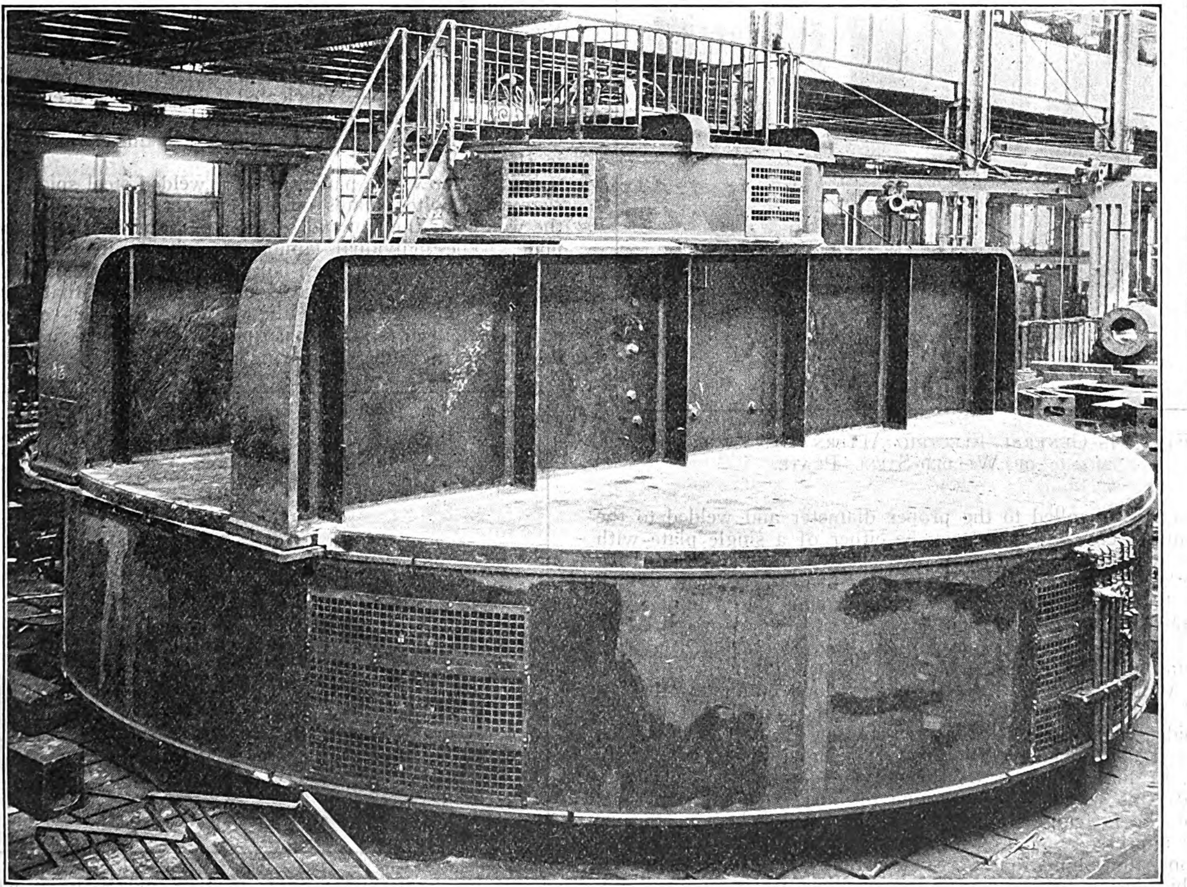


FIG. 13—19,000-KV-A. GENERAL ELECTRIC WATERWHEEL GENERATOR WITH AUXILIARY GENERATOR.

on a rolled plate. When load and span are such that rolled beams of the largest commercial size are not strong enough, the proper shapes are built up by welding together steel shapes of commercial sizes. The largest bracket of this type so far used supports a weight of 750,000 lb., in a 19,000-kv-a. generator recently sold to the Dixie Construction Company.

Practically the only cast frames which are used at the present time are for high-speed synchronous motors, in which it is possible to use the standard frames built on a quantity basis by the induction motor department.

The disadvantages of castings are of even greater importance when rotating elements are considered, especially those rotors which are subjected to high stresses from overspeed. As a result, structural-steel spiders of several types have been developed.

Spiders for small rotors have been built in considerable number of welded steel plate, one such spider being shown in Fig. 14. The hub is flame-cut from thick steel plate or from shaft stock, and is welded to a center web also flame-cut from heavy plate or stock. The outside rim is of steel plate, rolled to the proper diameter and welded to the center web. This rim may be either of a single plate with arc-welded butt joint or of two plates completely welded together around the outer edges. Since the rim is welded to both sides of the web plate around the complete periphery, the welded joint of the rim is not required to withstand the entire centrifugal force occasioned by the rotating of the poles.

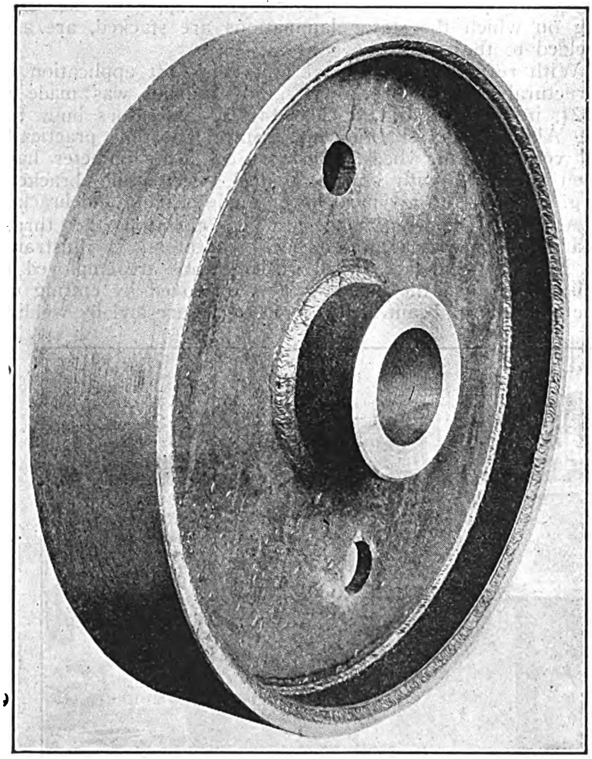


FIG. 14—GENERAL ELECTRIC ALTERNATOR ROTOR SPIDER OF WELDED-STEEL PLATE.

Another design of rotor spider which eliminates the use of castings is the so-called laminated punched type. A spider of this design is shown in Fig. 15, and it should be noted that such spiders can now be used in sizes up to 10 ft. in diameter, whereas the previous limit was about one-half this size. The ventilating openings and dove-tail slots for the fastening of pole pieces are all punched in advance by a press. Spiders of this type are usually built in sections, the laminations of each section being bolted together. This design has been used on machines of from five kv-a. to 100,000 kv-a. in capacity.

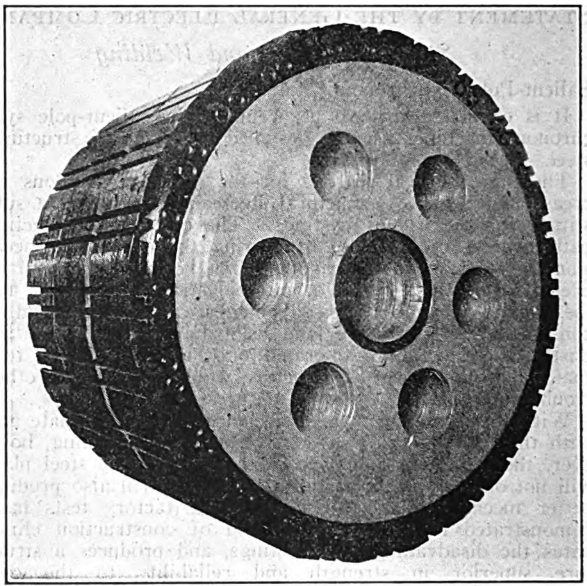


FIG. 15—LAMINATED STEEL-PLATE ROTOR SPIDER OF 30,000-KV-A. GENERAL ELECTRIC VERTICAL WATERWHEEL GENERATOR.

An entirely new development is represented by the rotor spider of the third general type. This spider has a free rim, made of segmental punched laminations mounted on a centering spider, which may be of either structural or cast construction. The laminated rim is not anchored to the centering spider, and therefore must carry all the centrifugal force occasioned by the rotating of the poles. Since the center has only to support the weight of the rim and of the poles, and to transmit the torque from the shaft, it is permissible to use cast material in this part of the structure. However, fabricated centers have been used in a number of machines, and it is expected that few cast centers will be used in future. This, the third type of spider, is shown in Fig. 16.

Fig. 17 shows the plate rim of a welded steel spider. The segmental bolted plates on the end serve as a support for the weight of the rim and of the poles, and also as a braking plate. The individual laminations, shown in Fig. 18, are held in place by through-bolts in reamed holes, the bolts being so designed for shear and compression that the rim has the same strength as the plates. The holes of square cross-section around the periphery are intended to have inserted in them the coil springs, which are designed to sup-

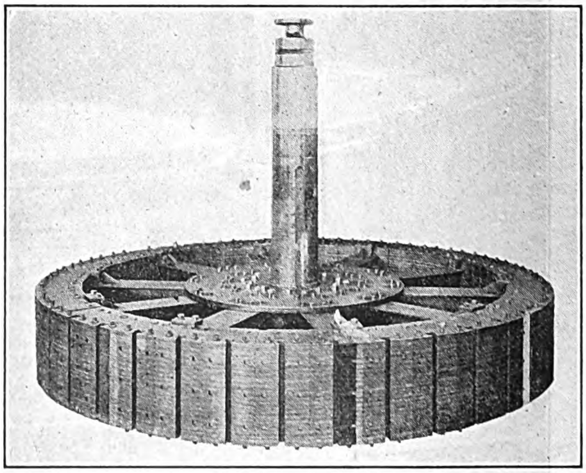


FIG. 16—STRUCTURAL-STEEL SPIDER, WITH FREE RIM, OF 9400-KV-A. GENERAL ELECTRIC VERTICAL GENERATOR.

port the field coils and to keep them tight regardless of insulation shrinkage.

Structural steel has been used in one way or another in a great many recent designs. The four 40,000-kv-a., 13,800-volt, 81.8-r.p.m. waterwheel generators for the Conowingo Station of the Philadelphia Electric system and the eight 12,550-kv-a., 14,000-volt, 100-r.p.m. waterwheel generators for the new hydro-electric station of the Louisville Gas & Electric system have their frames and lower-bearing brackets of structural steel. The three condensers recently sold to the Southern California Edison Company and rated at 50,000 kv-a., 13,200 volts and 600 r.p.m., have structural-steel frames, rotor spiders and ventilating shields, as has the 20,000-kw. frequency converter sold to the New England Power Company.

Turbo-Generators

Almost all large turbo-generator frames are built of structural steel and are constructed from flame-cut boiler plate. A rib support is welded to the inside of the supporting plate in order to secure sufficient surface for the bolting of the ribs. The ribs themselves are cut from steel plate and have machined surfaces, with a keyway left for supporting the punchings. On the outside of the circular supporting plates, which make up the sections of the units, there are welded ribs of steel plate for spacing and supporting the plates. This construction is illustrated in Fig. 19.

It is still the practice to cast out of non-magnetic steel the end flanges for large units. However, in the case of auxiliary generators and even in the case of some of the smaller main generators, the flanges have been made of steel plate. They have given very satisfactory service and there is, therefore, the possibility that plate flanges will be used in future on larger units.

On generators which are too large to ship with foot plates in place, the plates are made detachable, as are the steel-plate hoods covering the units. It is, therefore, possible completely to assemble the core and windings at the factory without exceeding shipping dimensions and weights. By constructing units in this manner, it is also possible to test them at the factory, such not having been the case with respect to large units in the past.

The outer shell for the large unit is also made of boiler plate and is rolled to fit the supporting plates of the unit, as illustrated in Fig. 20. All the partitions are of steel plate, welded to the shell, an air-tight cover for the unit thereby resulting. Some of the large units which have recently been constructed of structural steel include the 100,000-kv-a., 0.9-power-factor, 16,500-volt, 1500-r.p.m. unit for the Southern California Edison Company; the 235,000-kv-a., 0.85-power-factor, 22,000-volt, 1800-r.p.m. cross-compound unit for the State Line Generating Company; the 187,000-kv-a., 0.85-power-factor, 11,000-volt, 1800-r.p.m., cross-compound unit for the Amercan Gas & Electric Company, and the 160,000-kv-a., 1.0-power-factor, 11,400-volt, 1500-r.p.m. single unit for the New York Edison Company. The use of structural steel for the frames of the units mentioned above has resulted in the manufacture of stronger and lighter machines, and has made possible the shipment of the generators as assembled at the factory, with the exception of the New York unit.

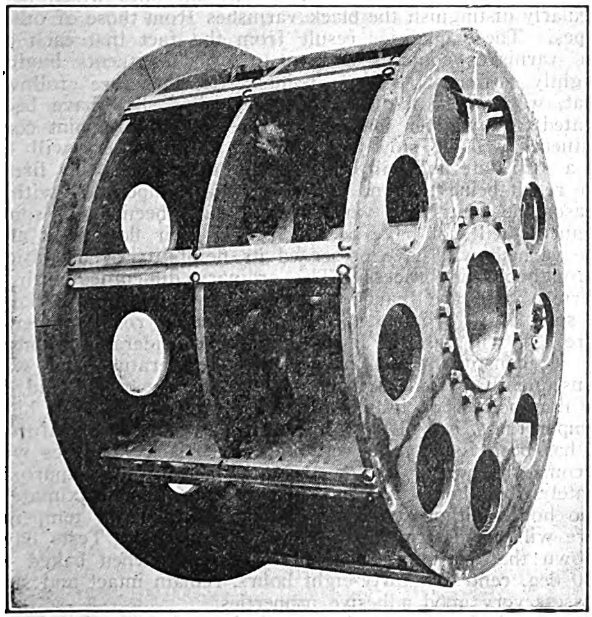


FIG. 17—WELDED-PLATE SPIDER FOR FREE-RIM ROTOR OF 20,000-KV-A. GENERAL ELECTRIC VERTICAL GENERATOR.

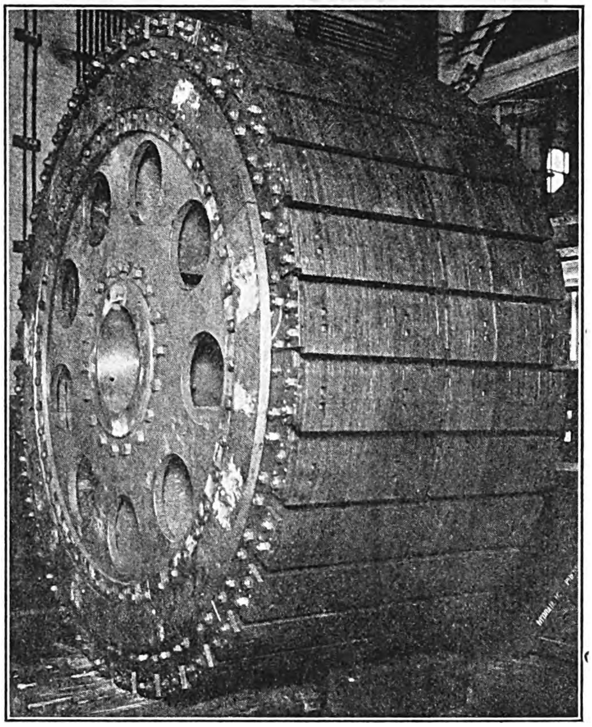


FIG. 18—LAMINATIONS AND SPIDER OF FREE-RIM ROTOR OF 20,000-KV-A. GENERAL ELECTRIC VERTICAL GENERATOR.

Direct-Current Machines

The mechanical structure of direct-current generators, motors and synchronous converters has been changed considerably in the last year or two. All the magnet frames for these units are now made of rolled steel, in two parts. Each of these parts is rolled into the form of a semi-circle, and then bolted together to form the magnet frame. Feet for supporting the unit are welded on to this frame. Rolled frames have been made in diameters as large as 160 in., with a thickness of 9¾ in. and a width of 26 in. In fact, in the case of a steel-mill motor, the frames were of such size that it became necessary to weld together two of these rolled frames to secure the proper width of magnet frame.

The rolled construction for magnet frames was adopted as a means of securing better commutation of direct-current machines, since there was felt to be less likelihood of flaws than in castings. Test results and experience with the rolled frame have justified its use and have proved conclusively that better commutation has been effected. In addition, the placing of the rolled frame on a so-called production basis has given rise to a less expensive unit than that with the cast frame.

One of the large synchronous converters constructed with rolled steel frame is shown in Fig. 21, the design being

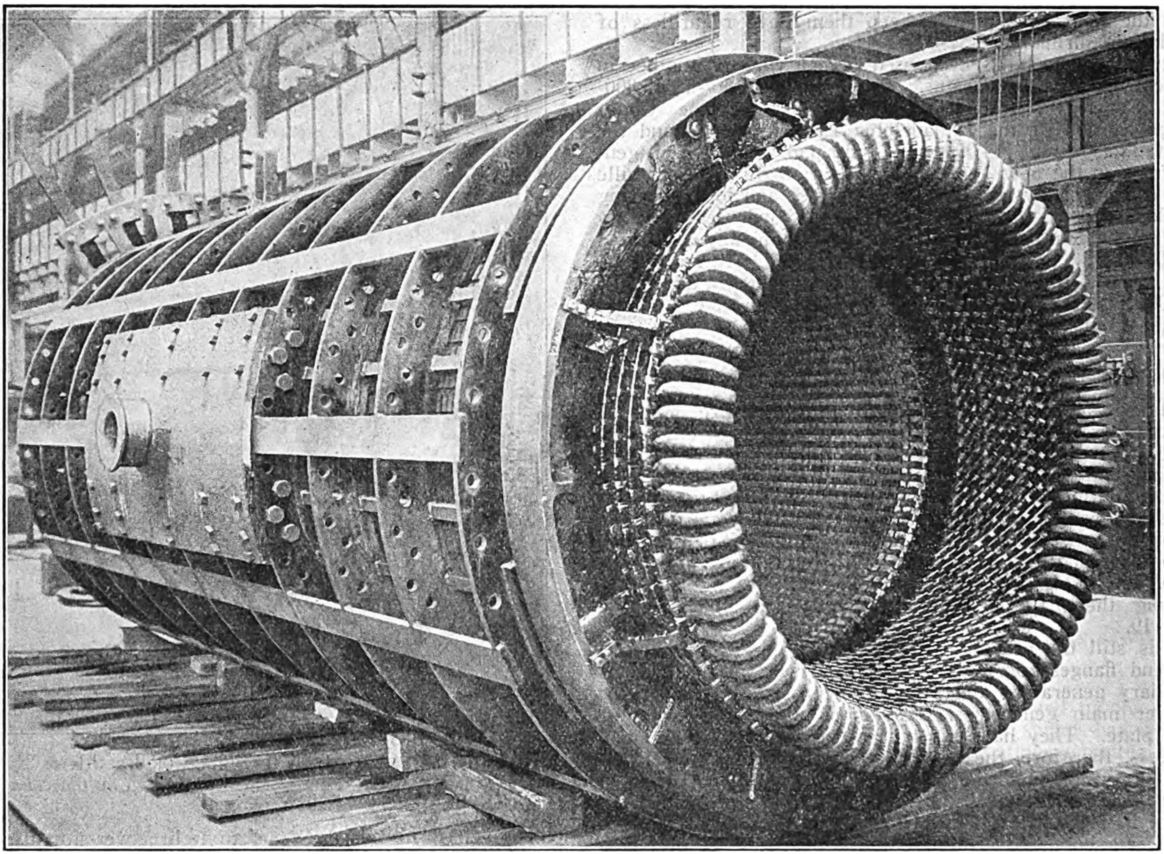


FIG. 19—STRUCTURAL-STEEL STATOR STRUCTURE AND ASSEMBLED WINDING OF 100,000-KV-A. GENERAL ELECTRIC TURBO-GENERATOR FOR SOUTHERN CALIFORNIA EDISON COMPANY.

typical of all new, large, direct-current generators, motors and converters.

On smaller converters and practically all motor-generator sets, the bases of the units are built of structural-steel shapes similar to the base of the small converter shown in Fig. 22. Bases of this type are easy to assemble, require no patterns and are much stronger than those of the cast type.

Other Mechanical Advances

There have in the past year been no other mechanical advances of sufficient importance to warrant their being mentioned in this report.

Insulating Compounds

Some of the early insulating varnishes were made by the dissolving of natural resins in alcohol or similar solvents. Such insulating media are characterized by a yellowish transparent color and are the so-called copal or shellac varnishes. Whereas these varnishes present an excellent appearance when first applied and so long as kept at low operating temperatures, it is unfortunately the fact that they ultimately lose their insulating properties due to their becoming dry and brittle, with consequent developing of cracks. Another defect of the yellow varnish as a base for insulating compounds is its hygroscopic quality.

The so-called black or bitumen varnish was developed some years ago by the research laboratory, which is even now engaged in an attempt further to improve this varnish, especially in its application to higher voltages and higher temperatures. At the present time the use of black varnishes has almost entirely replaced the use of yellow varnishes, the latter now being used almost solely for protection against oil.

The new varnishes are obtained by permanently combining mixtures of pure drying oils with either natural or artificial asphaltic compounds. The black varnishes have important advantages over the yellow varnishes in respect to flexibility, dielectric losses, resistance to heat and to moisture, and general insulating qualities.

The aging and plastic qualities are the ones which particularly distinguish the black varnishes from those of other types. These qualities result from the fact that each of the varnishes contains a great many constituents having slightly different boiling points. It therefore follows that, when one of these black varnishes shall have been heated to any given temperature, the low-boiling-point constituents will be slowly evaporated, while others will be in a soft state and still others will remain reasonably firm; the result being that, no matter at what temperature within reasonable limits the varnish shall have been aged, some elements will not have been heated to their flow point and the varnish will have preserved its flexibility of insulation throughout the process. The ordinary difficulties with a varnish base are that, on the one hand, if its flow point is such as to produce a firm compound at room temperatures, it will lose by evaporation a considerable number of its constituents at an increased temperature and will consequently become brittle, and that, on the other hand, if its flow point is such as to produce a firm compound at high temperatures, it will not become dry at room temperatures. It has been found, however, that some black varnishes will become thoroughly dry at room temperatures in approximately four hours and at 100 deg. cent. in approximately two hours, although further baking at the latter temperature will not destroy their desirable properties. Tests have shown that such varnishes on field coils, when baked at 200 deg. cent. for forty-eight hours, remain intact and still possess very good adhesive properties.

In conclusion it may be stated that, as a result of experiments, the black or bitumen varnish has become the standard for insulating compounds except when the insula-

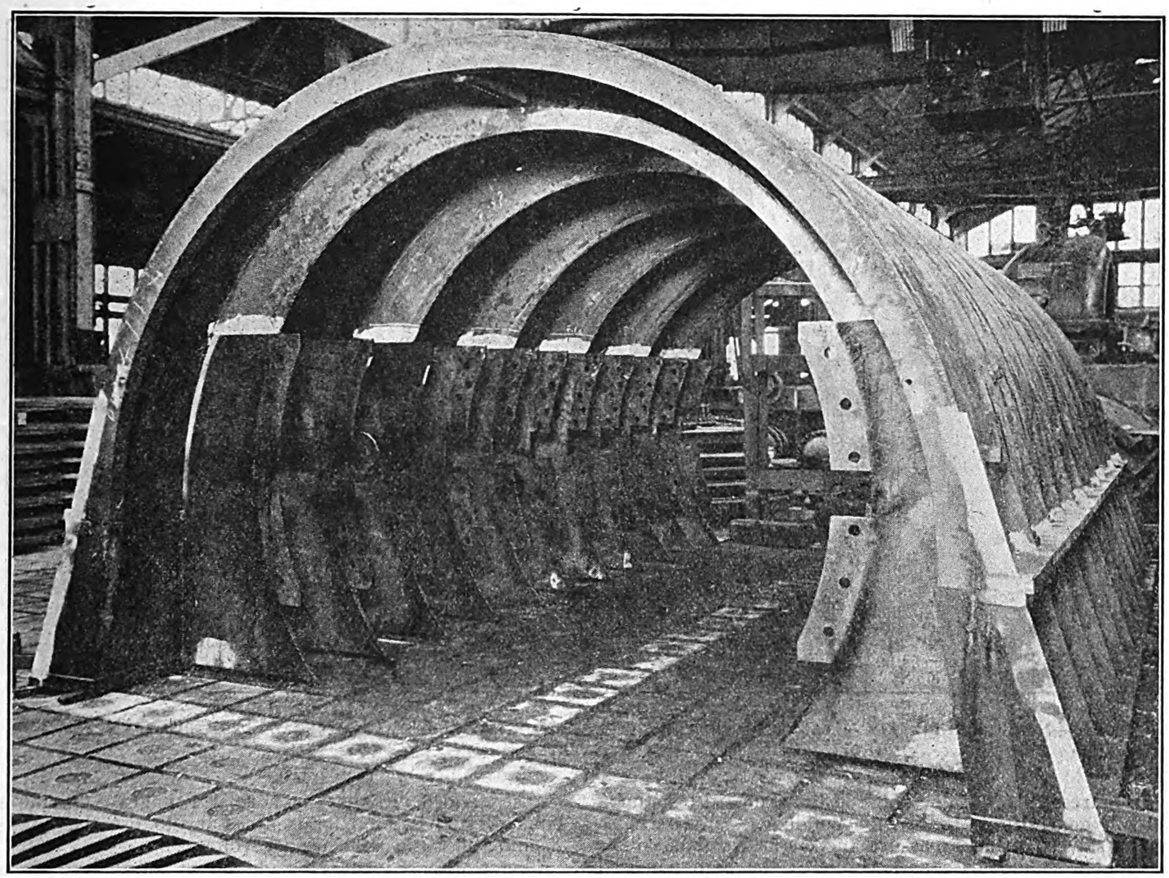


FIG. 20—STRUCTURAL-STEEL OUTER STATOR FRAME OF 100,000-KV-A. GENERAL ELECTRIC TURBO-GENERATOR FOR SOUTHERN CALIFORNIA EDISON COMPANY.

tion is to be immersed in oil, as in transformers. All the insulation used in the armature of generators, whether mica or varnished cambric, is now applied with black insulating varnishes, whose dielectric properties have lasting qualities far superior to those of the yellow varnishes. In fact, for this class of work, yellow varnishes are used only in the turn insulation of some of the field coils, which require adhesive qualities rather than dielectric properties. Shellac itself is used only in binding, where the cementing qualities are required for forming the strands of the bar or coil.

Higher Voltages

Within a relatively short time, enormous strides have been made in the development of generators and steam turbines. Rated capacities of single machines have increased to such an extent that the currents to be handled would greatly exceed the capacities of standard disconnecting switches and circuit breakers if the generators should be operated at voltages as low as 14,000. It has been found that generator voltages can be increased a certain amount with much less difficulty than would be encountered in developing circuit breakers of proportionately greater current-carrying capacity.

In 1918, two 12,500-kv-a., 22,000-volt, three-phase, 50-cycle, 500-r.p.m. synchronous condensers were sold to the Andhra Valley Power & Supply Company, Ltd., of Bombay, India. These condensers have been operated for eight years in an atmosphere of great humidity and high temperature without armature insulation failure.

In 1926, the Southern California Edison Company purchased two 100,000-kv-a., 16,500-volt, steam-driven turbo-generators, which are probably the first large generators purchased in America for operation at voltages decidedly higher than 14,000. The first of these two units has been constructed and is undergoing factory test at the time of this writing.

Several machines have been purchased for operation at 22,000 volts. A cross-compound unit rated at 235,000 kv-a. is now being built for the State Line Generating Company. A 61,765-kv-a. generator for the Super-Power Company of Illinois has already been shipped, after having been completely assembled and tested at the factory. All the high-potential tests, including the A. I. E. E. test of 45,000 volts, were made on the latter unit with no more appear-

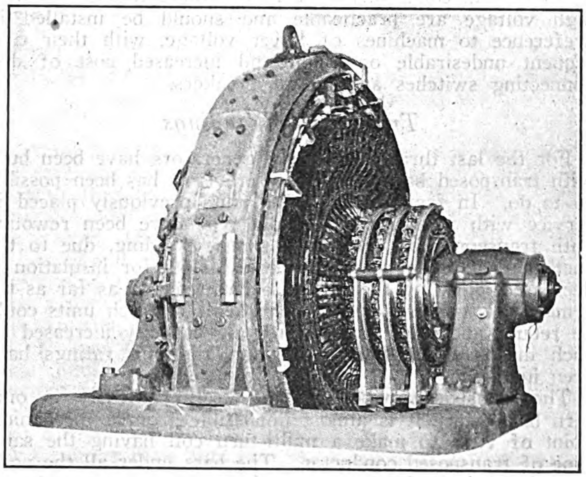


FIG. 21—4000-KW. GENERAL ELECTRIC SYNCHRONOUS CONVERTER WITH ROLLED-PLATE FRAME.

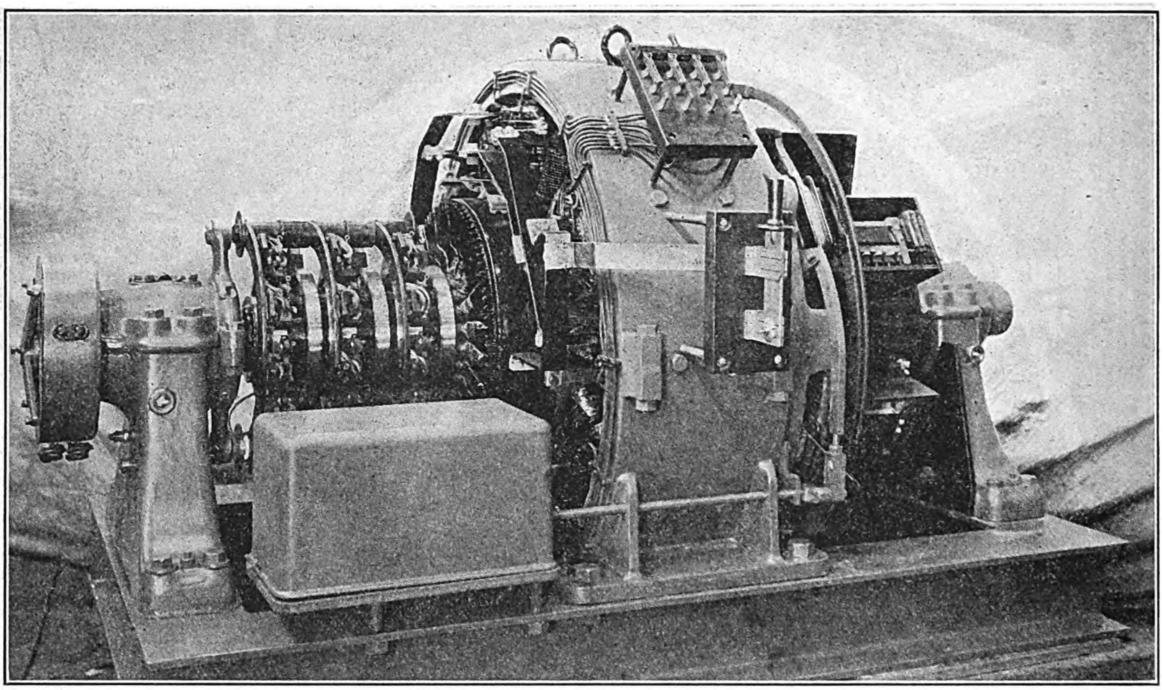


FIG. 22—Structural-Steel Base and Rolled-Steel Frame of 500-Kw. General Electric Synchronous Converter.

ance of distress than is to be noted in the standard tests upon 14,000-volt generators. Before the building of any of these units, tests were made to assure the engineers that no serious trouble should arise as a result of the high potential at which the stator windings would operate. Extra insulation was necessarily required, and certain changes were made in its application; however, no changes were made in the insulation itself. The extra insulation, unless the current density is reduced, increases the temperature difference between the copper and the cooling medium with respect to the difference existing in generators of lower voltage.

It is to be expected that generators, especially the smaller units, are more expensive when wound for 22,000 volts than for 14,000. More insulation is necessary, greater coil cross-section is required, a larger core is desirable, and the generator must be somewhat more liberally designed in respect to overall dimensions and weights than the generator of the same capacity wound for a lower voltage. However, under certain conditions large units wound for operation at high voltage are practicable and should be installed in preference to machines of lower voltage, with their consequent undesirable operation and increased cost of disconnecting switches and circuit breakers.

Transposed Windings

For the last three years turbo-generators have been built with transposed bar windings wherever it has been possible so to do. In fact, many of the units previously placed in service with windings of the old type have been rewound with transposed bar windings, such rewinding, due to the fact that the space taken up in the slots for insulation is decreased, allowing the rating to be increased as far as the armature is concerned; when the fields on such units could be rebuilt and their current-carrying capacity increased by such means as grooving the rotor, the unit ratings have been increased.

The transposed winding lends itself primarily to one-turn bars, since it is almost impossible from a mechanical point of view to make a multi-turn coil having the same type of transposed conductor. The bars under all the poles are placed in series on units of average size in order to secure the customary normal voltage. However, on larger units, voltage conditions are such that it becomes necessary to use divided circuits for normal voltages. On the small units of high voltage, it is necessary to use the multi-turn winding to secure the proper voltage.

The transposed bar is made up of a number of copper strips, these strips varying in width from 0.15 in. to 0.4 in., and in depth from 0.08 in. to 0.12 in. The width of the bar is always equal to the width of two of these strips, and the depth of the bar is determined by the current-carrying capacity necessary, the conductor on the larger units being from 15 to 24 strips in depth. Each individual strip of copper is insulated with asbestos, which is not only fire-proof but has sufficient insulation to prevent short circuits between strips, the multi-strip conductors being carefully tested to insure freedom from short circuits.

The method of transposition of the strips in the conductor is such that equal voltage is induced in each strip by the flux which leaks across the slots. Hence, there is no resultant voltage to cause circulating current in the conductor, and the transposed bar, therefore, has extremely low load losses.

As the bar is molded, it is wrapped with layers of mica tape, and is given a vacuum and compound treatment intended to dry the insulation and fill all the voids with compound. The bar is then wrapped with additional layers of mica tape, applied with a black varnish, until it is thought that sufficient layers have been applied safely to withstand the voltage of the generator. The bar is then given another compounding, followed by the application of a so-called stay binder. The final treatment consists of a wrapping with asbestos tape for the full length of the core, this tape serving as a combined mechanical protection and corona shield.

The use of bar windings permits the removal for repair or replacement of the top conductor without disturbing the remainder of the winding, whereas in the case of the coil winding it is necessary to disturb a considerable number of coil sides whether the defective coil side is in the top or the bottom.

It should be noted that the transposed bar is seldom used on salient-pole machines, since most units of this type require a multi-turn coil of more than two turns per coil, and since the inverted turn, whose load losses are almost as small as those of the transposed bar, presents considerably less difficulty in manufacture.

Divided Circuits

One of the outstanding developments of the year in the line of power generation is the double-winding generator. This machine has two completely independent windings, arranged in alternate slots and so connected under the poles that the terminal voltage of the corresponding phase of each winding is in phase with and numerically equal to that of the other winding.

Like the generator of higher voltage, the machine with divided circuits is the result of a demand to keep generator currents down to their present order of magnitude regardless of increases in unit capacities, in order that the disconnecting switches and circuit breakers so far developed will remain of adequate capacity. Although it was at first planned merely to divide the generator winding into two circuits, the idea was conceived, after a study of the design of the unit and its application to the central station, of using it in a bus arrangement similar to that diagrammatically shown in Fig. 23. It has been found possible under such conditions entirely to eliminate the necessity of installing bus reactors, since there is normally no electrical connection between bus sections and any transfer of kilovolt-amperage from one bus section to another must be made through the two generator circuits. It can readily be seen that the series reactance of these two circuits is interposed between bus sections, with a resultant greatly reduced value of short circuit on either bus. It can also be seen that, since the two generator windings are in the same structure and are therefore energized from the same magnetic field, they cannot fall out of step, and the reactance thereby introduced between bus sections in no way reduces system stability.

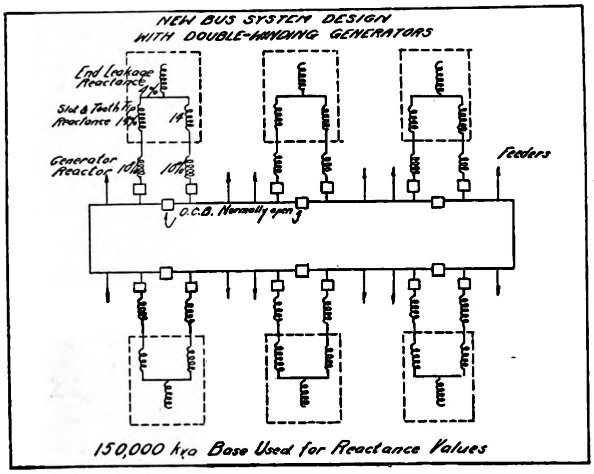

NEW BUS SYSTEM DESIGN
WITH DOUBLE-WINDING GENERATORS
End Leakage Reactance 4%
Slot & Tooth Tip Reactance 14%
14
Generator Reactor 10%
10%
Feeders
O.C.B. Normally open
150,000 kva Base Used for Reactance Values

FIG. 23—ONE-LINE DIAGRAM OF BUS SYSTEM WITH DOUBLE-WINDING GENERATORS.

In the past, two types of double winding have been considered, of which the first consists of two complete and independent windings in the same stator, each having two coil sides in every slot. Windings of this type are very expensive and are used mostly for multi-speed motors; it can readily be seen that the increased cost of installing four coil sides instead of two in every slot, and of making the corresponding end connections, is a considerable item, and that the cost of insulation is, to all intents and purposes, doubled by doubling the number of coils. These windings cannot be satisfactorily used in the double-winding generator, regardless of cost, since the two circuits would have slightly different values of reactance.

The second type of double winding consists merely of two circuits obtained by placing the coils under one-half the poles either in series or in multiple in each circuit. Such a winding, when arranged with coils under alternate poles in series so that the effects of uneven magnetic densities caused by rotor eccentricity, lamination joints and the like are as far as possible obviated, has been found very desirable for use with what is known either as split-conductor or interwinding differential protection. Unfortunately, however, two-circuit windings of the second type are impracticable for use in the double-winding generator: the placing in series of coils under alternate poles renders the series reactance between circuits of a high value, and adds greatly to the length and complexity of the pole connectors; the grouping together of coils under adjacent poles, or a separation of the coils under each pole of a two-pole unit, renders imminent the setting up of a prohibitive mechanical vibration as a result of the severe magnetic unbalance occasioned by the slightest inequality in loading.

What may be termed the third type of double winding, viz., the one originally mentioned herein and diagrammatically shown in Fig. 24, has permitted the introduction to the central-station industry of the double-winding generator. It can readily be seen from the illustration referred to that, whereas one winding always leads the other by one slot pitch under any given pole, two voltages are obtained which, as previously stated, are always in synchronism. It should be noted that, since each winding is uniformly distributed around the complete periphery, only perfectly balanced magnetic forces are produced. Another advantage in this method of winding is that no additional insulation or space is required, except for the additional number and special arrangement of the end connections and leads.

In calculating the characteristics of the double-winding generator, it is convenient to make use of the equivalent-circuit theory so familiar to all central-station engineers. Reference to the equivalent circuit obtained will suffice to show that power can be transmitted through the double-winding generator for the bus layout shown in Fig. 23.

Whereas it is of course necessary, in 13,200-volt generating stations whose units are rated at less than 135,000 kv-a. each, only to use one oil circuit breaker for each generator and, therefore, the use of the double-winding generator can eliminate only one breaker and one reactor for each bus section of a single ring bus; it is necessary, on the other hand, to use two breakers for each larger generator, and it is possible to eliminate two breakers and one reactor. However, in addition to the saving in number of breakers, there is a considerable saving in the interrupting capacity of the breakers required. As a matter of fact, such a generating station as is shown in Fig. 23 has only approximately one-half the interrupting duty imposed on its breakers for a bus fault as would be imposed by the same number of single-winding units with 10-per-cent reactors between the sections of a single ring bus. There is, of course, more of a hardship inflicted on the windings of the generator or generators nearest the fault, but the windings have sufficient thermal capacity to remain in operation under the circumstances for one minute with only approximately 30-deg.-cent. additional temperature rise in the copper.

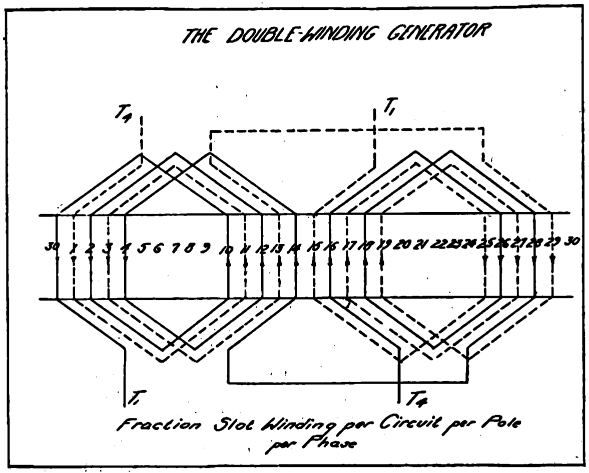

THE DOUBLE-WINDING GENERATOR
T4
T1
30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
T1
T4
Fraction Slot Winding per Circuit per Pole per Phase

FIG. 24—SCHEMATIC DIAGRAM OF THE GENERAL ELECTRIC DOUBLE-WINDING GENERATOR.

The double-winding generator is applied to its best advantage on systems where the loads on the bus sections can be reasonably balanced, thereby keeping the two circuits of each unit loaded equally. Although it is possible to carry load on either winding without carrying any on the other, the transferring of power through a unit under such circumstances results in a reactive voltage drop of from 25 to 30 per cent in the 60-cycle case, and of approximately 15 per cent in the 25-cycle case. It should be noted that if it should be desired to carry more than half of the generator capacity on either winding, it would be necessary to increase the copper cross-section, and, in effect, build a generator of larger capacity.

From calculations made on various systems and from actual tests made in the factory, there is believed to be a very strong tendency on the part of the rotors of synchronized double-winding generators to remain in synchronism with each other under fault conditions. In fact, when a three-phase short circuit was made on one bus section of a ring bus provided with no reactors and connected to two model double-winding generators, each of which was carrying load, the strength between the windings connected to the non-short-circuited section proved to be sufficient to hold the units in step for approximately one second; the oscillographs show that first one unit and then the other tried to speed up, but could not do so on account of the strength of the tie. In similar tests, where more than two machines were used in a ring bus, the units never pulled out of step with each other on three-phase faults and the voltages on the non-short-circuited bus sections held up to approximately twice the corresponding voltages of a system being fed by the same number of single-winding units and having 10-per-cent reactors between the sections of a single ring bus.

Tests and studies of the double-winding generator have shown that, in addition to being able to transfer through the unit from one section to another and to generate in either winding almost irrespective of the load carried by the other winding, one can vary the voltage of either winding of the unit to a certain extent by varying the field current. In fact, it is even possible to produce a lower terminal voltage on an unloaded winding than on a loaded winding by under-exciting the field when the unit is tied into such a bus arrangement as is shown in Fig. 23.

STATEMENT BY THE WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY

Structural Steel and Welding

The present tendency in the design of generators is toward the more general use of structural steel and fabricated construction. Such material is inherently more suitable than that used in the older designs, due to its absence of flaws and to its uniformity of strength. In fact, its strength and permissible working stresses are quite accurately known, whereas with cast material much dependence must be placed upon the soundness of the casting, which is, unfortunately, a more or less indeterminate factor. Furthermore, the use of fabricated construction has materially increased production, because there has been an elimination of large patterns and a reduction in the amount of machining required, and also because standard structural-steel sections, which are used to a great extent, can be kept in stock.

In the early designs of steam-turbine-driven generators, the frames were made of cast iron and, because the casting included the ducts for conducting the cooling air to and from the core, the frame widths became too great for shipment with the usual railroad clearances. The excessive weight involved is another objection to the cast frame. These objections led to the separation of the frame into two parts; a superstructure of light structural steel for the air passage and a skeleton frame for carrying the core.

This improvement in stator construction has resulted in such designs that the heaviest pieces to be shipped weigh approximately 30 per cent less than formerly, and the weights of the installed stators are approximately 15 per cent less. A similar improvement, leading to the construction of structural-steel skeleton frames, has decreased the stator weight for a given capacity by another 10 per cent, and has raised the capacity limit of machines which can be built and wound at the factory from 75,000 kv-a. to approximately 100,000 kv-a. A frame of the older type is shown in Fig. 25, whereas the skeleton-frame construction is illustrated in Fig. 26.

The use of structural steel for frames and similar parts is a logical extension of the practice of using rolled plate or laminated construction in the rotors of all the more important generators which have been built. The uniform structure of the material can be depended upon and, where this characteristic is essential, complete satisfaction cannot be obtained with castings. The inherent limitations in the use of castings for rotating parts has long been recognized, and in the past their application to such parts has been made chiefly in low-speed machines.

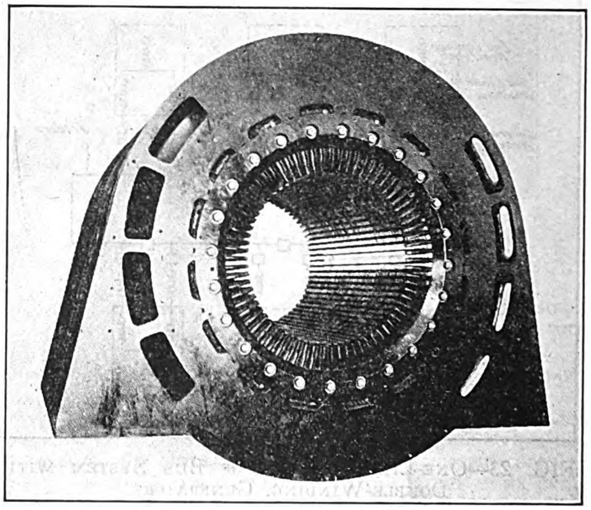


FIG. 25—WESTINGHOUSE FRAME USED IN THE OLDER TYPE OF GENERATOR.

During the past year, fabricated construction has been adopted for the standard lines of moderate-size low-speed horizontal and vertical synchronous motors and generators, general-purpose synchronous motors and the corresponding sizes of generators, direct-current generators and motors, and 3600-r.p.m. steam-driven turbo-generators. The full benefits of the fabricated construction have been obtained through complete redesign of the lines of machines in question.

Several illustrations may be given of present designs employing structural steel. A 7500-kv-a., 225-r.p.m. vertical waterwheel generator built for the city of Eugene, Ore., is of particular interest in that it is built entirely of fabricated material; the frame, the upper bracket and the lower bracket are of structural steel, and the rotor consists of a steel rim and I-beam spokes. The Aluminum Company of America has recently ordered two 45,000-kv-a., 150-r.p.m. vertical waterwheel generators, each of which will be built with a structural-steel frame and a structural-steel lower bracket; the rotor will be built of structural arms and hubs and a laminated rim. For the W. S. Barstow Management Corporation's Saluda River development, the four 40,625-kv-a., 138-r.p.m., vertical waterwheel generators will be unique in that they will be of the umbrella type, with only one guide and one thrust bearing, mounted below the rotor, from the lower bracket; the usual upper bracket will not be furnished, although a support for the direct-connected exciter will be necessary. The umbrella machines will have a structural frame and a structural lower bracket, but the

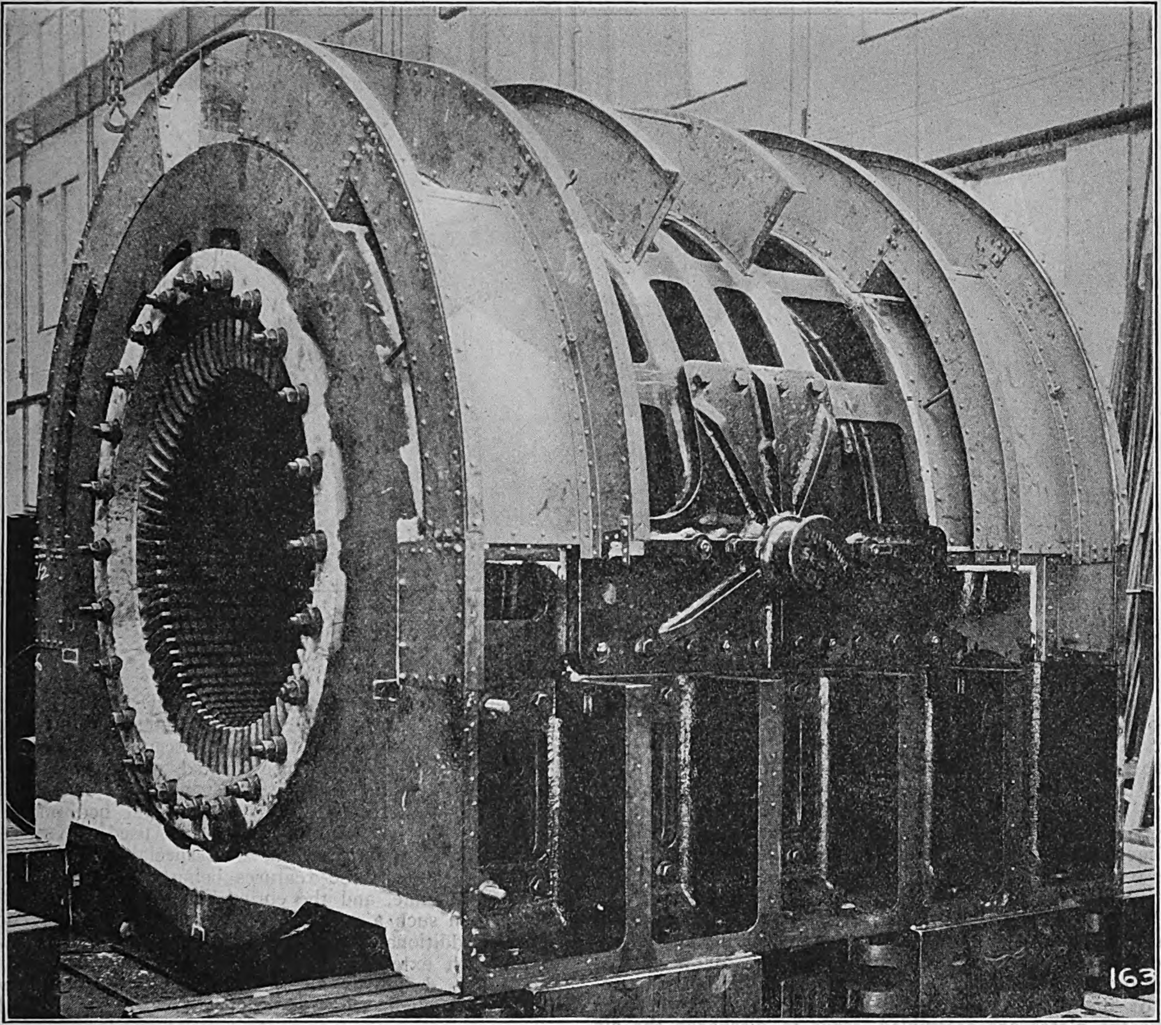


FIG. 26—WESTINGHOUSE SKELETON-FRAME CONSTRUCTION USED ON THE NEWER TYPE OF GENERATOR.

rotor will be of the cast-steel center-laminated-rim type; no oiling system will be required, since the thrust bearing and the guide bearing will operate in a floor of oil.

During the past year, there has been brought out a new line of low-speed vertical waterwheel generators employing fabricated construction throughout, the line including ratings of from 62½ kv-a. to 3000 kv-a. For this line the construction of fabricated frames is illustrated in Fig. 27; fabricated lower brackets, in Fig. 28; fabricated upper brackets, in Fig. 29; and built-up rotors, in Fig. 30. The rotors of this new line will consist for the most part of either cast-steel or forged-steel rims shrunk onto the structural-steel spider, with sufficient pressure to withstand the centrifugal forces obtained at the required overspeeds; the rims are either rim-keyed or welded to the spiders. Fig. 31 shows a 2000-kv-a., 180-r.p.m. vertical waterwheel generator for the Central Power & Light Company, and Fig. 32, a 100-kv-a., 450-r.p.m. machine for the Wisconsin Power & Light Company.

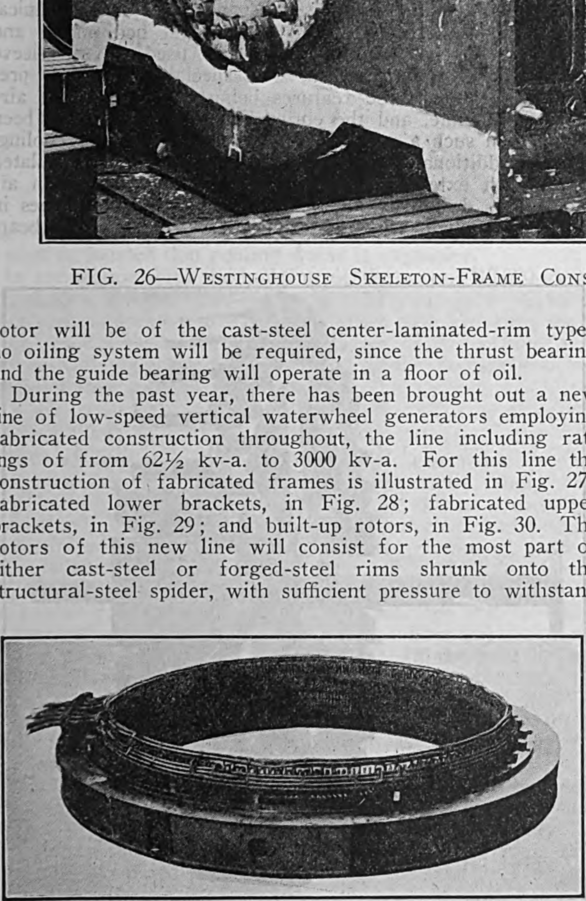


FIG. 27—FABRICATED FRAME OF WESTINGHOUSE VERTICAL WATERWHEEL GENERATOR.

Other Mechanical Advances

Size Considerations

The size of machines is increasing from year to year in order to satisfy the needs of the industry. The largest machines so far constructed, from the point of view of physical dimensions, are the 40,000-kv-a., 81.8-r.p.m. vertical waterwheel generators at the Conowingo Station of the Philadelphia Electric system. The largest steam-turbine generators constructed to date are the two 94,000-kv-a., 1800-r.p.m. machines comprising the cross-compound unit for the Hell Gate Station of the United Electric Light & Power Company. There has also been completed a 12,500-kv-a., 3600-r.p.m. steam-turbine generator with shaft fans of novel design. Three 30,000-kv-a. synchronous condensers have been built for operation at 720 r.p.m.

The Conowingo generators are, as previously stated, physically the largest generators ever constructed, each machine having a weight of approximately 1,140,000 lb. and an overall diameter of approximately 37 ft. Each unit is complete with an auxiliary shaft alternator, which furnishes power to a motor-generator set, which in turn furnishes the

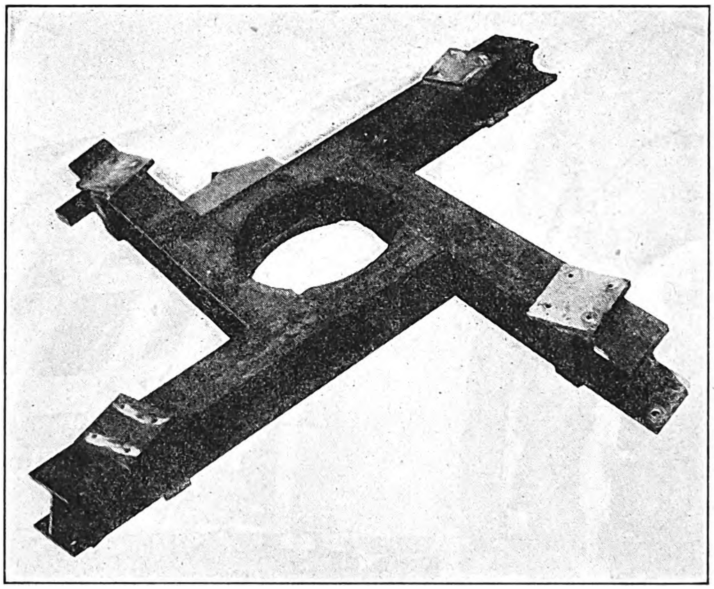


FIG. 28—FABRICATED LOWER BRACKET OF WESTINGHOUSE VERTICAL WATERWHEEL GENERATOR.

excitation for the main alternator. The auxiliary alternator is excited by means of a small direct-connected exciter.

The rotor construction of the large 1800-r.p.m. machines, as in the past, is of built-up plate. On the largest machines built, however, the rotor plates have a large central bore, possible only in rotors of this construction, such an arrangement providing greater facility for rotor cooling. A cross-section through one of the largest generators, showing the modified system of ventilation, is illustrated in Fig. 33. Oblique holes, drilled in the shaft ends before assembly with the plates, carry a portion of the cooling air to the center of the rotor. The remainder of the air is carried through the teeth by means of axial holes in the end portion of the rotor. Radial slots, cut into each rotor tooth before the plates are assembled, serve to discharge the air from the center of the rotor. Fig. 34 shows the rotor of a 94,000-kv-a. machine of the hollow-plate construction.

The 12,500-kv-a., 3600-r.p.m. steam-turbine generator referred to was built for the Kansas City Power & Light Company. A shop view of this machine is shown in Fig. 35. The machine has self-contained fans of novel design, the measured fan efficiency being 43 per cent, double the efficiency of any shaft fans previously designed to meet the difficult conditions imposed by large 3600-r.p.m. generators.

During the past year there has been developed a new line of synchronous condensers rated at from 500 kv-a. to 30,000 kv-a., embodying the latest practices in mechanical construction. Structural-steel frames and bed plates, and laminated punched rotor centers are used. New sleeve bearings have been designed, with special features to prevent oil leakage, these features being based upon the air-by-pass principle, and the entire line of bearings has been designed in such a manner as not to require water cooling. In case additional cooling is required, the oil is circulated through an external cooler, located in the foundation air duct. This design avoids the use of water-cooled pipes in the bearing shell, which, in some cases, have led to bear-

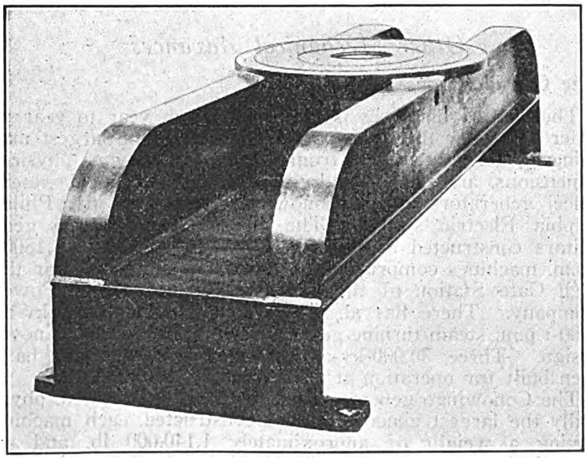


FIG. 29—FABRICATED UPPER BRACKET OF WESTINGHOUSE VERTICAL WATERWHEEL GENERATOR.

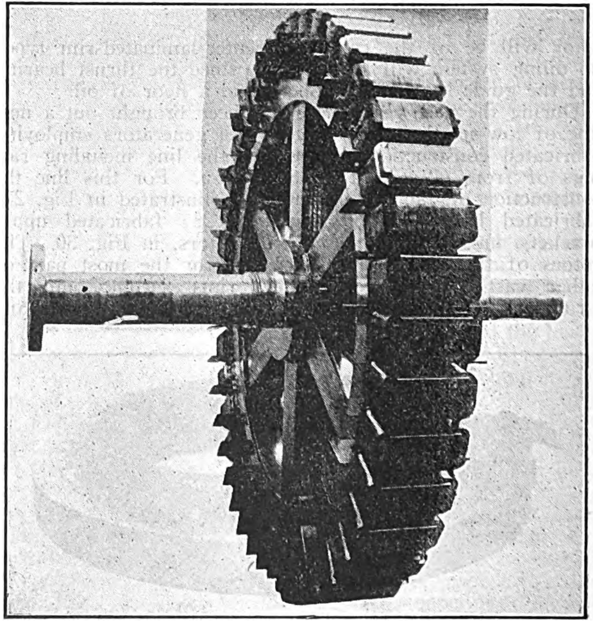


FIG. 30—BUILT-UP ROTOR OF WESTINGHOUSE VERTICAL WATERWHEEL GENERATOR.

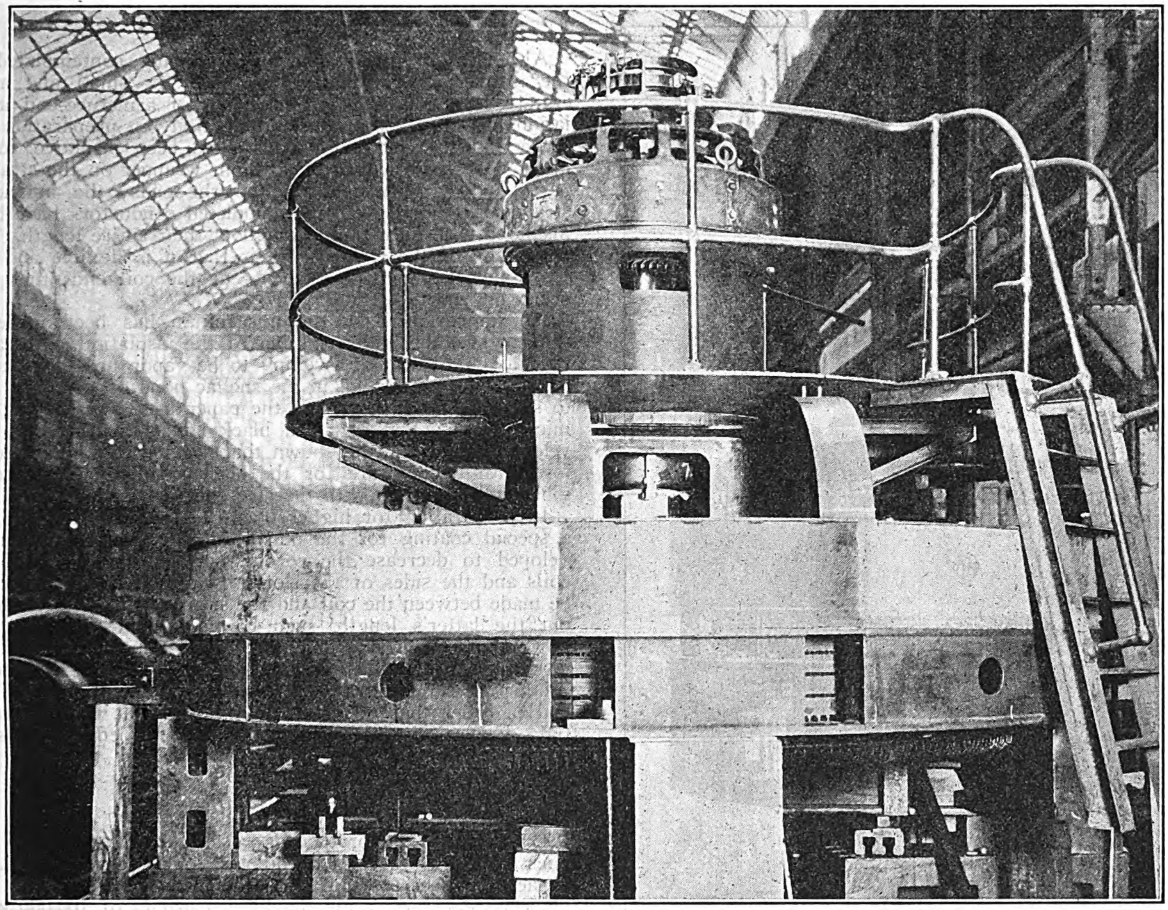


FIG. 31—2000-KV-A. WESTINGHOUSE VERTICAL WATERWHEEL GENERATOR FOR THE CENTRAL POWER & LIGHT COMPANY.

ing failures, and is of particular importance in the substation so located that cooling water is expensive.

In connection with the building of the second 40,000-kv-a. frequency-converter set for the Commonwealth Edison Company, a frame-shifting device of a new hydraulic type is being developed. This device consists of two pistons and hydraulically connected cylinders, with the necessary pressure-applying equipment.

Lubrication System

Several improvements have recently been made in the design of bearings and in the arrangement of oiling systems in order to lengthen the life of the oil, to reduce the amount of leakage and otherwise to improve lubrication. These improvements may be said to have eliminated certain oiling difficulties which are experienced in operation and which may largely be attributed to two principal causes, viz., the drawing of oil vapor out of the bearings and oil fans by suction created by the rotor, and the flow and creepage of any excess oil fed to the bearings. In the past it has been necessary to adjust the oil flow to the bearings to almost the exact amount required, i.e., sufficient oil had to be supplied adequately to lubricate the bearings but no excess could be permitted since such excess would be likely to overflow and to find its way into the machine itself.

The so-called pressure overflow system has been developed to remedy the difficulties experienced with the old method of lubrication, and is shown diagrammatically in Fig. 36. In the new system, the oil is discharged from the pump and is carried to a header, where the feed lines to the various bearings are connected. In the header is a pressure-relief valve adjustable for pressures of from two to ten pounds per square inch, the arrangement being such that any pressure between these limits can be maintained practically constant at the point where the three connections for the bearing feeds are made and the oil flow to individual bearings is therefore not influenced by the adjustment of oil flow to any other bearing. It can readily be seen that, if more oil should be fed to one of the bearings than to either of the others, less oil would overflow to the relief valve and the pressure at the point where the feed lines are connected would therefore remain practically unchanged. In addition to the fact that vapor formation and oil creepage are practically eliminated by the new oiling system, there is the marked advantage that oil will be delivered to the bearings, as the generator is started from rest, much sooner than with the old system.

In the new system, overflow connections have also been provided at the top of each guide bearing. These connections permit excess oil to be supplied to each bearing as an assurance of adequate lubrication, but without any danger of flooding the machine.

It has been customary in the past to return the oil from the upper guide bearing directly to the lower oil pan, through pipes in the rotor, with a consequent tendency, due to the rotation of these pipes, for the production of vapor where the oil would be discharged from the pan. The present practice is to provide a stationary oil pan beneath the upper guide bearing, from which a drain is connected to the lower pan.

Outdoor Generators

Some attention in recent years has been given to so-called outdoor generators. So far as the generator itself is concerned, investigation seems to indicate that there is little in the requirements for this service necessitating modification of the present type of construction. Generators of standard construction, but with housings for protection and ventila-

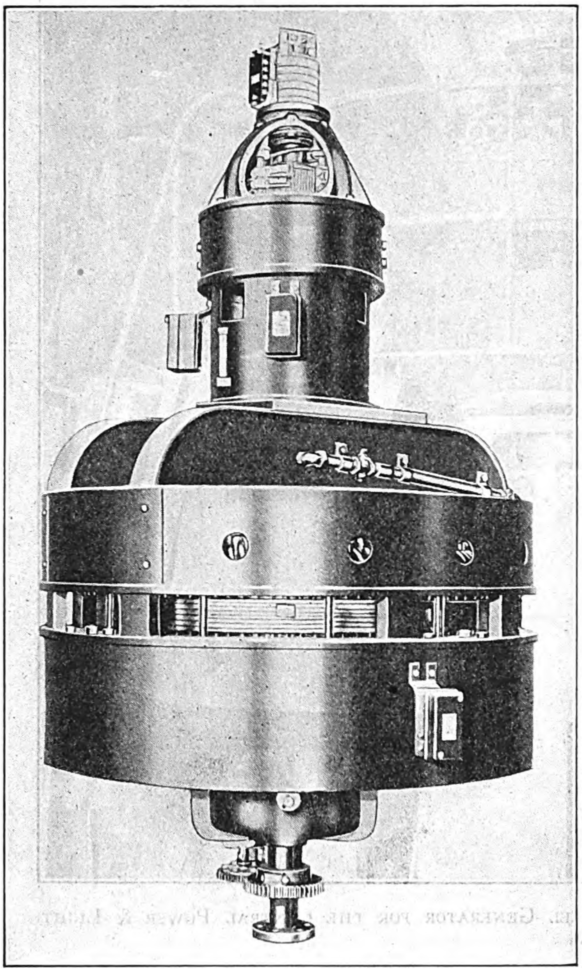


FIG. 32—100-Kv-a. Westinghouse Vertical Waterwheel Generator for the Wisconsin Power & Light Company.

tion, have been installed in a number of instances. These may be more logically termed semi-outdoor installations, and actually represent no departure from ordinary practice insofar as generator design is concerned. The novelty is found in the reduction of the building to the simplest structure, location being permitted in the dam or other advantageous place. Such an installation is shown in Fig. 37. It has even been proposed that the usual frame be omitted and the various parts of the generator built into and supported by the concrete foundations. There is little merit in this scheme, since some supporting structure for the stator punchings would be necessary in any event and since the problem of alignment would be extremely difficult of solution.

Power-Operated Brakes

Power-operated brakes are occasionally installed in connection with automatically controlled waterwheel generators. The value of brakes appears to lie principally in the assurance that the waterwheel will be brought to a complete stop when not delivering power. Water leakage sometimes causes rotation in reaction-wheel installations and, under such conditions, the brake will prevent useless wear and tear or bring the unit to rest for inspection or repair. The necessity for the extra expense and complication of brakes is much reduced when leakage can be controlled. There appears to be little excuse for the use of brakes where the driving force can be positively removed, as it can in the case of impulse-wheel installations.

Insulating Compounds

Although no major changes are being contemplated in the insulation of armature windings for small and moderately sized machines, the question of armature-coil insulation has been given considerable study in preparation for larger units. The stator coils have been insulated for a number of years with a micafolium wrapper on the straight parts and with treated tape on the ends; the individual strands in the coils and the completed conductors have been insulated with mica tape throughout their entire length. The advantage of the treated tape is that it is flexible and can withstand the slight movements of the coil ends that will occur on short circuits.

An improvement in the micafolium has been made to prevent swelling and wrinkling of the insulation. Research revealed the cause of swelling to be vapor pressure due to the presence of alcohol in the shellac bond of the mica and, to some extent, moisture in the paper used for backing the mica. A new and so-called black bond was therefore developed, and it can be shown that the increase in dielectric loss with temperature for the black bond is almost negligible in comparison with that for the shellac bond.

In preparation for higher operating voltages than 13,800, a special coating for the outside of the coils has been developed to decrease the corona between the sides of the coils and the sides of the slots. If a perfect contact could be made between the coil and the sides of the slots throughout the latter's length, such corona would not exist; if, however, the coil side touches the slot only at points, there is corona from the other points of the coil side. A semiconducting film is therefore required on the surface of the coil in order that all points may be kept at ground potential. Experiments have demonstrated the effectiveness of such a conducting film.

Higher Voltages

Considerable importance is at present attached to the question of using higher voltages for generators of large capacity. Whereas, so far as the manufacture of the machine is concerned, a unit having a capacity of 100,000 kv-a. can be rated at 13,800 volts, nevertheless the cost of circuit breakers, disconnecting switches and busses makes it desirable to build such machines, especially for new generating stations, with terminal voltages as high as 22,000.

Transposed Windings

In order to build machines of extreme core lengths, for large ratings, it became necessary to modify the design of the stator coils. On shorter machines it had been customary to build each coil in one piece, the coil being continuous from the front, without any connection in the rear. Such a coil has the advantage of being turned over in the rear-end connection, i.e., the top conductor of the top coil side in one slot becomes the bottom conductor in the bottom coil side in the return slot. Partial transposition is thereby had and, when additional transposition is provided at the front of the coil, the eddy-current losses remaining will be less than 30 per cent of the copper loss.

If long coils were to be constructed in this manner, they might weigh as much as 350 lb. each, and would be difficult to handle in the insulating process and in the winding of the coils in the core. It is therefore desirable to construct them in halves, and to make connections at both the front and the rear. If it were possible to connect each strand individually at the rear, the structure of the half-coils would be the same as of the full coils so far as eddy current losses are concerned, but unfortunately, in the case of deep coils, such construction is impossible because of insufficient space to make the connections of the many strands. It is therefore necessary to transpose the strands somewhere between the front and rear of the machine, it being the easiest to perform this transposition in the straight, buried part of the coil.

The method used in large machines is a combination of transposition of strands within the slot and transposition outside the slot at the ends of the coils. Every conductor in the coils is split up into groups of several strands in

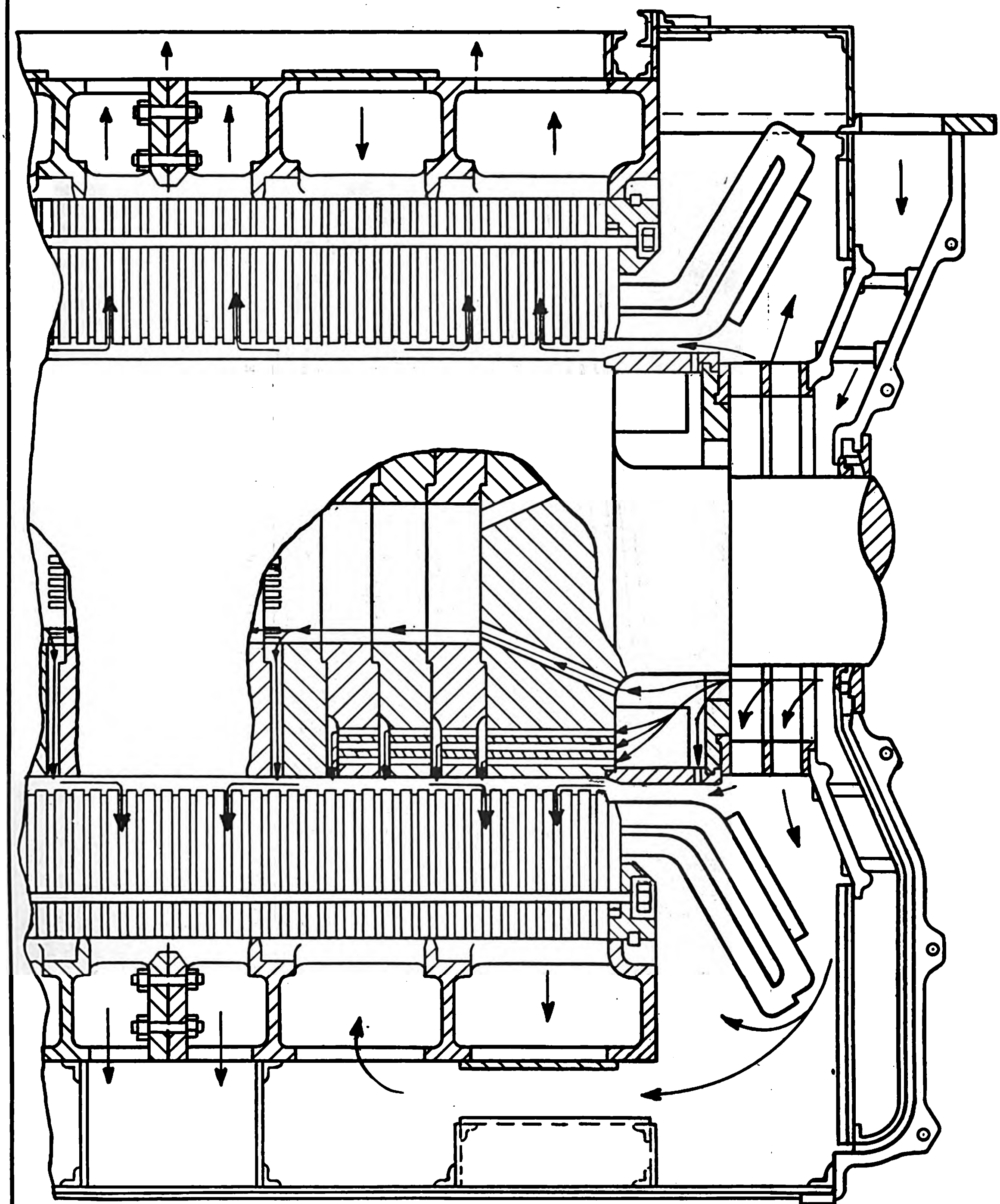


FIG. 33—CROSS-SECTION THROUGH LARGE WESTINGHOUSE GENERATOR SHOWING MODIFIED SYSTEM OF VENTILATION.

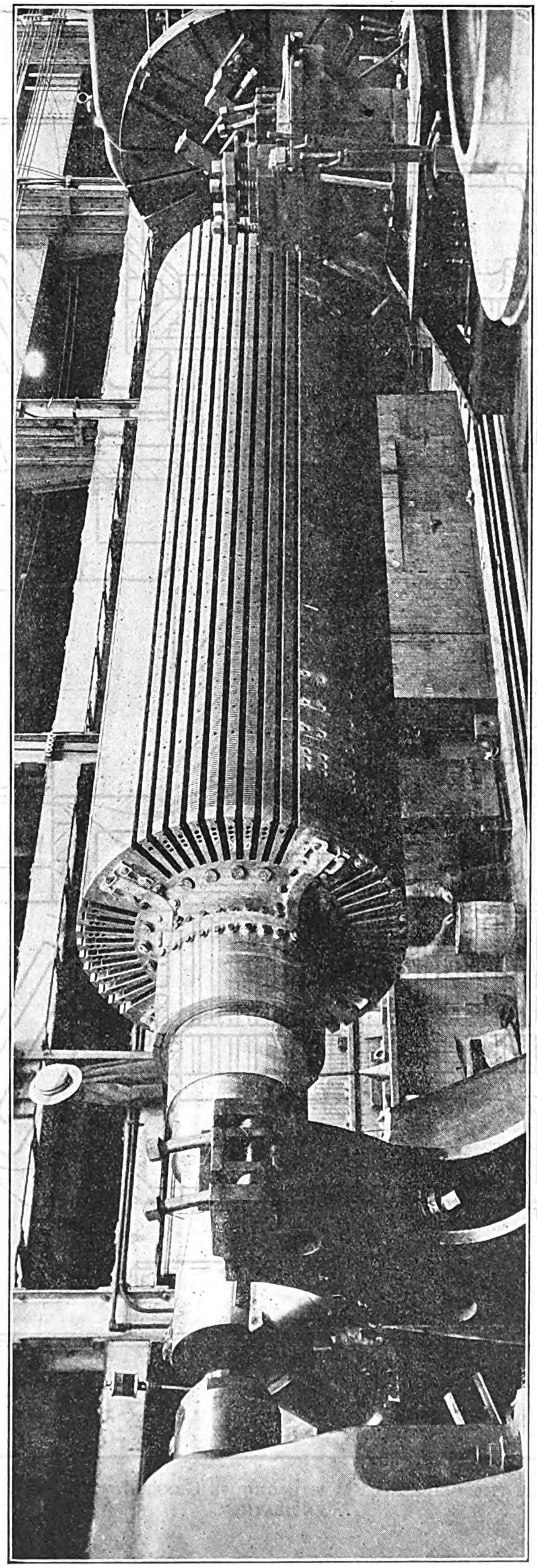


FIG. 34—ROTOR OF 94,000-KV-A. WESTINGHOUSE MACHINE OF THE HOLLOW-PLATE CONSTRUCTION.

depth, and the strands in each group are transposed within the slot to eliminate the eddy currents between the strands in that particular group. The groups are then transposed with respect to each other at the front end of the coil to eliminate the eddy currents between whole groups. One group and the details of one strand are shown in Fig. 38.

Each strand is insulated with mica tape in the same manner as though the coil had no internal transposition. At the points of transposition, half the cross-section of the strand is removed but, because the amount is a small percentage of the total and also because of the high thermal conductivity of copper, the temperature at these points is not materially different from that at other points of the conductor. Tests made with thermo-couples located at different points on the coil have shown no greater temperature variation than would be expected in a conductor of uniform cross-section.

Divided Circuits

Divided circuits have been used to a great extent on large turbo-generators, some of the larger units having as many as three circuits in parallel. The particular windings, however, have always been tied solidly into one bus section and the problem of unbalance between windings has not been encountered.

The use of divided windings has been given considerable study during the past year, particularly with respect to the possibility of connecting the parallel sections of each phase winding to a separate bus in order to reduce the value of normal current that the generator breakers and disconnecting switches are required to carry, and also to reduce the value of short-circuit current which the breakers must interrupt.

An analysis of the situation brings out the following methods of obtaining separate circuits:

Type I—Standard parallel-circuit generators having

A. Windings in two parallel circuits on the same part of the magnetic circuit.

1. When both circuits are equally loaded, the generator is perfectly balanced.
2. When windings are operated at different loads and

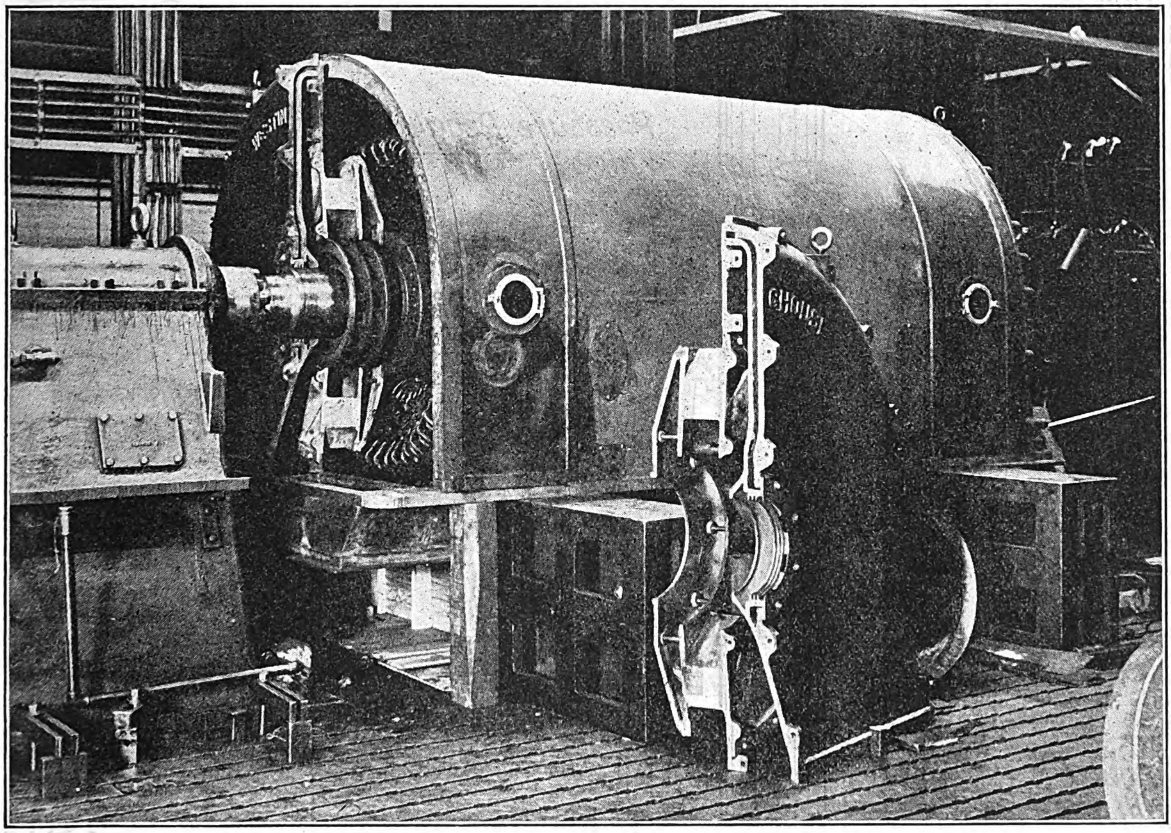


FIG. 35—SHOP VIEW OF 12,500-KV-A. WESTINGHOUSE STEAM-TURBINE GENERATOR FOR THE KANSAS CITY POWER & LIGHT COMPANY.

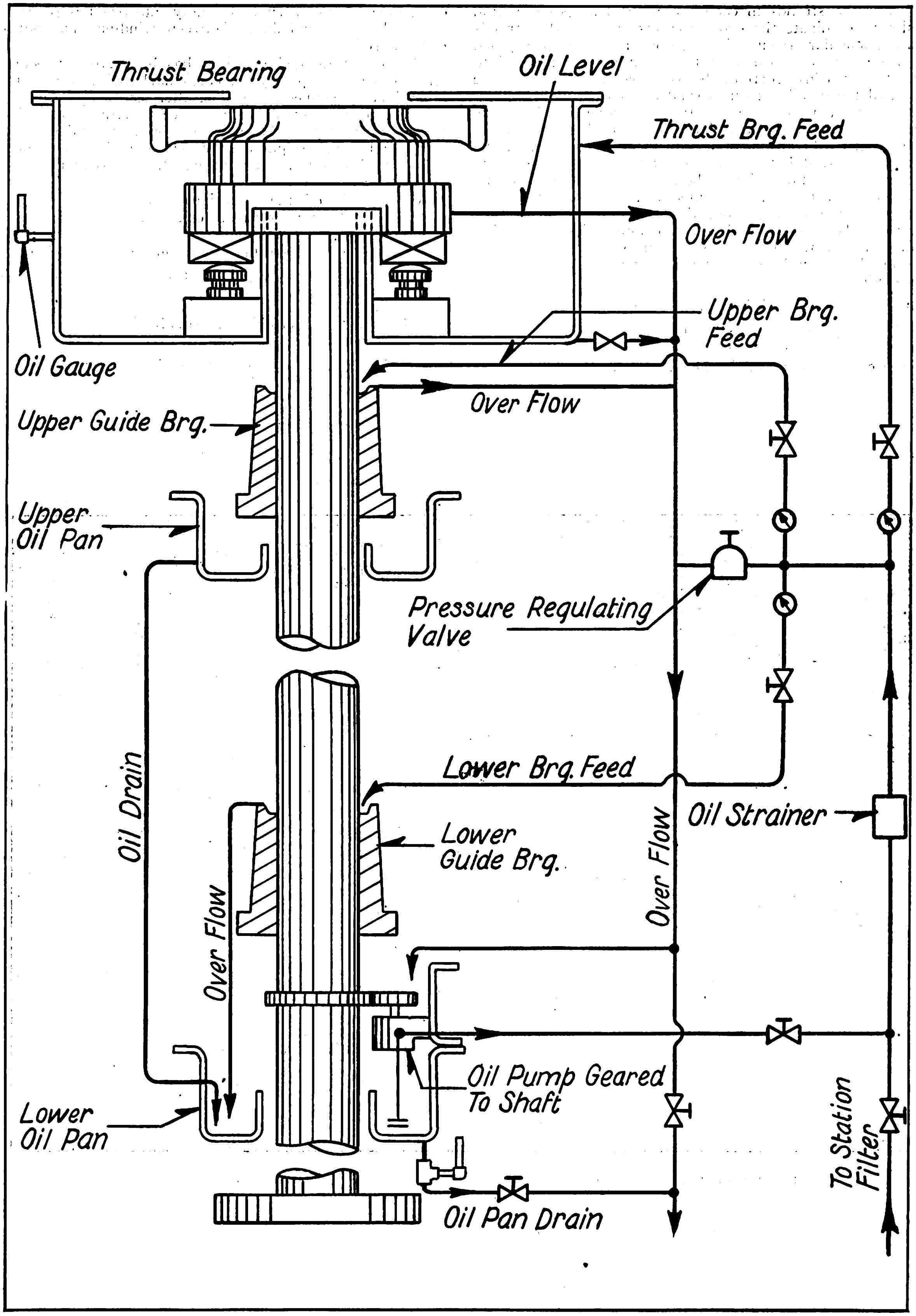

Thrust Bearing
Oil Level
Thrust Brg. Feed
Over Flow
Upper Brg. Feed
Oil Gauge
Over Flow
Upper Guide Brg.
Upper Oil Pan
Pressure Regulating Valve
Lower Brg. Feed
Oil Drain
Oil Strainer
Over Flow
Lower Guide Brg.
Over Flow
Oil Pump Geared To Shaft
Lower Oil Pan
To Station Filter
Oil Pan Drain

FIG. 36—Schematic Diagram of Westinghouse Pressure Overflow Lubrication System.

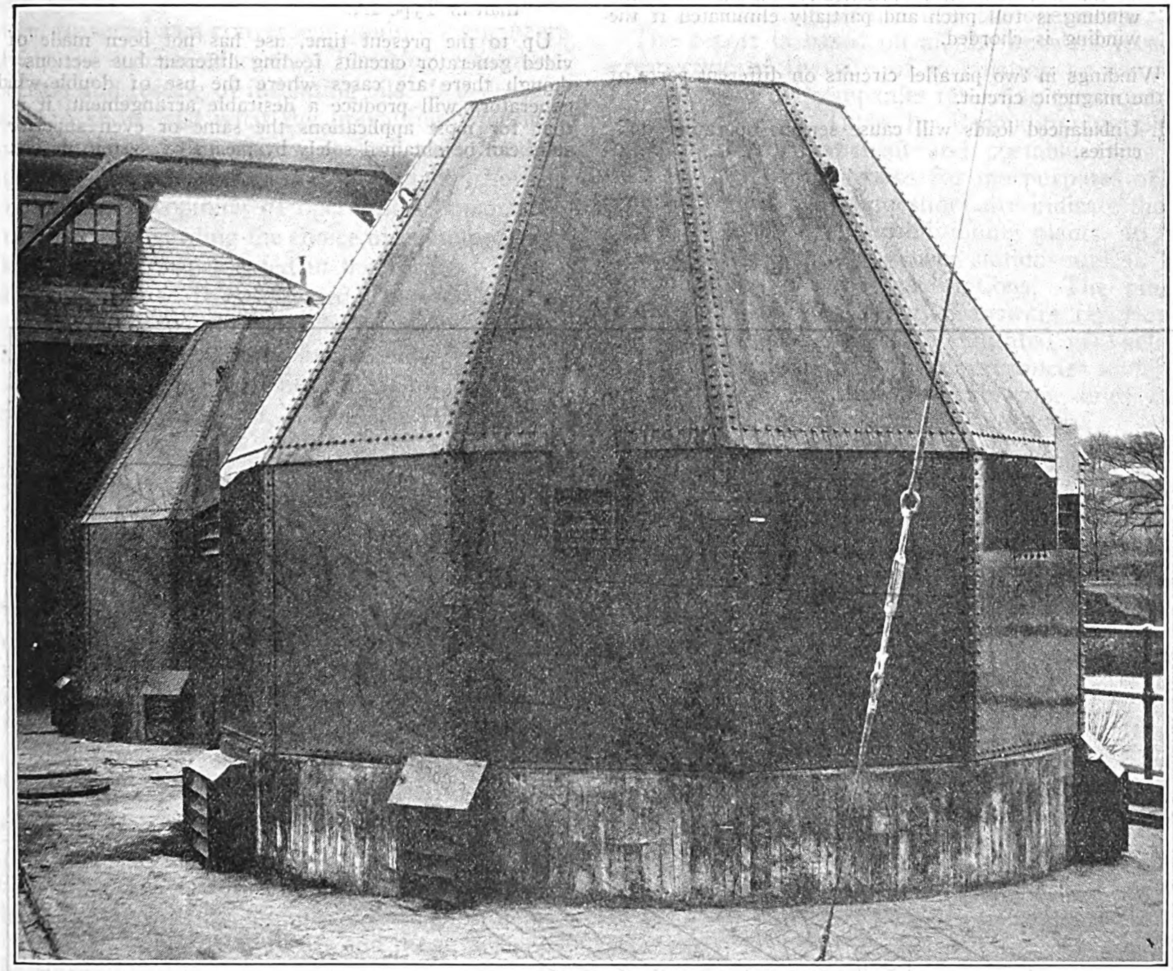


FIG. 37—Installation of Westinghouse Semi-Outdoor Vertical Waterwheel Generators.

different power factors, the generator is perfectly balanced, but consideration must be given to

a. Overloading individual windings.

b. Possibility of obtaining only average voltage regulation of the two windings.

3. When short circuit occurs on one winding only, the other being open-circuited, the current delivered by the one winding will equal approximately that of both windings when short-circuited simultaneously; special end-turn bracing will therefore be required.
4. The reactance between the terminals of the two windings is approximately equal to the sum of the end-leakage reactance of each circuit; the reactance of the slot portion is practically eliminated if the winding is full pitch and partially eliminated if the winding is chorded.

B. Windings in two parallel circuits on different parts of the magnetic circuit.

1. Unbalanced loads will cause serious operating difficulties.
2. When short circuit occurs on one winding, the current will be the same as that per circuit when both windings are short-circuited.
3. Each winding can exert a torque on the common rotor and thus the generators on adjacent busses have considerable capacity for the interchange of synchronizing power.

Type II—Generators having double windings under the same poles but not occupying the same slots.

A. Unbalanced loads may be carried in normal operation.

B. The short-circuit current per circuit is reduced somewhat.

C. There is higher mutual reactance between windings than in Type IA.

Up to the present time, use has not been made of divided generator circuits feeding different bus sections. Although there are cases where the use of double-winding generators will produce a desirable arrangement, it is felt that for most applications the same or even superior results can be obtained solely by means of system design.

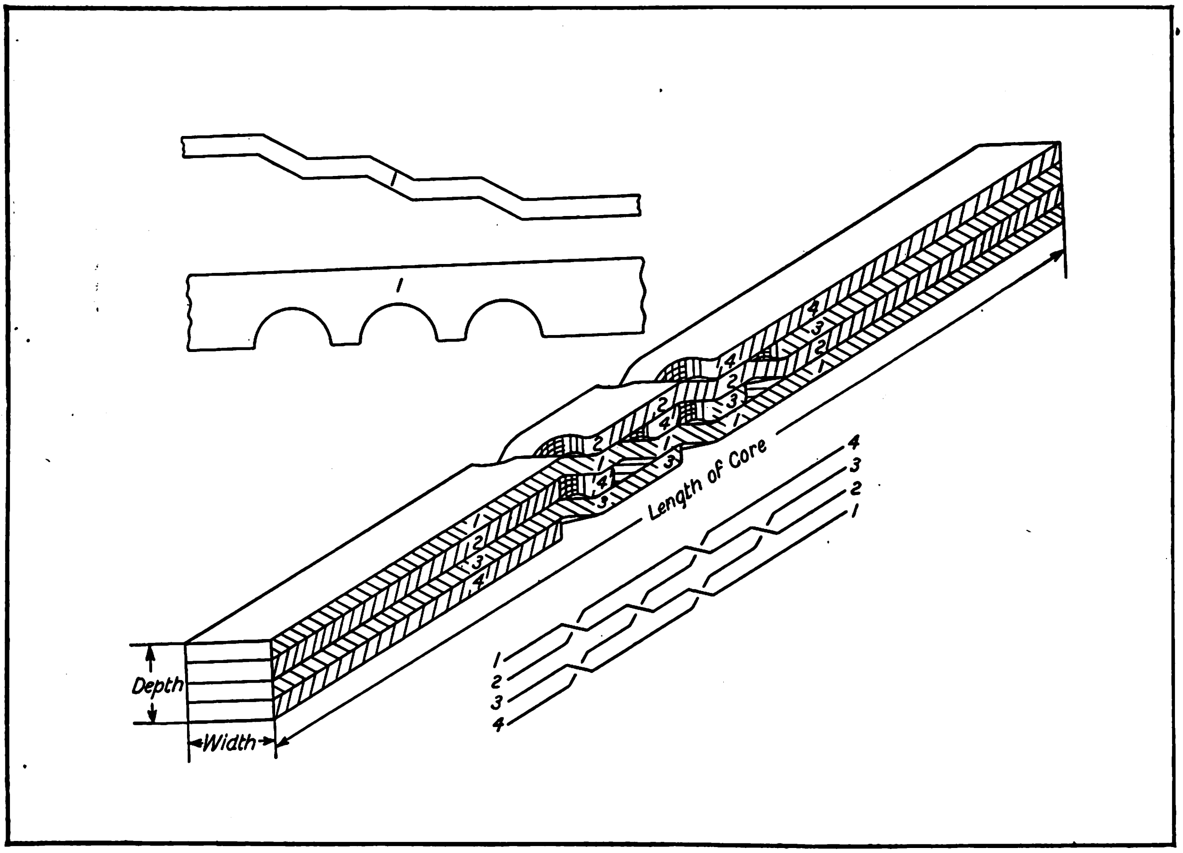


FIG. 38—WESTINGHOUSE TRANSPOSED WINDINGS, SHOWING ONE GROUP AND THE DETAILS OF ONE STRAND.

STORAGE, HANDLING, TREATMENT, INSPECTION AND TESTING OF INSULATING OILS

This serial report of the Electrical Apparatus Committee shows the trend in practice for the storage and treatment of insulating oils as reported by 57 representative operating companies.

The report includes a summary of the prevailing practice throughout the United States and presents Tables, Data, Appendices and Actual Layouts of outstanding Oil Conditioning Plants.

PURPOSES AND CONCLUSIONS

The report which follows has but one purpose, namely, to serve as a convenient guide for engineers studying the subject of storage, handling, treatment, inspection and testing of insulating oils. It is detailed enough to show just what the prevailing American practice is on various points, as well as to outline minority usage. Actual figures are given showing the consensus of opinion of operating companies.

Conclusions regarding the choice of equipment and methods have been presented in the form of appropriate subcaptions. It is intended that each subcaption shall summarize the prevailing practice outlined in the paragraph or paragraphs immediately following it; as, for example, "Separate Storage Tanks Predominate."

The replies of the various companies reporting indicate that the utilization and reclamation of oils are given exacting attention by the operators.

The report is based on all the answers received, irrespective of the size of installation or company. The names of the companies returning questionnaires will be found in Table I. Reconditioning plants, including both permanent and portable types, are classified into three groups for the purposes of this report. Replies to the questionnaire indicate the existence of 29 central reconditioning plants, 46 local reconditioning plants at power stations and 42 local reconditioning plants at substations. The number of direct positive or negative answers reported by the operating companies are indicated in Table II. It should be noted that the discrepancies in figures not totaling 57 are due to certain companies which were not able to answer all the questions.

PART I

DESIGN OF HANDLING AND TREATING EQUIPMENT

Permanent Facilities Usually at Power Stations

Permanent facilities for the storage and treatment of insulating oils for electrical equipment are provided by more companies at power stations than at central reconditioning plants, and by considerably less than either at local substation reconditioning plants. (Table II, Part I, 1.)

Importance of Installation Determining Factor

At power stations, the decision to install permanent oil handling facilities is based in most cases on the importance of the station. At the substations, however, the amount of oil in use and the importance of the substation are each equally important factors in determining whether such permanent facilities shall be installed. (Table II, Part I, 2.)

Oil Quantities Large

The total quantity of transformer and circuit breaker oil in service varies with the size of the power stations and the substations.

The maximum quantity of transformer oil reported used at power stations was 550,000 gallons and at substations 950,000 gallons. The maximum quantity of circuit breaker oil reported in service at the power stations was 322,000 gallons and at substations was 304,000 gallons. (Table II, Part I, 3.)

Separate Storage Tanks Predominate

The majority of companies provide separate tanks for clean and dirty oil storage at power stations rather than at central reconditioning plants or at substations. (Table II, Part I, 4.)

Separate tanks for transformer and circuit breaker oil respectively are provided at central reconditioning plants and at local reconditioning plants by the majority of companies. Companies each having an installed capacity of 100,000 kv-a. or more provide separate tanks for transformer and circuit breaker oil respectively at all reconditioning plants.

Permanent Tanks Preferred for Clean Oil

Permanent tanks are installed for clean oil storage, in most cases, at power stations and at central reconditioning plants, but only in a limited number of cases at substations. (Table II, Part I, 5.)

Where permanent tanks are not installed for clean oil storage, the majority of companies use drums in preference to portable tanks or tank trucks. The Toledo Edison Company and the Commonwealth Edison Company use portable tanks and tank trucks respectively for handling clean oil at power stations. The Toledo Edison Company also uses portable tanks at its substations; tank trucks are utilized at substations for clean oil storage by the Commonwealth Edison Company and the Puget Sound Power & Light Company respectively. (Table II, Part I, 6.)

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* Publication No. 289-48, Serial Report, Electrical Apparatus Committee.

TABLE I

COMPANIES HAVING RECONDITIONING PLANTS—PERMANENT AND PORTABLE

COMPANY	Central Reconditioning Plant	Local Plant at	
		Power Station	Sub-station
1. Alabama Power Co. Birmingham, Ala.	No	Yes	Yes
2. Arkansas Power & Light Co. Little Rock, Ark.	No	Yes	Yes
3. The Bronx Gas & Electric Co. New York, N. Y.	Yes	Yes	Yes
4. Brooklyn Edison Co. Brooklyn, N. Y.	Yes	Yes	No
5. The California-Oregon Power Co. San Francisco, Cal.	No	Yes	No
6. Canadian Niagara Power Co. Niagara Falls, Ont., Can.	Yes	No.	No
7. The Cleveland Electric Illuminating Co. Cleveland, Ohio	No	Yes	Yes
8. Commonwealth Edison Co. Chicago, Ill.	Yes	Yes	Yes
9. Consolidated Gas, Electric Light & Power Co. of Baltimore Baltimore, Md.	Yes	No	No
10. Consumers Power Co. Jackson, Mich.	No	Yes	Yes
11. Dallas Power and Light Co. Dallas, Tex.	Yes	Yes	Yes
12. Day & Zimmermann, Inc. Philadelphia, Pa.	Yes	Yes	Yes
13. The Dayton Power & Light Co. Dayton, Ohio	Yes	Yes	No
14. The Detroit Edison Co. Detroit, Mich.	Yes	Yes	Yes
15. Duquesne Light Co. Pittsburgh, Pa.	Yes	Yes	Yes
16. The Edison Electric Illuminating Co. of Boston Boston, Mass.	Yes	Yes	Yes
17. The Empire District Electric Co. Joplin, Mo.	No	No	Yes
18. Fall River Electric Light Co. Fall River, Mass.	No	Yes	Yes
19. Federal Light & Traction Co. New York, N. Y.	No	Yes	Yes
20. Fort Worth Power & Light Co. Fort Worth, Tex.	Yes	Yes	No
21. Grays Harbor Railway & Light Co. Aberdeen, Wash.	No	Yes	No
22. Houston Lighting & Power Co. Houston, Tex.	No	Yes	Yes
23. Idaho Power Co. Boise, Idaho	Yes	Yes	No
24. Kansas City Power & Light Co. Kansas City, Mo.	Yes	No	Yes
25. Los Angeles Gas & Electric Corp. Los Angeles, Cal.	Yes	Yes	Yes
26. Louisville Gas & Electric Co. Louisville, Ky.	No	No	Yes
27. The Milwaukee Electric Railway & Light Co. Milwaukee, Wis.	No	Yes	Yes
28. Minnesota Power & Light Co. Duluth, Minn.	No	Yes	Yes
29. Narragansett Electric Co. Providence, R. I.	Yes	Yes	No
30. The New York Edison Co. New York, N. Y.	Yes	No	No
31. New York & Queens Electric Light & Power Co. Long Island City, N. Y.	Yes	No	Yes
32. The Niagara Falls Power Co. Niagara Falls, N. Y.	No	Yes	Yes
33. Ohio Public Service Co. Cleveland, Ohio	No	No	Yes
34. Oklahoma Gas & Electric Co. Oklahoma City, Okla.	Yes	Yes	Yes
35. Pacific Gas & Electric Co. San Francisco, Cal.	No	Yes	Yes
36. The Philadelphia Electric Co. Philadelphia, Pa.	Yes	Yes	Yes
37. Public Service Co. of Colorado Denver, Col.	No	Yes	Yes
38. Public Service Company of Northern Illinois Chicago, Ill.	Yes	Yes	No
39. Public Service Electric & Gas Co. Newark, N. J.	No	Yes	Yes
40. Puget Sound Power & Light Co. Seattle, Wash.	Yes	Yes	Yes
41. Rochester Gas & Electric Corp. Rochester, N. Y.	Yes	Yes	Yes
42. San Diego Consolidated Gas & Electric Co. San Diego, Cal.	Yes	Yes	No
43. San Joaquin Light & Power Corp. Fresno, Cal.	Yes	Yes	Yes

TABLE I—(*Continued*)

COMPANIES HAVING RECONDITIONING PLANTS—PERMANENT AND PORTABLE

COMPANY	Central Reconditioning Plant	Local Plant at	
		Power Station	Substation
44. The Shawinigan Water Power Co. Montreal, Que., Can.	No	Yes	No
45. Southern California Edison Co. Los Angeles, Cal.	Yes	No	Yes
46. Southern Sierras Power Co. Riverside, Cal.	Yes	Yes	Yes
47. Tenney, Charles H., & Co. Boston, Mass.	No	Yes	Yes
48. Texas Power & Light Co. Dallas, Tex.	No	Yes	Yes
49. Toledo Edison Co. Toledo, Ohio	No	Yes	Yes
50. The Trinidad Electric Transmission Railway & Gas Co. Trinidad, Col.	No	No	Yes
51. The Tucson Gas, Electric Light & Power Co. Tucson, Ariz.	No	Yes	No
52. Turners Falls Power & Electric Co. Turners Falls, Mass.	No	Yes	Yes
53. Union Gas and Electric Co. Cincinnati, Ohio	Yes	Yes	Yes
54. The United Electric Light & Power Co. New York, N. Y.	Yes	Yes	Yes
55. Utah Power & Light Co. Salt Lake City, Utah	No	Yes	Yes
56. Utica Gas & Electric Co. Utica, N. Y.	No	No	Yes
57. The Washington Water Power Co. Spokane, Wash.	No	Yes	No
Total	29 Yes	46 Yes	42 Yes

Drums Preferred for Dirty Oil

Whereas, permanent tanks for dirty oil storage are installed at power stations by slightly more companies than those which use drums, only a few companies report such tanks at central reconditioning plants and at substations. (Table II, Part I, 7.)

There are, however, several notable exceptions to the indicated preference for drums rather than portable tanks. The Southern Sierras Power Company reports the use of portable tanks, as well as drums, at its central reconditioning plant and at power stations. The Niagara Falls Power Company, in addition to using drums, also uses portable tanks at power station and substation reconditioning plants. The following three companies report the use of portable tanks at their substations: The New York & Queens Electric Light & Power Company, the Niagara Falls Power Company and the Southern Sierras Power Company. The use of a tank truck at substation reconditioning plants is reported by the Puget Sound Power & Light Company. (Table II, Part I, 8.)

Clean Oil Tanks Usually Above Ground

The majority of permanent clean oil storage tanks are located above ground; and except at substations, where they are usually outdoors, opinion seems to be about equally divided as to whether they should be located outdoors or indoors. The Public Service Company of Colorado reports that, due to condensation and water leakage during storage the use of storage tanks placed outdoors and below ground has resulted in a decrease of the dielectric strength. However, Day & Zimmermann, Inc., states that, in its opinion, the location of these tanks depends upon other features of design, and that it has no objection to the installation of tanks below ground. (Table II, Part I, 9.)

No Thermal Insulation for Clean Oil

Permanent clean oil storage tanks are not thermally insulated against atmospheric changes by any reporting company. A few companies report sealing the tanks and using moisture-extracting breathers on clean oil storage tanks at central reconditioning plants. Companies sealing air tight the tanks at central reconditioning plants, when not draining or filling, are the Dallas Power & Light Company, Day & Zimmermann, Inc., and the New York Edison Company. Whenever moisture-extracting breathers are employed, the material used is calcium chloride; such breathers are employed at central reconditioning plants by the Los Angeles Gas & Electric Corporation, the Philadelphia Electric Company, the Puget Sound Power & Light Company and the Idaho Power Company. (Table II, Part I, 10.)

Dirty Oil Tanks Also Above Ground

When provided at central reconditioning plants, separate dirty oil storage tanks are usually located above ground and either outdoors or indoors. The Turner Falls Power & Electric Company has found it advisable to mount its later installations above ground in order to reduce condensation. At power stations the locations for their separate dirty oil storage tanks seem equally divided as to whether they are placed above ground or below ground, and outdoors or indoors. At substations, however, these tanks appear more often to be located outdoors and above ground. Companies having indoor locations at substations are the Cleveland Electric Illuminating Company, the Puget Sound Power & Light Company and the Rochester Gas & Electric Corporation. (Table II, Part I, 11.)

Dirty Oil Tanks Not Air Sealed

Where separate dirty oil storage tanks are used, it seems that very little effort is made to seal them thoroughly or thermally to insulate them against atmospheric changes. The companies using moisture extracting chloride breathers are the Los Angeles Gas & Electric Corporation and the Narragansett Electric Company. The Texas Power & Light Company uses galvanized steel tanks equipped with moisture-extracting breathers at power stations. The only companies sealing their dirty oil storage tanks air tight at substations are Day & Zimmermann, Inc., the Philadelphia Electric Company and the Turner Falls Power & Electric Company. (Table II, Part I, 12.)

Tank Capacities Evenly Divided

From a study of the capacity of clean oil storage tanks, it is felt that substations have on the average more local tank capacity for transformer oils than either central reconditioning plants or power stations. As far as circuit breaker clean oil tanks are concerned, power stations have the greatest capacity. (Table II, Part I, 13.)

In regard to dirty oil storage tanks for transformer oil, it has been found that the larger sizes are at power stations. For storing dirty circuit breaker oil, the tanks at both power stations and substations have essentially the same average capacity. Apparently very little dirty circuit breaker oil is stored at central reconditioning plants, for the general practice is to treat and return the oil to service as fast as it arrives, thus avoiding the necessity for large storage tanks. (Table II, Part I, 14.)

Oil Capacity Provided for Largest Unit

Most of the companies reporting provide both clean and dirty oil tanks of sufficient capacity to hold the oil from the largest unit. However, whereas the Shawinigan Water Power Company provides clean oil tanks of sufficient capacity to take care of the oil for its largest unit, it does not provide sufficient dirty oil tank capacity. (Table II, Part I, 15.)

Independent Oil Lines Provided

Independent oil lines are provided for clean and dirty oil respectively in all three types of reconditioning plants, and the same decision appears to hold true in the operation of oil lines for transformer and circuit breaker oil respectively. Table II, Part I, 16.)

Permanent Piping Usually Above Ground

In the majority of cases reports indicate that permanent oil piping is located above ground except at substations, where it is buried unprotected in the ground. At central reconditioning plants some of the companies burying their pipe lines in concrete or protective envelopes are the Brooklyn Edison Company, the Bronx Gas & Electric Company and the Canadian Niagara Power Company. Some of the companies which, at substations, provide accessible trenches for their piping, considering flexibility and continuity of operation an item worthy of consideration, are the Detroit Edison Company, the Niagara Falls Power Company, the New York & Queens Electric Light & Power Company and the Rochester Gas & Electric Corporation. (Table II, Part I, 17.)

Wrought Iron and Steel Piping Used

Regarding the material used for piping, it is found that wrought iron has been used by the majority of companies for all three locations. At power stations some companies using uncoated steel are the Philadelphia Electric Company, the Public Service Company of Colorado and the Shawinigan Water Power Company. Wrought iron and galvanized steel are specified equally for substation use. Four companies report the use of uncoated steel pipe: namely, the Philadelphia Electric Company, the Public Service Company of Colorado, Duquesne Light Company and Day & Zimmermann, Inc. (Table II, Part I, 18.)

Piping Connected Permanently

The great majority of companies report that their piping is permanently connected to the electrical equipment. At the same time, however, provision has been made by most of the companies to connect the electrical equipment to the oil piping by means of flexible metallic hose. Further flexibility is secured by providing means for cutting in portable oil heating apparatus in the oil lines of the electrical equipment if, upon occasion, the permanent heating units should develop trouble. (Table II, Part I, 19-20-21.)

Non-portable Types of Equipment Used

The use of different types of non-portable equipment at the central reconditioning plants appears to be equally divided between centrifugal and filter press equipment. A few companies are using both types of treating equipment in order to secure complete reconditioning when treating very dirty oil. The Duquesne Light Company is the only company reporting the installation of chemical treating equipment. The Rochester Gas & Electric Corporation uses lye when treating badly burned oil, showing discoloration or sludging; it uses one pound of lye to approximately three barrels of oil. Non-portable equipment is used at both power stations and substations, with the filter press type predominating. (Table II, Part I, 22-23.)

The prevailing rated capacity of non-portable centrifugal apparatus for use in central and local plants is 600 gallons per hour at a temperature of 50 deg. cent.; the prevailing rated capacity of filter press equipment for use in central and local plants, 1000

TABLE II

SUMMARY OF INSULATING OIL PRACTICES

Part One—Design of Oil Handling and Treating Equipment	At Your Central Reconditioning Plant		At Your Local Reconditioning Plants			
			At Power Stations		At Substations	
	Yes	No	Yes	No	Yes	No
1. Do you provide permanent facilities for:						
a. The storage of oils for electrical equipment	29	10	30	19	22	25
b. The treatment of these oils	28	9	35	14	22	24
2. Is the decision to install permanent oil handling facilities at individual stations based on:						
a. Importance of station	....	....	36	3	25	6
b. Amount of oil in use at the typical station you are describing { transformer oil / oil circuit breaker oil }	....	....	32	1	27	2
c. Distance or inaccessibility of station from central oil treating facilities	....	....	21	9	16	9
3. Referring to the particular stations at which the individual plants you are reporting on are located:			(Min.)	(Max.)	(Min.)	(Max.)
a. What is the total quantity of transformer oil in service (state in gallons)	....	....	7,000	550,000	2,700	950,000
b. What is the total quantity of oil circuit breaker oil in service (state in gallons)	....	....	1,000	322,000	2,500	304,000
4. Are separate tanks provided for:						
a. Clean and dirty oil storage	22	14	31	14	17	20
b. Transformer and oil circuit breaker oil	19	16	22	19	16	19
5. Are permanent tanks installed for clean oil storage	24	13	29	18	18	21
6. If not, what are used in their stead (drums, portable tanks, tank trucks, etc.) Drums	16	1	18	3	19	3
Port. tanks	0	2	1	2	3	2
Tank trucks	0	2	1	1	2	2
7. Are permanent tanks installed for dirty oil storage	16	19	26	18	15	24
8. If not, what are used in their stead (drums, portable tanks, tank trucks, etc.) Drums	20	3	20	1	22	0
Port. tanks.	1	3	2	1	4	1
Tank trucks	0	4	0	2	1	2
9. Are clean oil storage tanks located:						
a. Above ground	24	5	22	13	17	9
b. Below ground	7	16	14	17	10	12
c. Outdoors	16	11	21	12	22	4
d. Indoors	17	9	20	17	9	14
10. Are they:						
a. Thermally insulated against atmospheric changes	0	32	0	41	0	31
b. Sealed air tight when not draining or filling	4	27	9	32	7	23
c. Equipped with moisture extracting breathers	5	26	9	32	6	24
11. If separate dirty oil storage tanks are provided are they located:						
a. Above ground	17	1	15	5	9	2
b. Below ground	3	8	13	8	7	3
c. Outdoors	9	4	14	12	10	0
d. Indoors	11	5	15	11	3	8
12. Are they:						
a. Thermally insulated against atmospheric changes	0	20	0	28	0	15
b. Sealed air tight when not draining or filling	5	15	8	21	3	0
c. Equipped with moisture extracting breathers	1	18	4	25	2	14
13. What is the capacity of clean oil storage tanks which are used for:	(Min.)	(Max.)	(Min.)	(Max.)	(Min.)	(Max.)
a. Transformer oil (state in gallons)	1,000	75,000	1,000	30,000	1,250	60,000
b. Oil circuit breaker oil (state in gallons)	600	45,000	4,400	30,000	1,000	36,000
14. What is the capacity of dirty oil storage tanks which are used for:						
a. Transformer oil (state in gallons)	600	5,000	1,000	39,000	1,200	10,000
b. Oil circuit breaker oil (state in gallons)	1,200	26,000	1,250	23,500	1,200	10,000
15. Are clean and dirty oil tanks each of sufficient capacity to hold the oil from the largest piece of equipment in the station	....	....	37	1	28	1
16. Are independent oil lines provided for:						
a. Clean and dirty oil	15	10	26	15	20	12
b. Transformer and oil circuit breaker oil	7	11	20	16	13	11
17. Is permanent oil piping run:						
a. Above ground	16	6	20	15	9	14
b. Below ground in a concrete or other protective envelope	3	11	12	14	6	12
c. Buried, unprotected	6	5	14	15	18	7
d. Below ground in an accessible trench	9	2	17	14	9	13
18. Is the following material used for permanent piping:						
a. Wrought iron	15	2	21	12	13	11
b. Uncoated steel	6	7	5	16	4	13
c. Galvanized steel	7	9	12	12	12	11
d. Other material (state material)	1	10	1	17	2	15
e. Are joints welded	1	19	1	30	1	24

TABLE II—(*Continued*)

SUMMARY OF INSULATING OIL PRACTICES

Part One—Design of Oil Handling and Treating Equipment	At Your Central Reconditioning Plant		At Your Local Reconditioning Plants			
			At Power Stations		At Substations	
	Yes	No	Yes	No	Yes	No
19. Is piping permanently connected to electrical equipment	....	....	30	11	20	13
20. Is provision made to connect electrical equipment to oil piping mains by flexible metallic hose	....	....	16	18	19	7
21. Is provision made to cut in portable oil treating equipment in the oil lines at the electrical equipment	....	....	36	4	32	0
22. Does your non-portable oil treating equipment include:						
a. Centrifugal equipment	16	4	16	11	11	5
b. Filter press equipment	17	3	24	2	14	1
c. Chemical treating equipment	1	15	0	23	0	14
d. Other equipment	5	9	4	15	5	7
(Portable equipment will be described under questions 27)						
23. If answer to 22-d is yes, please describe	....	....	See	Text		
24. What is the manufacturer's rated capacity in gallons per hour of the following non-portable equipment, stating specified oil temperature in °C.:	(Min.)	(Max.)	(Min.)	(Max.)	(Min.)	(Max.)
a. Centrifugal equipment	150 @100 °C.	2000 gals./hr. @ 30 °C.	150 gals./hr.	1,200	400 gals./hr. @ 40 °C.	1,200
b. Filter press equipment	150	2000 gals./hr. @ 25 °C.	150 gals./hr.	1800 @25 °C.	150	1800 @25 °C.
c. Chemical treating equipment	....	....	....	....	....	....
d. Other equipment (referred to under 22-d)	....	....	....	....	....	....
25. Which of the following facilities are provided for heating oils during treating processes:						
a. Steam heaters	2	12	3	11	0	10
b. Electric heaters	23	2	24	4	20	1
c. Other facilities	2	8	2	10	1	9
26. If answer to 25-c is yes, please describe	....	....	See	Text		
27. Which of the following *portable* equipments are used in connection with your central and local reconditioning plants:						
a. Centrifugal equipment	16	6	24	7	21	7
b. Filter press equipment	25	3	35	1	35	2
c. Chemical treating equipment	0	16	0	18	0	13
d. Other equipment	1	12	2	15	2	10
28. If answer to 27-d is yes, please describe	....	....	See	Text		
29. What is the manufacturer's rated capacity in gallons per hour of the portable equipments reported under 27, stating specified oil temperature in °C.:	(Min.)	(Max.)	(Min.)	(Max.)	(Min.)	(Max.)
a. Centrifugal equipment	100	750	100 @50 °C.	800 @65 °C.	150	800 @65 °C.
b. Filter press equipment	100	1800 @68 °C.	200 @60 °C.	1800 @50 °C.	150	1,800
Part Two—Operation and Maintenance of Oil Handling and Treating Equipment						
1. Have you found it necessary to apply paint, varnish or other material to prevent rusting on the interior surfaces of:						
a. Transformers	....	11	8	39	5	40
b. Oil storage tanks and containers	5	18	9	31	4	31
If answer to 1-a or 1-b is yes, please describe materials used	....	....	See	Text		
2. Are you successful in maintaining adequate dielectric strength of oil in the clean oil storage tanks during storage period	21	8	21	6	18	7
3. If answer to 2 is yes, state maximum time satisfactory dielectric can be maintained	6 M	onths	12 M	onths	6 M	onths
4. Referring to 2, describe procedure to maintain dry oil	....	....	See	Text		
5. Do you experience trouble in maintaining your clean oil storage tanks clean	7	21	5	26	5	19
6. What is your method of maintaining these tanks	....	....	See	Text		
7. If your portable facilities for shipping oil include tanks or drums, what method of cleaning is used:						
a. Washing by means of steam	4	15	3	7	1	10
b. Washing with water and alkali	0	16	0	9	0	11
c. Washing with clean oil	24	3	24	1	22	2
d. After washing, do you dry the containers by means of ovens	3	20	0	13	1	13
e. After washing, do you dry the containers by inserting heating elements	0	22	0	13	0	12
f. After washing, do you dry the containers by means of blowers	1	22	0	13	0	13

TABLE II—(*Continued*)

SUMMARY OF INSULATING OIL PRACTICES

Part Two—Operation and Maintenance of Oil Handling and Treating Equipment	At Your Central Reconditioning Plant		At Your Local Reconditioning Plants			
			At Power Stations		At Substations	
	Yes	No	Yes	No	Yes	No
8. Do you inspect your fixed containers to find rust or sediment.	22	6	29	1	26	1
9. Describe the method of inspection.......... Visual........	20	2	29	0	23	0
Other methods	4	3	4	0	6	0
10. Do you inspect your portable containers to find rust or sediment	26	9	26	11	21	10
11. Describe the method of inspection.......... Visual........	26	3	26	3	22	2
Other methods	2	2	2	1	3	1
12. Which methods are used in transporting oil to and from your permanent reconditioning plants or your central storage:						
a. Drums..	32	0	31	0	26	2
b. Portable tanks....................................	2	9	3	6	2	6
c. Tank trucks..	3	9	2	8	2	8
d. Tank trailers......................................	0	10	1	8	1	7
e. Tank cars..	2	10	3	8	3	7
f. Pipe lines...	2	9	6	7	5	7
g. If other methods are used, please describe................	....	....	See	Text		
13. Have you experienced any difficulty in the maintenance of oil piping due to:						
a. Corrosion..	1	21	1	26	3	21
b. Joint leakage......................................	8	15	10	21	9	17
c. Valve packing leakage..............................	6	16	7	23	3	22
d. Valve seat leakage.................................	6	17	7	23	6	21
e. Describe briefly your method of overcoming any of these difficulties which you have experienced................	....	....	See	Text		
14. Do you experience any difficulty due to congealing of oil in buried oil lines....................................	0	18	0	26	0	24
15. Do you prevent congealing of oil by:	Average	3 ft.	Average	2½ ft.	Average	2½ ft.
a. Increased depth of burial (state depth)................	1	2	5	5	5	4
b. By thermal insulation..............................	1	4	1	9	2	5
c. If answer to 15-b is yes, state material used.............	....	....	See	Text		
d. By preheating oil..................................	2	4	2	8	2	6
e. If answer to 15-d is yes, describe method and state approximate temperature.............................	....	....	See	Text		
16. Have you experienced corrosion of pipe lines buried in the soil..	1	9	3	18	5	12
17. Is this corrosion due to:						
a. Water drainage.....................................	0	0	0	2	1	2
b. Character of soil or fill............................	1	0	2	0	3	0
c. Electrolysis.......................................	1	16	0	1	0	2
18. Describe briefly methods of combating corrosion reported under 17-a, b. c..	....	....	See	Text		
19. Do you permit clean oil to remain in pipe lines not in actual use..	12	14	15	23	10	19
20. Do you successfully dehydrate transformer oil by:						
a. Centrifuge...	19	11	22	9	17	10
b. Filter press.......................................	30	1	37	1	35	1
c. Combination of centrifuge and filter press................	14	6	16	6	13	5
d. Chemical treatment.................................	1	11	0	11	0	9
e. Other processes (describe method)......................	....	....	See	Text		
21. Do you successfully dehydrate circuit breaker oil by:						
a. Centrifuge...	18	9	22	8	16	7
b. Filter press.......................................	29	1	34	1	34	2
c. Combination of centrifuge and filter press................	15	7	16	5	12	6
d. Chemical treatment.................................	1	12	0	11	0	9
e. Other processes (describe method)......................	....	....	See	Text		
22. Do you successfully remove sediment and sludge from transformer oil by:						
a. Centrifuge...	17	9	21	6	16	7
b. Filter press.......................................	31	2	30	2	35	1
c. Combination of centrifuge and filter press................	15	4	12	1	12	7
d. Chemical treatment.................................	0	9	1	7	0	10
e. Other processes (describe method)......................	....	....	See	Text		

TABLE II—(*Continued*)

SUMMARY OF INSULATING OIL PRACTICES

Part Two—Operation and Maintenance of Oil Handling and Treating Equipment	At Your Central Reconditioning Plant		At Your Local Reconditioning Plants			
			At Power Stations		At Substations	
	Yes	No	Yes	No	Yes	No
23. Do you successfully remove carbon from circuit breaker oil by:						
a. Centrifuge	6	18	10	14	6	13
b. Filter press	19	8	24	3	29	5
c. Combination of centrifuge and filter press	16	6	14	4	1	7
d. Chemical treatment	2	7	0	12	0	8
e. Other processes (describe method)	....	....	See	Text		
24. What is the total volume of oil reconditioned per year for:						
a. Transformers (state in gallons)	....	....	See	Text		
b. Circuit breakers (state in gallons)						
25. Insert values for average pass of oil through various pieces of equipment	....	....	See	Table 3		
26. Describe in detail any of the following operating difficulties which you experience in any now commercially available oil purification processes which you use:						
a. Design			See	Text		
b. Mechanical defects						
c. Electrical defects						
d. Inadequate capacity due to failure to meet ratings						
e. Inadequate quality of oil						
f. Excessive operating cost						
g. Lack of portability						
h. Difficulty in training operators to obtain satisfactory and consistent results						

Part Three—Use and Inspection of Insulating Oils	Yes	No
1. Do you purchase the following insulating oils on specification:		
a. Transformer oil	11	47
b. Circuit breaker oil	8	46
2. If answer to 1 is "yes," please submit copies of the complete specifications used	See Appendic	es 3 and 4
3. Do you purchase your insulating oils from the following:		
a. Electrical apparatus manufacturer	56	0
b. Oil refiner	11	30
c. Oil jobber	1	38
4. Do you inspect and test the following new oils as received:		
a. Transformer oil	46	11
b. Circuit breaker oil	43	12
5. State the limits of physical, chemical, and electrical qualities which the oil must meet before it is accepted by your company	See Tab	le 4
6. Do you find oil from new shipments to obtain:		
a. Water	32	24
b. Sediment or "dirt"	20	32
c. Metallics	12	37
7. Do you transfer your oil shipments to storage tanks when received	27	26
8. Do you dehydrate or blotter press new oil shipments:		
a. On receipt, before storing	21	30
b. After storing and prior to using	48	6
9. State the ratio in percent of the new oil maintained in storage to the total oil in service on the system:	(Min.)	(Max.)
a. Transformer oil (all applications) %	1	10
b. Circuit breaker oil (for indoor types) %	1	50
c. Circuit breaker oil (for outdoor types) %	1	15
10. Do you find any change in the quality of new oil after it is installed in apparatus but before apparatus is energized	15	38
11. If answer to 10 is "yes," describe briefly the changes experienced and methods of overcoming same	See	Text
12. Do you have a scheduled inspection period for oil in service	52	5
13. State length of time between inspections for oil in:		
a. Indoor transformers	See	Text
b. Outdoor transformers		
c. Indoor circuit breakers		
d. Outdoor circuit breakers		

TABLE II—(*Continued*)

SUMMARY OF INSULATING OIL PRACTICES

Part Three—Use and Inspection of Insulating Oils	Yes	No
14. Which of the following methods do you use for determining the condition of oils in service:		
a. Visual inspection for sediment	37	6
b. Dielectric strength	55	1
c. Free water	20	12
d. Carbon	18	8
e. Physical tests	4	25
f. Chemical tests	6	25
15. If answer to 14-e or 14-f is "yes," describe briefly the nature of tests	See	Text
16. Have you established limiting values in the properties of oil as determined from periodic test which dictate that oil in apparatus should be changed	42	10
17. If answer to 16 is "yes," describe briefly the oil characteristics and limiting values used:		
a. Electrical	See	Text
b. Physical		
c. Chemical		
18. Have you experienced any difficulty in equipment operation due to mixture of serviced transformer and circuit breaker oil in the apparatus	1	51
19. If answer to 18 is "yes," describe the difficulty and your method of overcoming	See	Text
20. Would your company be able to effect economies in oil utilization if the apparatus manufacturers would reduce the required number of oils to:		
a. One for outdoor and indoor transformers	28	14
b. One for outdoor and indoor circuit breakers	31	21
21. If answer to question 20 is "yes," by what percent would you be able to reduce your storage stock of oils:	(Min.)	(Max.)
a. Transformer oil.......%.	10	50
b. Circuit breaker oil.......%.	10	50
22. If you recondition your oils, what are the quality limits required or found before oil is reused:	(Min.)	(Max.)
a. Dielectric strength (kv. 1/10 in. gap).......kv.	22.0	26.0
23. Have you experienced any inability to maintain adequate quality of reconditioned service oil in the apparatus after it has been reconditioned	7	38
24. Do you make an inspection of the oil in oil circuit breakers:		
a. After every automatic operation	10	11
b. If answer to 24-a is "yes," what is the elapsed time between operation and inspection	See	Text
c. If answer to 24-a is "no," how many automatic operations take place before inspection of oil	See	Text
25. Do you use any sampling connections on transformers other than that supplied by the manufacturer	8	46
26. If answer to 25 is "yes," describe briefly	See	Text
27. Do you use any sampling connections on circuit breakers other than that supplied by the manufacturer	12	43
28. If answer to 27 is "yes," describe briefly	See	Text
29. Are sampling connections desirable at other points on equipment than normally supplied by the manufacturer in order to permit taking a more representative sample	10	42
30. If answer to 29 is "yes," describe the locations in transformers and breakers which you consider would give a more representative sample of oil	See	Text

gallons per hour at a temperature of 50 deg. cent. (Table II, Part I, 24.)

Electric Heaters Predominate

Facilities for heating oils during treating processes include electric heaters in the majority of cases. Very few companies use steam or other facilities for heating. The Detroit Edison Company has installed 5 kw. 220 volt heaters under its circuit breaker tanks, for use during severe weather. The Dayton Power & Light Company employs two immersion heaters rated at 2 kw. each. The Duquesne Light Company reports the installation of steam heating units in their reconditioning plant in order to prevent oxidation of aerated oil produced by the use of electrical heating units which have no adequate temperature control. (Table II, Part I, 25-26.)

Filter Press Choice in Portable Equipment

For portable equipment at central and local reconditioning plants the greatest usage seems to lie in filter press apparatus. The Dayton Power & Light Company and the Texas Power & Light Company are each using a combination unit consisting of a centrifuge and a filter press mounted on one machine. (Table II, Part I, 27-28.)

Equipment Rated Capacities Vary Widely

For portable apparatus at power stations the rated capacity of centrifugal equipment varies from 100 to 800 gallons per hour at a temperature average of 50 deg. cent., and filter press equipment ranges in capacity from 200 to 1800 gallons per hour at a temperature average of 50 deg. cent., depending upon the size of the company. The rated capacity of the centrifugal equipment most frequently used is 400 gallons per hour; for the filter press equipment most frequently used the rated capacity is 800 gallons per hour.

TABLE III

MINIMUM AND MAXIMUM VALUES OBTAINED IN THE OPERATION OF RECONDITIONING EQUIPMENT

	Centrifuge		Filter Press		Centr. and Filter Press	
	Non-Portable	Portable	Non-Portable	Portable	Non-Portable	Portable
a. Actual output, gals. per hr., min.-max.	150 to 1500	60 to 800	150 to 2000	150 to 1800	300 to 1000	100 to 500
b. Actual oil temperature °C. during operation, min.-max.	35 to 70	35 to 90	25 to 72	20 to 75	70 to 100	50 to 70
c. Number of hours of continuous operation between cleaning equipment or changing blotters, min.-max.	1 to 24	1 to 30	0.5 to 8	0.5 to 8	5 to 8	1 to 5
d. Energy consumption per 1000 gal.:						
1. Motive power in kw-hr., min.-max.	2.5 to 15	1 to 17	1.8 to 11	1 to 14	10 to 25	15 to 25
2. Heat in B.t.u. (approx. average summer and winter conditions), min.-max.	42,000 to 116,000	28,000 to 116,000	....	50,000 to 61,470	....	....
e. Dielectric strength of Reconditioned Oil after first pass, kv., min.-max.	20 to 25	18 to 25	17.5 to 25	15 to 27	22.5 to 30	22.5 to 30
f. Dielectric strength of Reconditioned Oil after final pass, kv., min.-max.	22 to 30	22 to 35	22 to 32	22 to 35	22 to 35	22.5 to 33
g. If difficulty is experienced in getting guaranteed quality of oil in a single pass of oil through the equipment, state number of passes of oil through each piece of equipment, min.-max.	2 to 6	2 to 6	1 to 3	2 to 6	....	2 to 4
h. Is sediment completely removed after first pass?:						
Companies ans. YES	7	15	8	25	2	5
Companies ans. NO	6	7	2	2	0	0
i. Is acidity reduced after first pass?						
Companies ans. YES	4	5	4	5	1	2
Companies ans. NO	2	2	3	1	0	0
j. State value of acidity after first pass milligrams, KOH			No Records	Secured		
k. State value of acidity after final pass milligrams, KOH			No Records	Secured		
l. Is sludge completely removed after first pass?						
Companies ans. YES	2	6	4	7	1	3
Companies ans. NO	10	14	6	13	1	2
m. Is sludge completely removed after final pass?						
Companies ans. YES	8	12	9	19	3	4
Companies ans. NO	3	4	1	2	0	0
n. What is per cent of oil wastage per batch for:						
1. Transformer oil %, min.-max.	0.2 to 1.0	0.02 to 1.0	0.15 to 5.0	0.10 to 5.0	0.10 to 0.17	0.17 to 0.5
a. Number of passes, min.-max.	....	1 to 4	1 to 4	1 to 4	....	2 to 3
2. Breaker oil %, min.-max.	0.25 to 5.0	0.05 to 1.0	0.05 to 5.0	0.1 to 3.0	....	....
a. Number of passes, min.-max.	....	1 to 4	2 to 5	1 to 5	....	....

PART II

OPERATION AND MAINTENANCE OF HANDLING AND TREATING EQUIPMENT

Interior Surfaces Do Not Rust

Only a comparatively few of the fifty-seven reporting companies have found it necessary to apply paint or varnish in order to prevent rusting on interior surfaces of transformers or oil storage tanks and containers. The materials used by these companies include shellac, red metal paint, lacquer, varnish and bakelite varnish. The Edison Electric Illuminating Company of Boston uses bakelite varnish and a cork lining on covers, as well as an external coating of paint and ground cork, in order to prevent internal condensation. The Idaho Power Company applies to the transformer covers, after a thorough cleansing, three coats of shellac. (Table II, Part II, 1.)

High Dielectric Strength Maintained

Many companies have facilities for maintaining during storage an adequate dielectric strength for more than six months, on an average, at their central reconditioning plants and for more than twelve months, on an average, at their power stations. The methods of accomplishing this result are varied. The Commonwealth Edison Company keeps the clean oil storage tanks entirely filled up in order to avoid entrapped air spaces and, when necessary, the oil is centrifuged. The Kansas City Power & Light Company stores the drums with the bungholes pointed down, thereby preventing the collection of water in empty drums. The Rochester Gas & Electric Corporation keeps the temperature of the room containing oil tanks at 15 deg. fahr. above the outside air temperature. The majority of the other companies maintain the dielectric strength by reconditioning the oil more frequently than condensation can occur in any appreciable quantity; others use small tanks and frequently change their oil. Since the average practice is to filter into and out of storage, no appreciable trouble is encountered in maintaining an adequate dielectric strength. (Table II, Part II, 2-3-4.)

Tanks Washed with Clean Oil

No apparent trouble in maintaining the cleanness of permanent oil storage tanks has been found, due to the methods employed in keeping this equipment clean. Almost all the companies report a periodic cleaning, ranging in time from four to six months, by flushing with clean oil and wiping when empty. The Southern California Edison Company paints the outside of its tanks with red lead and finishing coats, after sand blasting. The New York Edison Company keeps clean oil tanks in a dry, heated building. The Brooklyn Edison Company cleans and shellacs tanks yearly at the central and local reconditioning plants. (Table II, Part II, 5-6.)

The prevailing practice in the cleaning of portable tanks and drums is also to wash with clean oil. The only companies reporting washing by means of steam at central reconditioning plants are Day & Zimmermann, Inc., the Puget Sound Power & Light Company and the Rochester Gas & Electric Corporation. No use of water and alkali is reported for cleaning portable equipment. Neither has it been in many instances necessary to dry the containers by some means of heating or blowing, although the use of ovens at central plants for drying purposes is reported by the Puget Sound Power & Light Company and the Idaho Power Company, which operate these ovens at temperatures of 75 and 85 deg. cent. respectively. The Grays Harbor Railway & Light Company dries drums by placing them over the smoke ducts in the boiler room. The Southern California Edison Company is the only organization reporting the use of blowers for drying purposes after cleaning portable tanks and drums. (Table II, Part II, 7.)

Containers Rigidly Inspected

Reports indicate that inspection for rust or sediment in fixed containers is regularly conducted by the majority of companies, the method of inspection usually depending upon visual examination of tank interiors. At the Milwaukee Electric Railway & Light Company and the Texas Power & Light Company, it is customary for an operator to enter the tank being inspected. Another method of inspection includes sampling the oil for rust, and is employed by the Edison Electric Illuminating Company of Boston. (Table II, Part II, 8-9.)

A majority of the reporting companies inspect portable containers for rust or sediment by the visual method. The Puget Sound Power & Light Company uses a light lowered through the bungholes in order better to inspect the inside surface. (Table II, Part II, 10-11.)

Oil Usually Transported in Drums

In transporting oil to and from permanent reconditioning plants or central storage, drums are used by the majority of companies. At the central reconditioning plants, the practice is to use tank trucks, tank cars or portable tanks; the Commonwealth Edison Company, The Puget Sound Power & Light Company and the Southern California Edison Company using tank trucks whenever drums are not employed. At the power station and substation reconditioning plants, the practice is to use pipe lines, tank cars or portable tanks whenever drums are not used. It is to be noted that, at stations and substations, pipe lines are used for the local transportation of oil in more cases than any other instrumentality with the exceptions of drums. (Table II, Part II, 12.)

Pipe Joint Leakage Greatest Maintenance Trouble

Considerable trouble in the maintenance of oil piping is due to joint leakage, valve seat leakage and valve packing leakage, the greatest difficulty being experienced with the former. The remedy for joint leakage which has proved most valuable to the Public Service Company of Northern Illinois and the Texas Power & Light Company in the maintenance of oil pipe lines at reconditioning plants is first to cover the threads with white lead and oil, and then to cover them with bakelite varnish and a General Electric compound known as No. 880. Recommended remedies for leakage in valve seats and packing for the most part comprise renewing the seat or replacing the valve. (Table II, Part II, 13.)

No Difficulty Experienced from Congealing

No difficulty has been experienced by any company due to the congealing of oil in buried lines; satisfactory preventive measures having been obtained by burying the pipe to a depth of from two to three feet, by pre-heating the oil and by running steam lines in the same trench with the oil lines—the latter method being used by Day & Zimmermann, Inc. Thermal insulation is not employed by any reporting company to prevent the congealing of oils. The Public Service Electric & Gas Company (New Jersey), in order to prevent congealing in buried pipe lines and otherwise, requires that oil furnished for apparatus shall not congeal above a temperature of minus 20 deg. C. (Table II, Part II, 14-15.)

Pipe Corrosion Negligible

Corrosion of pipe lines buried in the soil is experienced more at substations than at either central reconditioning plants or local power station reconditioning plants, but the number of replies indicating any corrosion at all is relatively few. Day & Zimmermann, Inc., reports that the corrosion of its buried oil lines is due to the cinder fill used. Electrolysis and water drainage do not seem to be appreciable factors in causing the corrosion of the pipe lines of any reporting company. (Table II, Part II, 16-17.)

Several methods of combating corrosion of pipes are being used. The Pacific Gas & Electric Company cleans its pipes and coats them with tar. The Southern Sierras Power Company coats its pipes with pitch or with burlap strips dipped in hot asphalt. The Utah Power & Light Company reports that corrosion of buried oil lines is prevented by protecting the outer surface of the pipe with a coating of red lead. (Table II, Part II, 18.)

No Clean Oil Remains in Unused Lines

At their central reconditioning plants, as well as at their power stations and at their substations, the majority of companies do not permit clean oil to remain in pipe lines not in actual use. (Table II. Part II, 19.)

Filter Presses Preferred

When dehydrating transformer oil at central and local reconditioning plants, more companies use the filter press method than any other, although several companies use a combination centrifuge and filter press at all reconditioning plants. The only additional method employed in dehydrating transformer oil is the use of a filter of Fuller's earth, reported by The Shawinigan Water Power Company. Test runs with Fuller's earth have also been conducted by the Commonwealth Edison Company, which reports that the oil was successfully dehydrated. (Table II, Part II, 20.)

More circuit breaker oil is successfully dehydrated by filter press than by centrifuge or by a combination of centrifuge and filter press. (Table II, Part II, 21.)

The filter press is also accepted as the favorite apparatus for the removal of sediment and sludge from transformer and breaker oil, although the centrifuge and the combination of the two are also used and even the filter of Fuller's earth has some advocates. The San Diego Consolidated Gas & Electric Company reports the use of the following unusual formula for the removal of carbon: add one pound of gold dust dissolved in two gallons of water to fifty gallons of oil, heat to 200 deg. fahr. for one-half hour, then agitate with steam jet and run through centrifuge with water seal. The Rochester Gas & Electric Corporation reports that transformer and breaker oils are treated with lye when the presence of acid is noted; for burned oil showing discoloration, one pound of lye is used to three barrels of oil. The Cleveland Electric Illuminating Company reports that it is unable to remove all traces of carbon from heavily carbonized breaker oil but that the dielectric test, after one run through the centrifuge at 200 gallons per hour, is better than 25 kv. Operating instructions on the subject, issued by Charles H. Tenney & Company, are given in Appendix I. (Table II, Part II, 22-23.)

An engineering letter of the Electric Bond & Share Company, comparing the filter press and the centrifuge, is given in Appendix II.

Total Reconditioned Oil Volume Large

Some interesting figures have been obtained in regard to the total volume of transformer oil reconditioned each year by various operating companies. The New York Edison Company heads the list of companies reporting, with 400,000 gallons per year at its central reconditioning plant. The Alabama Power Company reports the greatest quantity handled by local reconditioning plants at power stations and at substations, the figures being 306,000 and 432,000 gallons per year respectively. (Table II, Part II, 24.)

Figures on the total volume of circuit breaker oil reconditioned per year are also significant. The Philadelphia Electric Company handled the largest quantity of any central reconditioning plant, viz., 80,892 gallons. The maximum quantity of oil reconditioned by any one company at power stations is 650,000 gallons, the figure submitted by the Duquesne Light Company. The largest quantity reported by any company under any method of reconditioning is the 1,100,000 gallons at the substation reconditioning plants of the Southern California Edison Company.

Experience with Two Types Varies

Comparison between the filter press and the centrifuge, in operating experience for one pass of oil, is given in Table III. It should be noted that two passes through the oil treating equipment are usually necessary in order to secure the return of a high dielectric strength. The number of hours of continuous operation between changing of blotters or cleaning of equipment depends entirely upon the original condition of the oil. The variation in filter press costs per thousand gallons of oil is so wide that it is omitted from this report. This variation can best be understood by an examination of the methods employed in treating very dirty oil; the companies showing low blotter costs make a practice of running their oil first through the centrifugal apparatus and then through the filter press, and are therefore able to use their blotters over again when handling fairly clean oil. (Table II, Part II, 25.)

Many Operating Difficulties Experienced

Many difficulties have been encountered in the operation and maintenance of handling and treating equipment. With regard to design defects, it has been reported that the time required to start and to stop the centrifuge is too great, that a blotter press driven by a repulsion motor constitutes a fire hazard as the result of motor sparking, that oil accumulation on the commutator contributes to dust collection and the motor should therefore be entirely inclosed, that a safety switch should be provided at the motor, and that thermostatic control of blotter press heaters would make operation simpler and safer.

With regard to mechanical defects, it has been reported that a by-pass relief valve should be placed on the centrifuge, that difficulty is experienced in cleaning centrifuges of certain types, that blotter press bearings require too frequent renewal, that difficulties have been experienced in renovating oil with the filter press in cold weather although the application of heat to the oil will probably overcome them, and that blotters should be shipped from the factory in sealed packages in order to eliminate the absorption of moisture during transportation.

With regard to electrical defects, it has been reported that certain electrical heaters are too small and not sufficiently rugged, that trouble has arisen from the burning out of heating units, that it has been necessary to replace centrifuge switches having insufficient capacity, that centrifuge heaters do not have sufficient capacity, that the electrical connections of heaters under blotters often become damaged because of insufficient flexibility and that heaters for portable presses should be weatherproof.

Numerous companies are experiencing difficulties in the consideration of ratings, it being stated that the rating of equipment depends entirely on the dirtiness of the oil, and that no comparison should be made between the actual rating and the rating given by the manufacturer; centrifugal equipment particularly is reported to be considerably overrated. It is quite obvious that the quality of oil obtained from centrifuge or filter press depends entirely on the dirtiness of the oil; it has been reported that it is sometimes necessary to pass oil once through a press after two or three passes through a centrifuge in order to dehydrate it and that, in a few cases, sludge could not be removed with a centrifuge.

In discussing the question of portability, the operating companies seem to feel that portable presses and heaters should be lighter and should be weatherproof, should be arranged for shipment without crating and should be provided with larger wheels, designed for running on cinders and loose dirt, and that containers for storing dry blotters should be added. The general opinion seems to be that the centrifuge requires a more skilled operator than the filter press, particularly on centrifuges necessitating the changing of dams to accomplish dehydrating economically, in which case operators find it difficult to select the proper size of dam. Operators also report difficulty in consistently maintaining the required oil temperature to the centrifuge, and in passing the hot oil to the cold breaker tanks without condensation and consequent decrease of dielectric strength. (Table II, Part II, 26.)

Total Costs Greatly Varied

The reconditioning costs per thousand gallons of oil submitted by a comparatively few companies were so divergent and contained so many unknown quantities that it is impossible to draw conclusions from them and they are therefore omitted from the report.

PART III

USE AND INSPECTION OF INSULATING OILS

Few Specifications in Existence

In the present state of oil treating and handling, very few companies purchase their insulating oils on detailed specifications. It seems rather to be the common practice for the operating companies to use the oils suggested or recommended by the equipment manufacturers for transformers and oil circuit breakers respectively. However, a growing tendency is noted toward the use of individual operating companies of their own detailed purchase specifications covering insulating oils. (Table II, Part III, 1.)

Such specifications, in use by the Commonwealth Edison Company and the New York & Queens Electric Light and Power Company, are given in Appendices III and IV respectively. (Table II, Part III, 2.)

Purchases Made from Equipment Manufacturers

The great majority of companies still purchase their insulating oils from the respective equipment manufacturers. However, a number of companies on the Pacific Coast buy directly from oil refiners, as do several of the largest utility companies scattered about the country. (Table II, Part III, 3.)

Inspection and Tests Made of New Oils

Inspection and tests of new oils are reported by the vast majority of companies, an indication that good care is taken to obtain proper oil. Average values for all the specified items are shown in the accompanying table of limits, designated Table IV. The tendency towards uniformity in the two classes of figures can best be explained by the fact that a large number of companies are using one oil for both transformers and circuit breakers. (Table II, Part III, 4-5.)

New Oil Received in Unserviceable Condition

Most companies report finding water, sediment and metallics in new oil shipments. The number of companies frequently finding water in their new oil is about twice the number finding sediment or dirt and about three times the number finding metallics. Because of these conditions, a considerable number of reporting companies make a practice of passing new oil through centrifuge or filter press before transferring it to storage tanks. After storage, on the majority of systems, the oil is similarly treated prior to being used when it does not meet the required dielectric test. (Table II, Part III, 6-7-8.)

TABLE IV

MINIMUM AND MAXIMUM LIMITING QUALITIES WHICH OIL MUST MEET BEFORE ACCEPTANCE

Tests	Transformer Oil, All Applications	Circuit Breaker Oil		Number of Companies Reporting
		Indoor	Outdoor	
a. Specific gravity at 15/15 °C. (min.-max.)	0.82 to 0.90	0.82 to 0.90	0.82 to 0.90	3
b. Flash test (°C.) (min.-max.)	130 to 150	130 to 188	130 to 180	7
c. Fire test (°C.) (min.-max.)	140 to 165	149 to 210	149 to 210	5
d. Pour test (°C.) (min.-max.)	Zero to minus 40	Minus 4 to minus 40	Minus 4 to minus 40	7
e. Viscosity Saybolt at 37.8 °C.—sec. (min.-max.)	55 to 65	55 to 128	55 to 121	7
f. Neutralization number (milligrams, KOH)		Must Be	Neutral	4
g. Sulphur corrosion	None	None	None	4
h. Dielectric strength—kv. across 0.1 inch gap (min.-max.)	20 to 31	20 to 31	20 to 30	26
i. Sediment (% by volume)	None	None	None	3
j. Sediment (% by weight)	None	None	None	2

Stored Oil Averages Five Per Cent

The ratio of new oil maintained in storage to the total oil in service on the system averages approximately 5 per cent for all classes of oil. For transformer oil, this ratio varies between one per cent and 10 per cent, and for indoor circuit breaker oil, the ratio varies between one per cent and 50 per cent. One western utility company reports as high as 50 per cent and a large middle western company reports a ratio of 30 per cent. For outdoor circuit breaker oil, the largest ratio reported was 15 per cent. (Table II, Part III, 9.)

Quality May Change in Deënergized Apparatus

Although the majority of reporting companies have experienced no difficulty with changes in the quality of oil remaining in apparatus which is not energized for a considerable period, companies reporting that such oil absorbs moisture are in sufficient number to indicate that a very real difficulty exists in this respect. Only two methods have been reported as being employed to eliminate this moisture and none to prevent absorption; the elimination methods are refiltering of the oil and drying out of the apparatus by means of circulating currents. (Table II, Part III, 10-11.)

Semi-Annual Inspection Periods

Approximately fifty companies report scheduled inspections of oil in service. The average length of time between inspection is seven months for indoor transformers, six months for outdoor transformers, nine months for indoor circuit breakers and six months for outdoor circuit breakers. Charles H. Tenney & Company has a scheduled inspection period for oil in service of once every four months for transformers and oil switches operating at 13,200 volts or higher; and of once every year for line transformers having a capacity of 25 kv-a. or more, operating at less than 13,200 volts, all subway transformers, and all station oil breakers except breakers of such types as are placed in special classes and therefore have their oil replaced by tested oil at each overhauling. (Table II, Part III, 12-13.)

The following test methods, in the order of their stated preference, are used for determining the condition of oils in service: dielectric strength, visual inspection, free water, carbon, chemical tests and physical tests. Both the Philadelphia Electric Company and the Louisville Gas & Electric Company make complete chemical analyses and dielectric tests on transformer oils every three months, and on circuit breaker oils at three months' intervals or after heavy duty performance, in accordance with the test program being conducted by the Insulating Oil Subcommittee of the N. E. L. A. Electrical Apparatus Committee. (Table II, Part III, 14-15.)

Tests Determine When Oil Should Be Changed

The majority of companies have established limiting values in the properties of oil as determined by periodic tests, which values dictate that oil in apparatus should be changed. The electrical limiting values range from 15,000 volts as a minimum requirement up to 25,000 volts as a maximum. Some of the determining physical characteristics are found to be had when a sample shows considerable carbon, when there is heavy sludge, free water and free carbon present, and when excessive sludging is indicated by overheating of the transformer. (Table II, Part III, 16-17.)

Serviced Oils Freely Mixed

No difficulty has been experienced from the use of a mixture of serviced transformer and circuit breaker oils by the vast majority of the reporting companies. It would seem unlikely that trouble should occur, provided that care is taken in obtaining good oil and in mixing only oils having similar characteristics. Operating instructions to the contrary, issued by The Philadelphia Electric Company, are given in Appendix V. (Table II, Part III, 18-19.)

Standardization Would Effect Vast Economies

Approximately one-fifth of the reporting companies are using only one oil for outdoor and indoor circuit breakers and approximately two-fifths are using one oil for both outdoor and indoor transformers. These companies report that their storage stocks of oil would be reduced from 10 to 50 per cent by the use of one oil for outdoor and indoor transformers and for outdoor and indoor circuit breakers. (Table II, Part III, 20-21.)

Reconditioned Oil Has Good Characteristics

When reconditioning oils, most of the companies strive to bring them back to the original condition. The figures given by the majority of companies for the reconditioned dielectric strength of transformer and circuit breaker oil do not materially vary from the respective limiting values used at the time of the original purchase. Furthermore, most companies require that the reconditioned oil shall be free from sediment or sludge, and free from water. When these conditions are complied with, very few companies experience any trouble in maintaining the quality of oil in service. (Table II, Part III, 22-23.)

Circuit Breaker Inspections at Short Interval

Only a small percentage of the companies report making inspection of oil in circuit breakers after every automatic operation of severe intensity, the number being, however, half of the twenty-one companies sending in information on the subject: these same companies report inspection of oil following each operation of their high voltage breakers. It should be noted that nearly all inspections are made within an average elapsed time of six hours after the breaker operation. Several large companies report their inspections conducted within twenty-four hours of elapsed time. Many others inspect after every severe operation. As to the number of automatic operations taking place before the inspecting of oil, the average is found to be six times. However, the actual number of times ranges from one to twenty, depending entirely upon the severity of operation and such signs of distress as the throwing of oil. (Table II, Part III, 24.)

Present Sampling Methods Suitable

Very little tendency to use any transformer sampling connections other than those supplied by the manufacturers is noted. Reports would indicate that the operating companies are apparently satisfied with the present installed sampling devices. However, a few companies feel it necessary to add refinements. The Edison Electric Illuminating Company of Boston has installed sampling cocks mounted outside of the main draw-off cock. The Southern Sierras Power Company has installed sampling pipes and petcocks in order to make it more convenient to secure a sample of oil without using the large valves. Day & Zimmermann, Inc., and the Public Service Electric & Gas Company (New Jersey) have all their transformers in excess of 750 kv-a. equipped with sampling valves independent of the drain valves. The Philadelphia Electric Company employs reducing valves and plugs in order to permit the withdrawal and limitation of samples without contamination of the oil. (Table II, Part III, 25-26.)

On circuit breakers most companies use the existing sampling connections installed by the manufacturers. A few companies add necessary connections when not provided by the manufacturers. The Ohio Public Service Company has mounted sampling devices at the top of the oil level and also near the bottom of the tank. Sampling cocks one-quarter inch in diameter are used by the Public Service Electric & Gas Company (New Jersey) and the Southern California Edison Company. (Table II, Part III, 27-28.)

Apparently most of the oil sampling connections on transformers and circuit breakers have been suitably located, since only a comparatively few companies offer any suggestions for changes or improvements. The Philadelphia Electric Company believes that the valve connection should be located on the tank itself and not on the drain pipe if a representative oil sample is to be obtained without undue wastage. All the companies offering suggestions emphasize the fact that sampling valves should be located at the lowest point of the tanks in order to show the presence of any sediment which may exist. (Table II, Part III, 29-30.)

APPENDIX I

OPERATING INSTRUCTIONS OF CHARLES H. TENNEY & COMPANY

(Abstracted for the Purposes of this Report)

All transformers shall be regularly inspected. All subway transformers, and all others rated at 13,200 volts or more and of 50 kv-a. capacity or more, shall, at least once each year, have their oil filtered by means of standard equipment of a type approved by the Engineering Department. Those of less than 50 kv-a. capacity and of less than 13,200 volt rating shall be inspected at least once in five years, and shall have their oil tested, and changed if necessary. When an excessive amount of water or sludge is found in oil upon filtering, the Engineering Department shall be notified immediately so that a special investigation can be made. At times of inspection terminals and connections shall be carefully examined and left in proper operating condition.

Whenever the results of tests of oil from breakers or transformers indicate low dielectric strength or the presence of sudge, the oil shall be refiltered with the approved equipment until brought up to the standard established by the Engineering Department.

APPENDIX II

ENGINEERING LETTER FROM THE ELECTRIC BOND & SHARE COMPANY

(Abstracted for the Purposes of this Report)

The filter press process of oil drying and purifying is the older one and has been in successful use for a number of years. It consists essentially of a motor-driven pump pressing the contaminated oil through a series of blotting papers. Recent improvements in design, notably the additions of an air bell for the testing of leaks in the suction piping, which bell can also be applied to existing presses, render the oil less subject to aeration during the operation.

The filter press process, nevertheless, still has several disadvantages. One of these arises from its slowness of operation, it having been our experience that the 1800 g.p.h. press will average only approximately 400 g.p.h. over extended periods of operation, due to the clogging of the blotting paper and the time consumed in changing the paper. The frequent renewal of blotting paper necessitated is in itself a disadvantage since the oil will not be successfully dehydrated if blotting paper is allowed to remain in the press after the paper has become too moist. Another difficulty experienced is in keeping the oil pressure low enough to prevent puncture of the blotting paper and consequent passing of contaminated oil.

The centrifugal process of oil drying and purifying is more recent in its application to insulating and cooling oils, although it has been used successfully for some time in the purification of lubricating oils. It consists essentially of a revolving vessel which whirls the oil against discs and permits the impurities to be separated through the operation of centrifugal force. A recent improvement is the addition of an aeration bowl, which insures the passing of the oil from the separator with no more entrapped air than it had when entering. This process permits of the combined centrifugal and chemical treatment by which impurities affecting the chemical and physical characteristics of the oil are eliminated by reagents at the same time that carbon and water are removed by centrifugal action. The method is fully described in "Purifying Circuit Breaker Oil," by Lee Hinchman Clark, Sept. 19, 1925, issue of the *Electrical World.*

The centrifugal process also has its disadvantages. It will not remove finely divided carbon particles held in suspension in the oil, which require for their removal either the filter press or a chemical treatment. It is necessary to heat the oil to approximately 100 deg. fahr. for the best results with the centrifuge. The apparatus for the centrifugal process costs approximately twice as much as the apparatus of the same actual capacity for the filter press process.

A comparison of the two methods based upon the information available seems to indicate that the filter press process is best suited to the reconditioning of lightly contaminated oils, and that the centrifugal process makes the best showing when used for heavily contaminated oils, where its greatest speed in operation has its maximum effect. The centrifugal process is admirably suited for the rapid purification of transformer oils and others containing large quantities of water. It is not, however, as well adapted for the purifying of circuit breaker oils and others which have considerable carbon therein.

Dependence solely upon the centrifugal process alone is scarcely to be recommended at this time, although a combination of the two methods should produce very satisfactory results; for example, passing oil which shows the greatest contamination in finely divided carbon first through the centrifuge and afterward through the filter press.

APPENDIX III

OIL SPECIFICATION OF THE COMMONWEALTH EDISON COMPANY

(Abstracted for the Purposes of this Report)

1. GENERAL: The oil furnished in accordance with this specification will be used in oil circuit breakers and transformers and other electrical apparatus. (Distribution Division Spec. S1950 has same requirements).

2. FLASH POINT: The flash point shall not be less than 130 deg. cent. (266 deg. fahr.). Test Method:—A.S.T.M. Standards, 1927, D92-24, pages 404-408.

3. FIRE POINT: The fire point shall be not less than 149 deg. cent. (300 deg. fahr.). Test Method:—A.S.T.M. Standards, 1927, D92-24, pages 404-408.

4. VISCOSITY: The viscosity shall be not more than 65 sec. at 37.8 deg. cent. (100 deg. fahr.). Test Method:—A.S.T.M. Tentative Standards, 1927, D88-26, pages 427-432

5. EVAPORATION: The evaporation loss shall be not more than 4.0 per cent by weight. Test Method:—Five cubic centimeters of the oil contained in an open dish, 2.5 in. in diameter and ⅝ in. deep, shall be heated in an oven at a temperature of 65-75 deg. cent. (149-167 deg. fahr.) for 8 hr.

6. POUR POINT: The pour point shall be not above —35 deg. cent. (—31 deg. fahr.). Test Method;—A.S.T.M. Tentative Standards, 1927, D97-27-T, pages 390-396.

7. NEUTRALIZATION NUMBER: There shall be required not more than 0.1 milligram potassium hydroxide to neutralize 1 gram of the oil. Test Method:—A.S.T.M. Tentative Standards, 1927, D188-27-T, pages 418-420, Method A, Section 4.

8. FREE AND CORROSIVE SULPHUR: The oil shall not contain free sulphur or corrosive sulphur compounds. Test Method:—A.S.T.M. Standards, 1927, D117-27, page 800.

9. MINERAL ACIDS: (Chlorides and Sulphates) The oil shall be free from mineral acids (Cl or SO_3). Test Method:—A.S.T.M. Standards, 1927, D117-27, page 800.

10. SLUDGE: The oil shall comply with the following sludge test requirements.

10.1. A deposit of sludge shall be not visible until a sludge test in accordance with the American Life Test method has been continued for at least 20 days on samples taken at the refinery, and for at least 12 days on samples taken from oil delivered to purchaser in drums or tank cars. Test Method:—A.S.T.M. Proceedings, June 1927, pages 541 to 549.

10.2 The amount of sludge obtained when a sample of the oil is heated to 85 deg. cent. (185 deg. fahr.) for 55 days in the presence of copper and iron shall not exceed 0.020 per cent by volume on samples taken at the refinery and shall not exceed 0.050 per cent by volume on samples taken from oil delivered to purchaser in drums or tank cars.

Test Method:—375 cubic centimeters of the oil under test is filtered into a clean one pint mason fruit jar, which has been cleaned according to procedure described in test method for paragraph 10.1 above. A piece of copper 8 x

1.25 x 0.16 cm. and a piece of transformer iron 8 x 1.4 x 0.04 cm. are thoroughly cleaned with emery and washed with acetone and with the oil to be tested, and then placed in the oil sample.

Test samples are placed in an oven having its temperature maintained within 2 deg. cent. of 85 deg. cent. The position of the samples in the oven is shifted each week to neutralize inequalities of temperature in the oven. A stream of air is passed into the oven through a wash bottle containing insulating oil.

After being heated for 55 days, the samples are removed from the oven and allowed to stand for 4 days at room temperature. The oil is then thoroughly mixed with the sludge and poured into a clean container. The test jar is washed with 10 cubic centimeters of acetone until any sludge film in the jar is dissolved, then 10 cubic centimeters of the tested oil is added and the acetone expelled by heating at 70 deg. cent., and then the residue of oil and sludge is added to the main test sample.

One hundred cubic centimeters of the sample is then placed in a graduated centrifuge tube and subjected to centrifuging at 1400 r.p.m. for 90 min.

There is practically no increase in the volume of sediment with centrifuging continued for more than 90 min., but occasionally a clear line of demarcation between sludge and oil will not be obtained in this time, and contrifuging is continued for 30 min. intervals until a clear separation is obtained. The volume of sludge in cubic centimeters is numerically equal to the percentage, by volume, of sludge in the oil at the end of the heating period.

11. DIELECTRIC STRENGTH: The dielectric strength of the oil shall be not less than 25 kilovolts. Test Method:—A.S.T.M. Standards, D117-27, pages 801-803.

12. SUBMISSION AND TEST OF SAMPLES: A 1 gal. sample of the kind of oil that is proposed to be furnished shall be delivered to the purchaser at the testing department. If the sample meets the specifications in all particulars, oil of the same quality can be shipped as instructed. This does not require that the oil supplied be of the same lot as the original sample, but it does require that the oil supplied be made in accordance with the same specifications and subject to the same control and inspection to have the same characteristics as the original sample.

Each shipment of oil will also be sampled and tested by the purchaser, including the sludge tests, and shipments not meeting these specifications will be rejected and shall be removed by the vendor. The vendor shall pay all expenses in delivering and removing the rejected oil.

13. SHIPMENT: Insulating oil shall be shipped in oil-tight steel drums, unless otherwise specified. Each container shall be legibly marked with purchase order number and vendor's name. Each drum which can be returned to the vendor for credit shall be marked with a serial number, either by figures stamped in relief on the barrel head or by figures stamped on a brass plate and the plate brazed to the barrel head. The figures shall be at least ½ in. high and preferably at least 1 in. high.

APPENDIX IV

OIL SPECIFICATION OF THE NEW YORK AND QUEENS ELECTRIC LIGHT AND POWER COMPANY

(Abstracted for the Purposes of this Report)

1. SCOPE: The oil furnished in accordance with this specification will be used in all oil immersed electrical devices for purposes of insulation and cooling. This specification will not cover oils used in cables and potheads.

The insulating oil shall be a pure mineral oil from which inorganic acids, alkalis and free sulphur shall be absent.

Oil purchased under this specification shall conform to the following requirements as determined by the test methods specially noted.

2. FLASH POINT: The flash point shall be not less than 130 deg. cent. as determined by test method D-92-24, A.S.T.M. Standards, 1927, Part II, page 404.

3. FIRE POINT: The fire point shall be not less than 150 deg. cent. as determined by Test Method D-92-24, A.S.T.M. Standards, 1927, Part II, page 404.

4. POUR POINT: The pour point shall be not higher than —40 deg. cent. (—40 deg. fahr.) as determined by Test Method D-97-27, T, A.S.T.M. Tentative Standards, page 390.

5. VISCOSITY: The viscosity shall be not greater than 50 seconds Saybolt at 37.8 deg. cent. as determined by Test Method D-88-26 A.S.T.M. Standards, 1928, page 427.

6. NEUTRALIZATION NUMBER: There shall be required not more than 0.05 milligram of potassium hydroxide to neutralize 1 gram of the oil as determined by Test Method D-188-27-T, A.S.T.M. Tentative Standards, 1928, page 431.

7. MINERAL ACIDS (Chlorides and Sulphates): The oil shall show the absence of mineral acids (chlorides and sulphates) as determined by Test Method D-117-27, A.S.T.M. Standards 1928, page 800.

8. FREE AND CORROSIVE SULPHUR: The oil shall not contain free sulphur or corrosive sulphur compounds as determined by Test Method D-117-27, A.S.T.M. Standards, 1928, page 800.

9. SLUDGE: A deposit of sludge shall not be visible until a sludge test has been continued for at least 18 days in accordance with the Snyder Life Test as published in Appendix to Report of Committee D-9, 1927 Proceedings, A.S.T.M., Part I, page 541.

10. RESISTANCE TO EMULSIFICATION: The precise R.E. number of the oil shall not exceed 25 sec. as determined by the Standard Method of Test for Steam Emulsion of Lubricating Oils, Serial Designation D-157-27, A.S.T.M. Standards 1927, Part II, page 414.

11. DIELECTRIC STRENGTH: The dielectric strength shall be not less than 22 KV. as determined by Test Method D-117-27, A.S.T.M. Standards, 1928, page 801.

12. SAMPLING METHODS: The oil sampling procedure for these tests shall conform to the methods outlined in D-117-27, A.S.T.M. Standards, 1928, page 796.

13. DETERMINATION OF QUANTITIES: Sixty degrees Fahrenheit (60 deg. fahr.) is established as the normal temperature for all oil to be delivered under this specification. Deductions shall be made and additions shall be made to the apparent quantity of oil contained in any delivery in accordance with the Standard Abridged Volume Correction Table for Petroleum Oils, A.S.T.M. Serial Designation D-206-25, A.S.T.M. Standards 1927, Part II, page 351. The temperature reading of the oil shall be made at time of volume measurement.

14. ACCEPTANCE TESTS: Proposed bidders shall submit a 2 quart sample in a glass container of the oil proposed in the bid.

Each shipment of oil will also be tested by the Purchaser after sampling at point of delivery. Oil which fails to comply with any one or all of the limits specified, will be rejected and must be removed by the Vendor, who shall pay all expenses of delivery and removing the rejected oil.

APPENDIX V

OPERATING INSTRUCTIONS OF THE PHILADELPHIA ELECTRIC COMPANY

(Abstracted for the Purposes of this Report)

Transformer oil shall be used only for transformers; circuit breaker oil shall be used only for oil circuit breakers.

All supply lines shall be kept filled with clean oil.

Dirty oil tanks may be used for either dirty transformer or dirty circuit breaker oil, but only one grade of oil is to be deposited in the tanks at one time. All dirty oil deposited in the tanks shall be immediately purified and returned to its respective clean oil storage system in order that the dirty oil tanks may be available at all times for oil of either type. It is extremely important that oils of different grades be not mixed except as noted below.

When the dirty oil drain header has been used, it shall be drained as dry as possible in order to prevent the mixing in the system of oils of the two classes. Operation of the purifier pump will clear this header. All oil drawn from the header when draining shall be purified and returned to clean breaker oil tanks, not to dirty oil tanks. After the header has been drained, it may be used for the emptying of either transformers or oil circuit breakers.

Before the 100-g.p.m. pump shall be used to fill with clean oil a transformer or oil circuit breaker, it shall be washed out by having run through it and out to the dirty oil tanks a small quantity of the oil to be pumped. The oil used for washing the pump shall be immediately purified and returned to the clean breaker oil tanks.

APPENDIX VI

STATEMENT BY THE WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY

(Abstracted for the Purposes of this Report)

Storage tanks may be placed either entirely above ground or entirely below ground. When placed below ground they should not be embedded in concrete, but should be arranged with plenty of space on all sides for inspection and for access of fresh air. The question of whether explosive vapors will accumulate in such an underground pit need not be considered since insulating oils are far different in this respect from such materials as gasoline, benzine and other volatile liquids. Wherever tanks are embedded in concrete, it is practically impossible to keep the oil free from an accumulation of moisture, because the temperature of the tank walls always lags behind the temperature of the oil sufficiently to permit the formation of dew on the inside surface of the tank, above the oil level.

Oil tanks should not be arranged with their axes exactly horizontal and a small drainage point should be provided at the lowest elevation, in order to permit of the drawing off of any sediment and moisture which may settle at the bottom. The incoming oil should enter near the surface, if possible, so that any such sediment will not be appreciably disturbed and will not be mixed with the oil to any great extent. For the same reason, the oil outlet should also be a certain distance from the bottom.

When oil tanks are arranged with their axes vertical, it is possible to have both the inlet and outlet pipes some distance above the bottom without involving a large volume of oil, especially when the ends of the tanks have considerable convexity.

Although the lagging of tanks may be of some assistance, it is doubtful whether the extra expense is ever warranted. In some cases, where it is easy to do so, tanks may be heated by steam coils. There is, however, some danger of the formation of a deposit on account of the extreme temperature which may exist at the surface of the source of heat, this temperature being quite likely to be high enough to cause sludging in any known insulating oil.

Piping in general should be so arranged that there will be no pockets of dead oil, accumulated air or moisture. If possible, in cases where both dirty and clean oil must be handled, separate pipes should be provided, especially in the case of circuit breaker oil. If impossible, means should be found for completely flushing out the piping with clean oil after carbonized oil has been passed through it and before reconditioned oil is returned through to the breaker itself. It may at times be advisable, even though expensive, to furnish parallel pipe lines, connected to the breaker tanks by three-way cocks; such an arrangement allowing the use of the dirty pipe line for the emptying of a tank which contains carbonized oil and the use of the other line for refilling the same tank with clean oil.

The capacity of oil reconditioning apparatus selected should depend entirely on whether or not it is more economical to be able rapidly to handle the oil in emergencies or to be required to have a large gang of men waiting while apparatus of small capacity is being used to empty, clean and refill apparatus tanks. It must always be remembered that a saving in the capacity of filtering or centrifuging outfits may be absorbed in a very short time if, in emergency, apparatus cannot be restored to service promptly, and a large crew is, therefore, kept waiting for an appreciable length of time. It should also be borne in mind that the interest on the capital invested in a large filtering outfit is likely to be much less than the cost of having important equipment out of service for any considerable length of time.

APPENDIX VII

POLICY ON THE UTILIZATION OF ELECTRICAL INSULATING OILS OF THE DUQUESNE LIGHT COMPANY

(Abstracted for the Purposes of this Report)

1. The departments of the Duquesne Light Co. purchasing, stocking and using electrical insulating oils shall observe the procedure outlined, effective Dec. 1, 1927.

2. New Oil Purchases and Stocks shall include:
   a. Wemco C oil—Westinghouse Electric & Mfg. Co.
   b. G.E. No. 21-C oil—General Electric Co.
   c. G.E. No. 6 oil—General Electric Co.

3. Application of New Oils shall include:
   a. Wemco C oil shall be used in all Westinghouse company oil submerged electrical equipment, both indoor and outdoor, and for replacement in General Electric Company indoor and outdoor transformers, induction voltage regulators and constant current transformers. Wemco C oil shall not be used in General Electric Co. indoor and outdoor circuit breakers.
   b. G.E. Co. No. 21-C oil shall be used in General Electric Company outdoor circuit breakers; in indoor breakers of the following types only: FK 130—FK 230—FHK 130—FHK 230, and in D. and W. Fuse Cutouts.
   c. G.E. Co. No. 6 oil shall be used only in General Electric Company indoor circuit breakers, Types FK 130—FK 230—FHK 130—FHK 230 excepted.

4. Reconditioned Serviced Oil Stocks shall include:
   a. 1. Serviced transformer oils, low-pour test as Wemco C, Transil No. 10-C.
      2. Service transformer oils, high-pour test as Wemco A, Transil No. 10—Pittsburgh.
   b. 1. Serviced circuit breaker oil—Wemco C.
      2. Serviced circuit breaker oil—G.E. No. 21-C.
   c. Serviced circuit breaker oil—G.E. No. 6
   d. Mixed serviced oils for use only in distribution transformers of 50 kv-a. and under for overhead line work.

5. Application of Reconditioned Serviced Oils shall include:
   A. From Transformers:
      1. Wemco A and G.E. 10 oils serviced in Westinghouse, General Electric and Pittsburgh transformers, indoor type, after reconditioning may be reused only in indoor transformers supplied by the Westinghouse, General Electric and Pittsburgh Companies.
      2. Pittsburgh Oil serviced in Pittsburgh Transformers after reconditioning may be reused only in Pittsburgh Transformers.
      3. Wemco C and G.E. 10-C oils which have been serviced in transformers may be reused for indoor or outdoor service in any manufacturer's transformers.
      4. Wemco A, G.E. 10 and Pittsburgh oils must not be used for make-up oil in outdoor transformers, which contain Wemco C or G.E. No. 10-C oils.
      5. Note: It will be the policy of the company to retire gradually from service Wemco A oil, G.E. Transil No. 10 and Pittsburgh oils, and in their placed to supply Wemco C oil, either new or serviced.

   B. From Circuit Breakers and Outdoor Regulators:
      The reuse of reconditioned serviced oils in circuit breakers and regulators shall conform to its original application in the apparatus specified.

Oil	Original Application	After Reconditioning
Wemco C	W. E. and M. Co. Circuit Breakers, indoor and outdoor	W. E. and M. Co. Circuit Breakers, indoor and outdoor
Wemco C	W. E. and M. Co. Regulators, outdoor	W. E. and M. Co. Regulators, outdoor
G. E. No. 21-C	G. E. Co. Circuit Breakers, outdoor only	G. E. Co. Circuit Breakers, outdoor only
G. E. No. 6	G. E. Co. Circuit Breakers, indoor only	G. E. Co. Circuit Breakers, indoor only

   C. From Lightning Arresters:
      Oils serviced in lightning arresters shall not be reused for any other service.

6. Removal of oils from service shall be made when the values do not conform as follows:

Determining Values	Circuit Breakers	Transformers Outdoor Regulators
Dielectric strength min. kv.	18.0	18.0
Suspension	visible	visible
Pour test not higher than deg. C.	—25*	—25*

*Applies to outdoor circuit breakers and regulators.

7. Reconditioning of oils may be made by a centrifuge, by blotter type filter press or by both as follows:
   a. Oils removed from outdoor circuit breakers will be reconditioned and reclaimed for reuse in outdoor circuit breakers when the pour test is below minus twenty-five (—25) deg. cent.
   b. Oils removed from outdoor regulators will be reconditioned and reclaimed for reuse in outdoor regulators when the pour test is below minus twenty-five (—25) deg. cent.
   c. Oils removed from transformers will be reconditioned and reclaimed for reuse in transformers when they show no evidence of mixture of circuit breaker and transformer oils.
   d. Oils removed from transformers showing evidence of mixture of circuit breaker and transformer oils will be reconditioned and reclaimed for reuse only in distribution transformers of 50 kv-a. and under on overhead line work.
   e. Oils removed from any other apparatus and showing evidence of mixture of circuit breaker and transformer oils will not be reconditioned, and will be permanently rejected from service.

8. Disposition of Oils.
   Oils removed from equipment and conforming to the intended service, when reconditioned in the field shall be restored to similar service. Oils removed from equipment for reconditioning at the Central Oil Reclamation Plant at Manchester shall be handled in containers provided, and shall not be mixed in the field. All such shipments shall be marked showing the previous service of the oil. Oils permanently rejected shall be disposed of by the Stores Department.

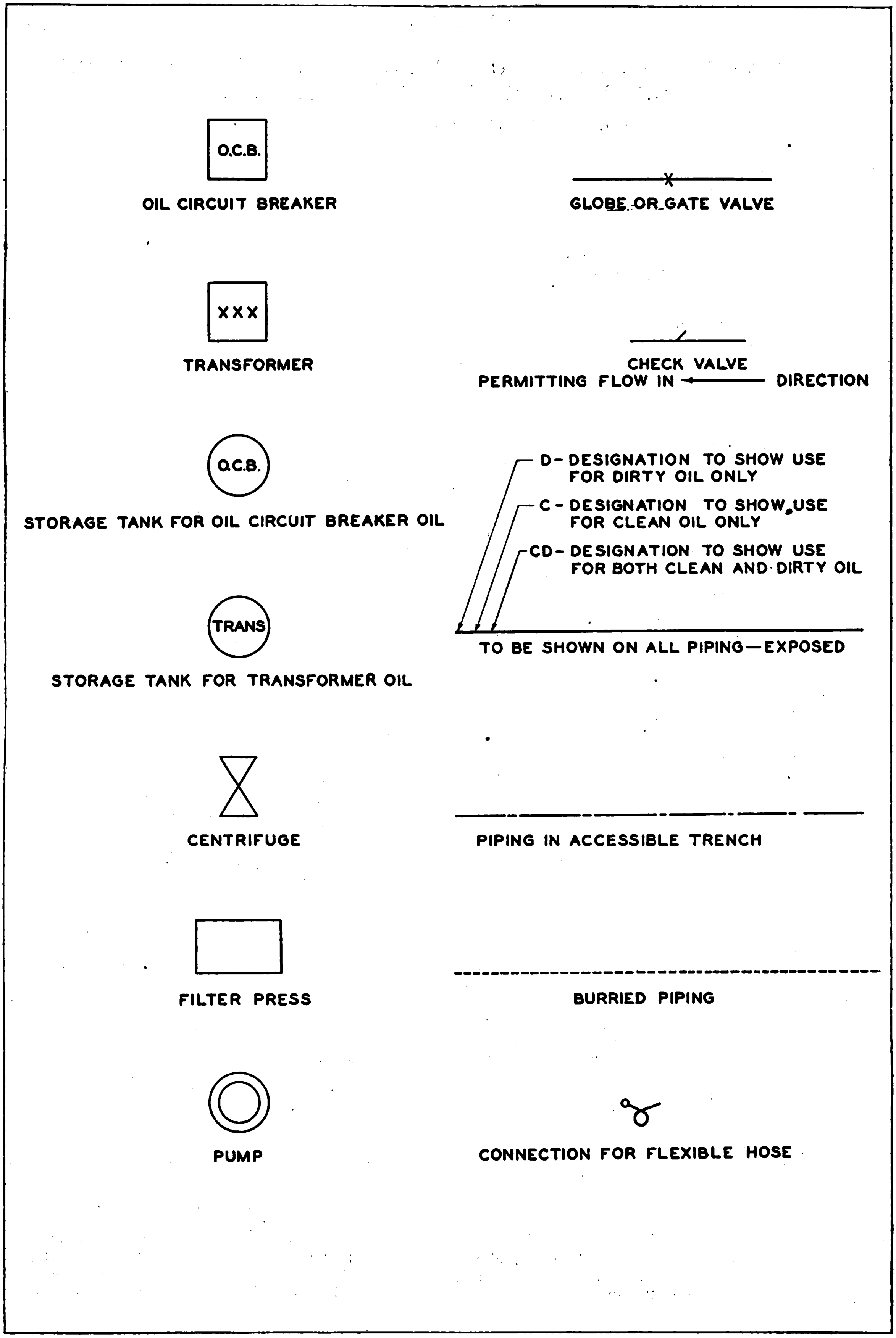

O.C.B.
OIL CIRCUIT BREAKER
GLOBE OR GATE VALVE
XXX
TRANSFORMER
CHECK VALVE
PERMITTING FLOW IN ← DIRECTION
O.C.B.
STORAGE TANK FOR OIL CIRCUIT BREAKER OIL
D- DESIGNATION TO SHOW USE FOR DIRTY OIL ONLY
C- DESIGNATION TO SHOW USE FOR CLEAN OIL ONLY
CD- DESIGNATION TO SHOW USE FOR BOTH CLEAN AND DIRTY OIL
TRANS
STORAGE TANK FOR TRANSFORMER OIL
TO BE SHOWN ON ALL PIPING—EXPOSED
CENTRIFUGE
PIPING IN ACCESSIBLE TRENCH
FILTER PRESS
BURRIED PIPING
PUMP
CONNECTION FOR FLEXIBLE HOSE

FIG. 1—LEGEND OF SYMBOLS USED ON DRAWINGS IN THIS REPORT.

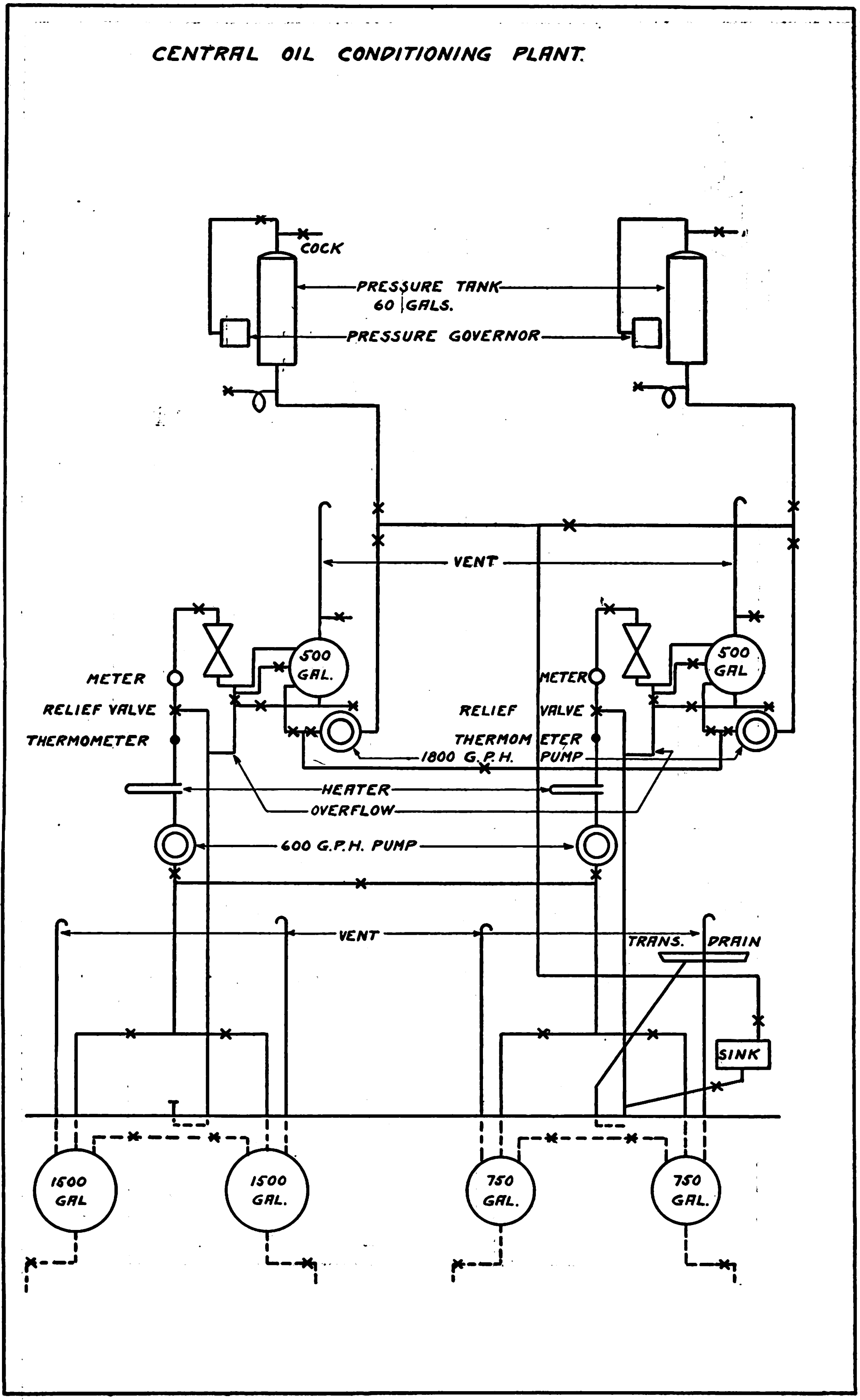

CENTRAL OIL CONDITIONING PLANT.
COCK
PRESSURE TANK 60 GALS.
PRESSURE GOVERNOR
VENT
500 GAL.
500 GAL
METER
RELIEF VALVE
THERMOMETER
METER
RELIEF VALVE
THERMOMETER
1800 G.P.H. PUMP
HEATER
OVERFLOW
600 G.P.H. PUMP
VENT
TRANS. DRAIN
SINK
1500 GAL
1500 GAL.
750 GAL.
750 GAL.

FIG. 2—CENTRAL RECONDITIONING PLANT—BROOKLYN EDISON CO.

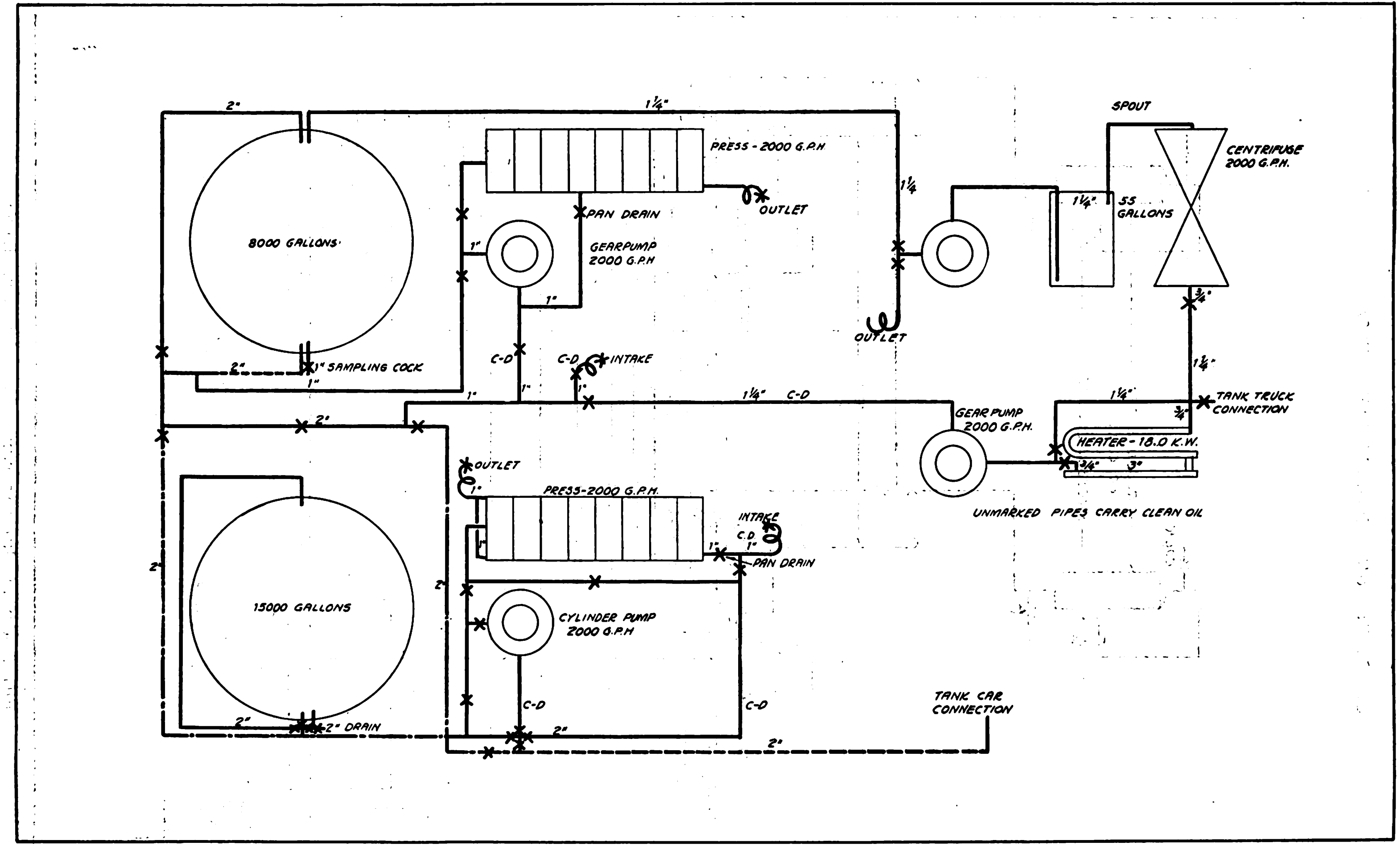

2"
1¼"
PRESS - 2000 G.P.H
OUTLET
PAN DRAIN
8000 GALLONS
1"
GEARPUMP
2000 G.P.H
1"
1¼
OUTLET
SPOUT
CENTRIFUGE
2000 G.P.H.
1¼"
55
GALLONS
¾"
1¼"
2"
1" SAMPLING COCK
1"
C-D
C-D
INTAKE
1"
1"
1"
1¼" C-D
GEAR PUMP
2000 G.P.H.
1¼"
TANK TRUCK
CONNECTION
¾"
HEATER - 18.0 K.W.
¾"
3"
2"
OUTLET
1"
PRESS-2000 G.P.H.
INTAKE
C.D
1"
1"
PAN DRAIN
UNMARKED PIPES CARRY CLEAN OIL
2"
2"
15000 GALLONS
CYLINDER PUMP
2000 G.P.H
C-D
C-D
TANK CAR
CONNECTION
2"
2" DRAIN
2"
2"

FIG. 3—CENTRAL RECONDITIONING PLANT—COMMONWEALTH EDISON CO.

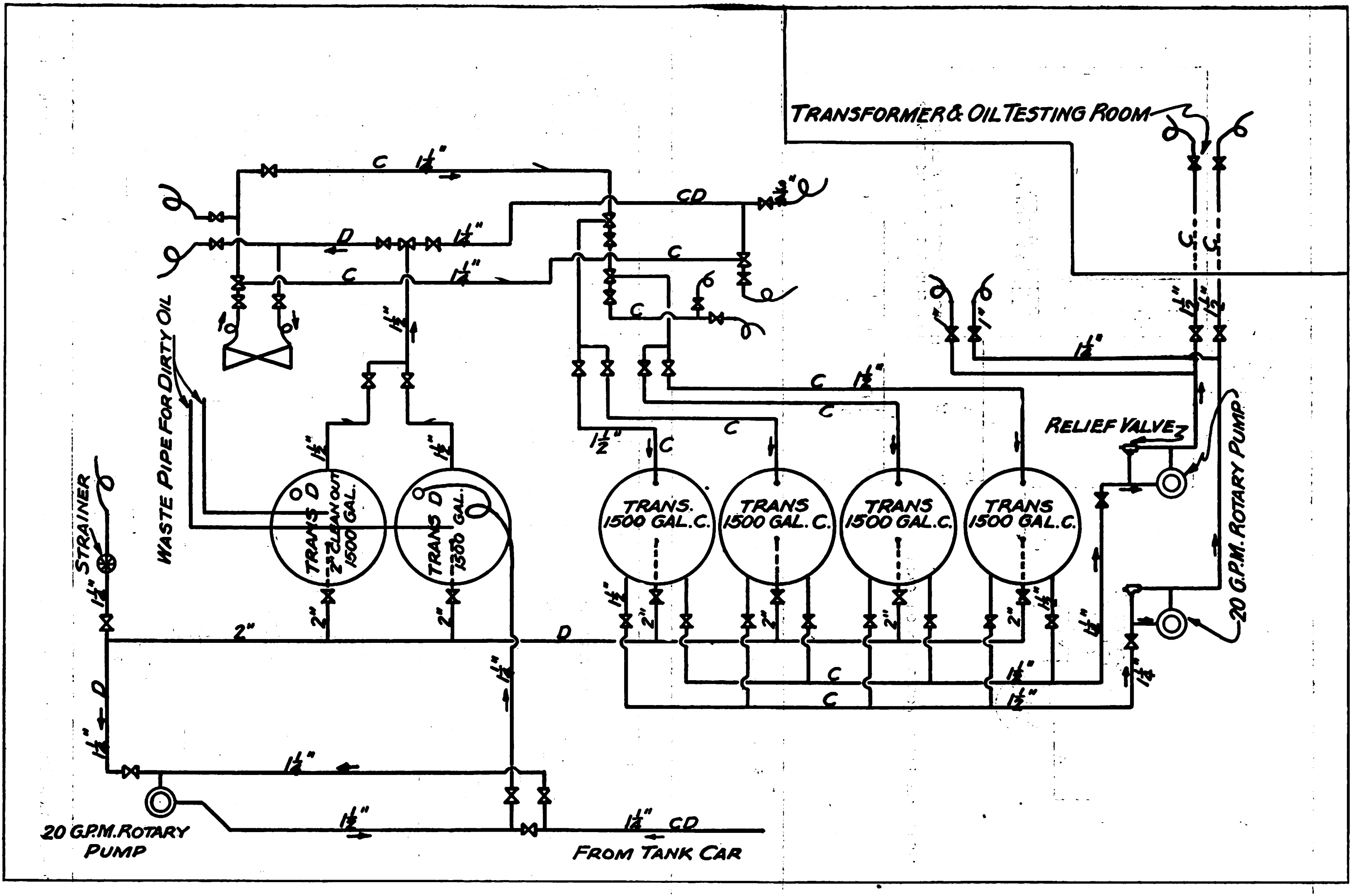
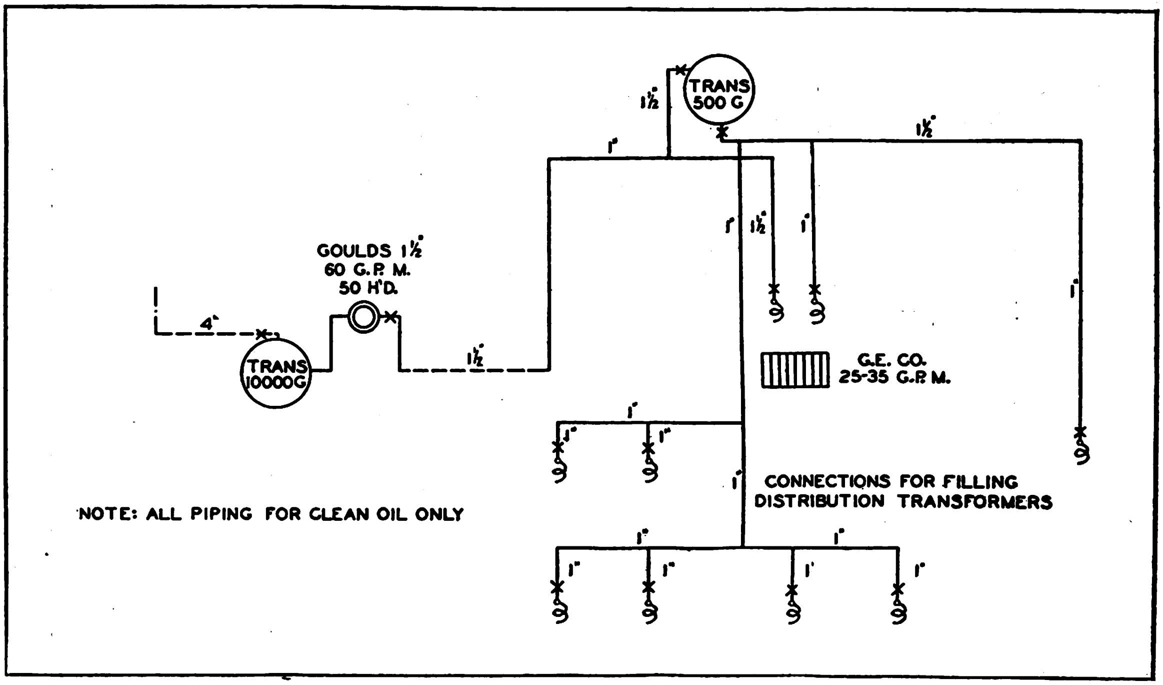
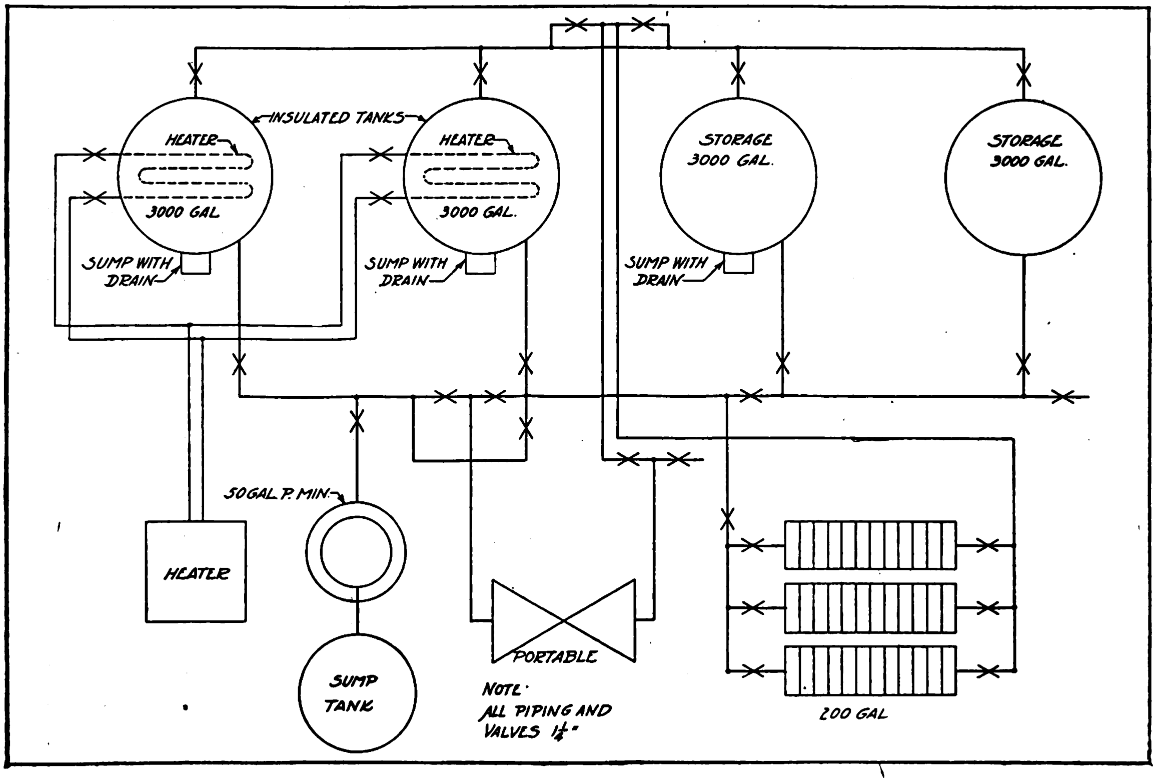

TRANSFORMER & OIL TESTING ROOM
RELIEF VALVE
20 G.P.M. ROTARY PUMP
WASTE PIPE FOR DIRTY OIL
STRAINER
TRANS D 2" CLEAN OUT 1500 GAL.
TRANS D 1350 GAL.
TRANS. 1500 GAL. C.
TRANS 1500 GAL. C.
TRANS 1500 GAL. C.
TRANS 1500 GAL. C.
20 G.P.M. ROTARY PUMP
FROM TANK CAR
C
CD
D
1½"
2"
1"
3"

FIG. 4—CENTRAL RECONDITIONING PLANT—NARRAGANSETT ELECTRIC CO.


TRANS 500 G
1½"
1"
1½"
1"
1½"
1"
GOULDS 1½"
60 G.P.M.
50 H'D.
4"
TRANS 10000G
1½"
1"
G.E. CO.
25-35 G.P.M.
1"
1"
1"
1"
CONNECTIONS FOR FILLING DISTRIBUTION TRANSFORMERS
1"
1"
1"
1"
1"
1"

NOTE: ALL PIPING FOR CLEAN OIL ONLY

FIG. 5—Central Reconditioning Plant—Central Service Station, New York & Queens Electric Light & Power Co.


INSULATED TANKS
HEATER
3000 GAL
SUMP WITH DRAIN
HEATER
3000 GAL.
SUMP WITH DRAIN
STORAGE 3000 GAL.
SUMP WITH DRAIN
STORAGE 3000 GAL.
50 GAL. P. MIN.
HEATER
SUMP TANK
PORTABLE
200 GAL

NOTE · ALL PIPING AND VALVES 1¼"

FIG. 6—Central Reconditioning Plant—Evanston Plant, Public Service Company of Northern Illinois.

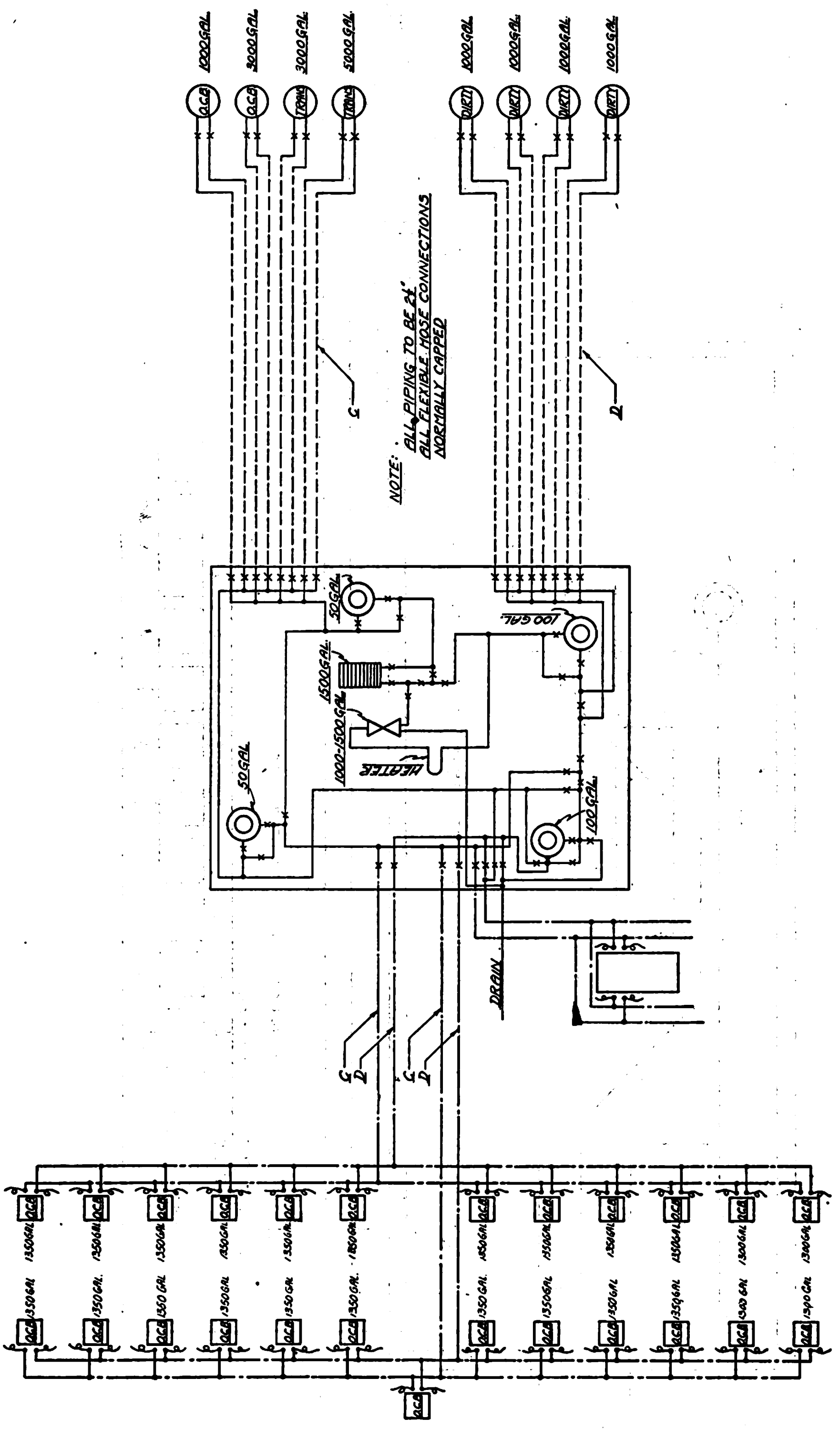

O.C.B. 1000 GAL
O.C.B. 3000 GAL
TRANS 3000 GAL
TRANS 5000 GAL
DIRTY 1000 GAL
DIRTY 1000 GAL
DIRTY 1000 GAL
DIRTY 1000 GAL
NOTE: ALL PIPING TO BE 2"
ALL FLEXIBLE HOSE CONNECTIONS NORMALLY CAPPED
C
D
50 GAL
100 GAL
1500 GAL
1000-1500 GAL
HEATER
50 GAL
100 GAL
DRAIN
C
D
C
D
O.C.B.
1350 GAL
1300 GAL
1390 GAL
1850 GAL

FIG. 7—CENTRAL RECONDITIONING PLANT—HARTWELL TERMINAL, UNION GAS & ELECTRIC CO.

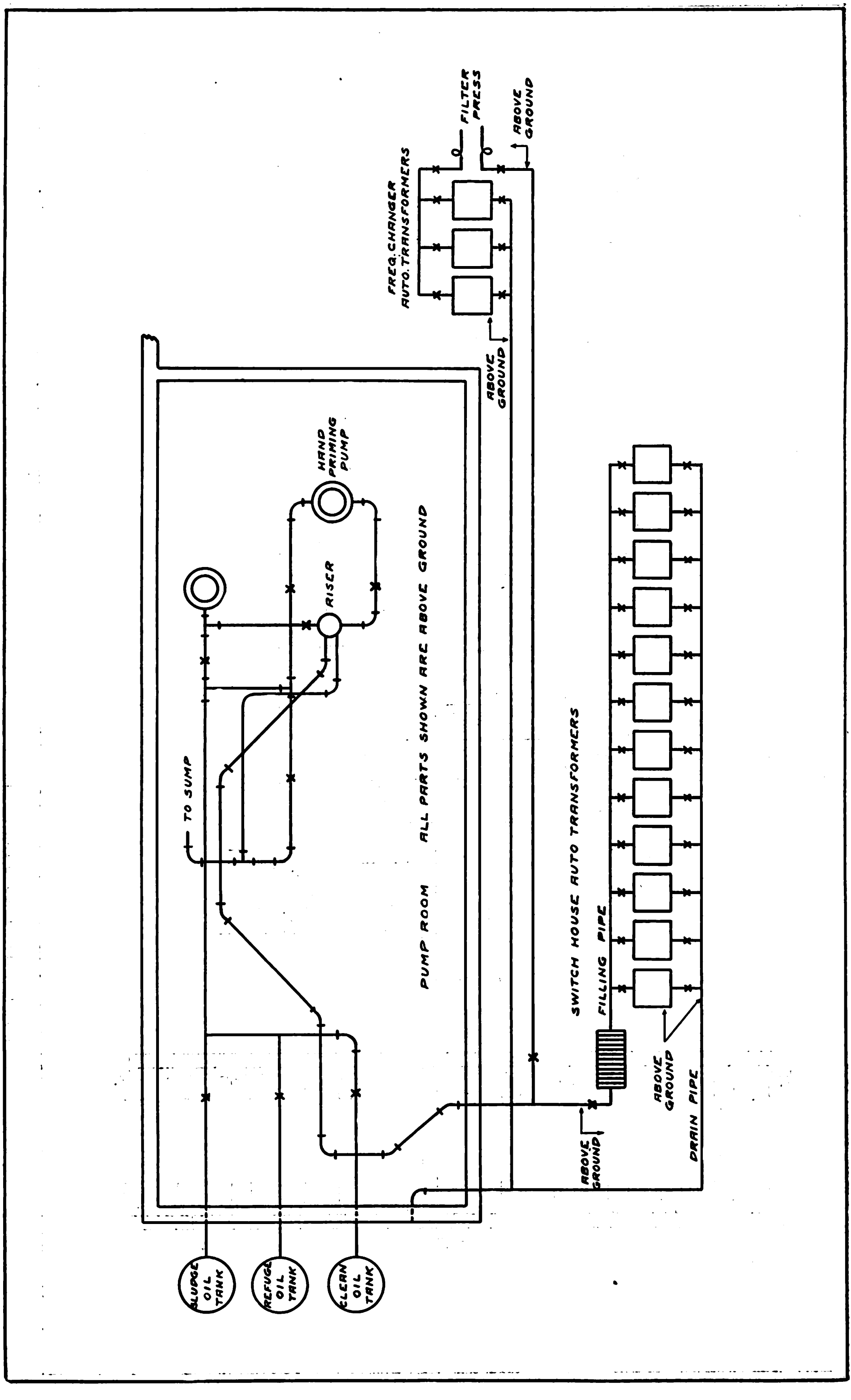

FILTER PRESS
ABOVE GROUND
FREQ. CHANGER AUTO. TRANSFORMERS
ABOVE GROUND
HAND PRIMING PUMP
RISER
TO SUMP
ALL PARTS SHOWN ARE ABOVE GROUND
PUMP ROOM
SWITCH HOUSE AUTO TRANSFORMERS
FILLING PIPE
ABOVE GROUND
ABOVE GROUND
DRAIN PIPE
SLUDGE OIL TANK
REFUGE OIL TANK
CLEAN OIL TANK

FIG. 8—Power Station Reconditioning Plant—Brooklyn Edison Co.

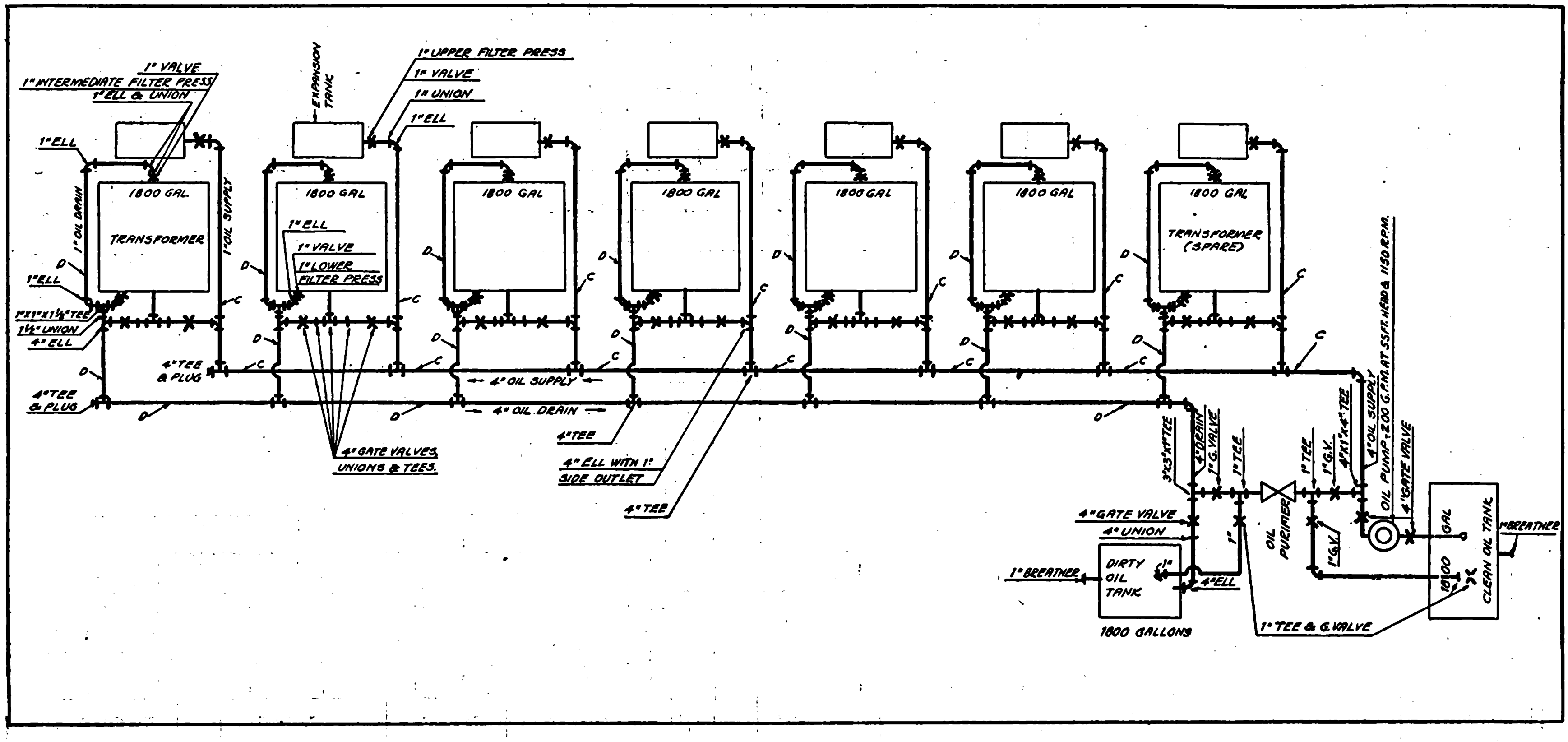

1" VALVE
1" INTERMEDIATE FILTER PRESS
1" ELL & UNION
1" ELL
1" OIL DRAIN
D
1" ELL
1"x1"x1½" TEE
1½" UNION
4" ELL
4" TEE & PLUG
1800 GAL.
TRANSFORMER
1" OIL SUPPLY
4" TEE & PLUG
EXPANSION TANK
1" UPPER FILTER PRESS
1" VALVE
1" UNION
1" ELL
1800 GAL
1" ELL
1" VALVE
1" LOWER FILTER PRESS
4" GATE VALVES, UNIONS & TEES.
C
4" OIL SUPPLY
4" OIL DRAIN
4" TEE
4" ELL WITH 1" SIDE OUTLET
4" TEE
TRANSFORMER (SPARE)
3"x3"x1" TEE
4" DRAIN
1" G. VALVE
1" TEE
OIL PURIFIER
1" TEE
1" G.V.
4"x1"x4" TEE
4" OIL SUPPLY
OIL PUMP - 200 G.P.M. AT 55 FT. HEAD & 1150 R.P.M.
4" GATE VALVE
4" GATE VALVE
4" UNION
1" BREATHER
DIRTY OIL TANK
1"
4" ELL
1800 GALLONS
1"
1" G.V.
1" TEE & G. VALVE
18100 GAL
CLEAN OIL TANK
1" BREATHER

FIG. 9—POWER STATION RECONDITIONING PLANT—PROSPECT NO. 2 PLANT, CALIFORNIA OREGON POWER CO.

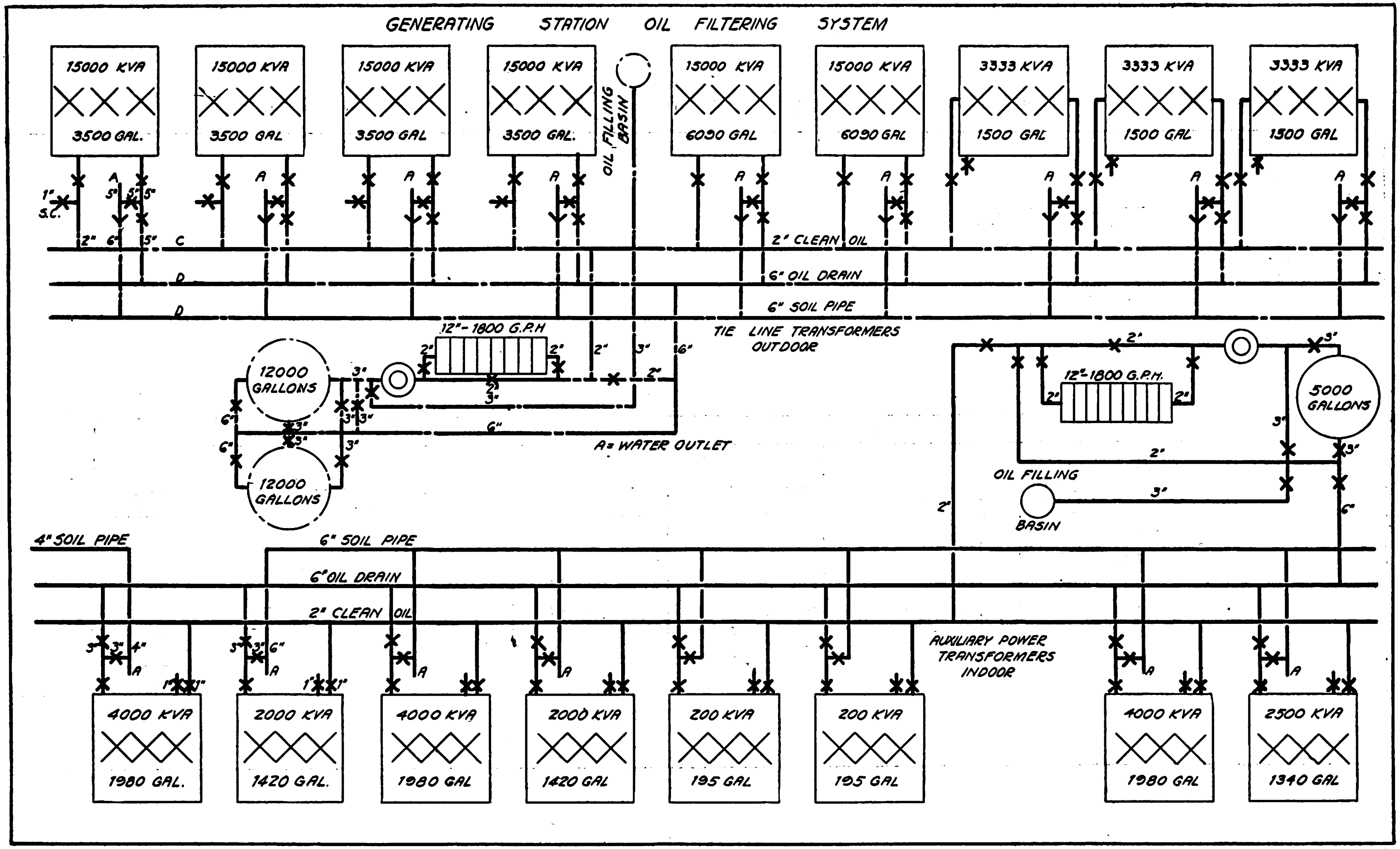

GENERATING STATION OIL FILTERING SYSTEM
15000 KVA
3500 GAL.
15000 KVA
3500 GAL
15000 KVA
3500 GAL
15000 KVA
3500 GAL.
OIL FILLING BASIN
15000 KVA
6030 GAL
15000 KVA
6030 GAL
3333 KVA
1500 GAL
3333 KVA
1500 GAL
3333 KVA
1500 GAL
1"
S.C.
A
5"
2"
6"
C
D
2" CLEAN OIL
6" OIL DRAIN
6" SOIL PIPE
TIE LINE TRANSFORMERS OUTDOOR
12"-1800 G.P.H
12000 GALLONS
12000 GALLONS
3"
6"
2"
A = WATER OUTLET
12"-1800 G.P.H.
5000 GALLONS
OIL FILLING
BASIN
4" SOIL PIPE
6" SOIL PIPE
6" OIL DRAIN
2" CLEAN OIL
AUXILIARY POWER TRANSFORMERS INDOOR
4"
1"
4000 KVA
1980 GAL.
2000 KVA
1420 GAL.
4000 KVA
1980 GAL
2000 KVA
1420 GAL
200 KVA
195 GAL
200 KVA
195 GAL
4000 KVA
1980 GAL
2500 KVA
1340 GAL

FIG. 10—Power Station Reconditioning Plant—Commonwealth Edison Co.

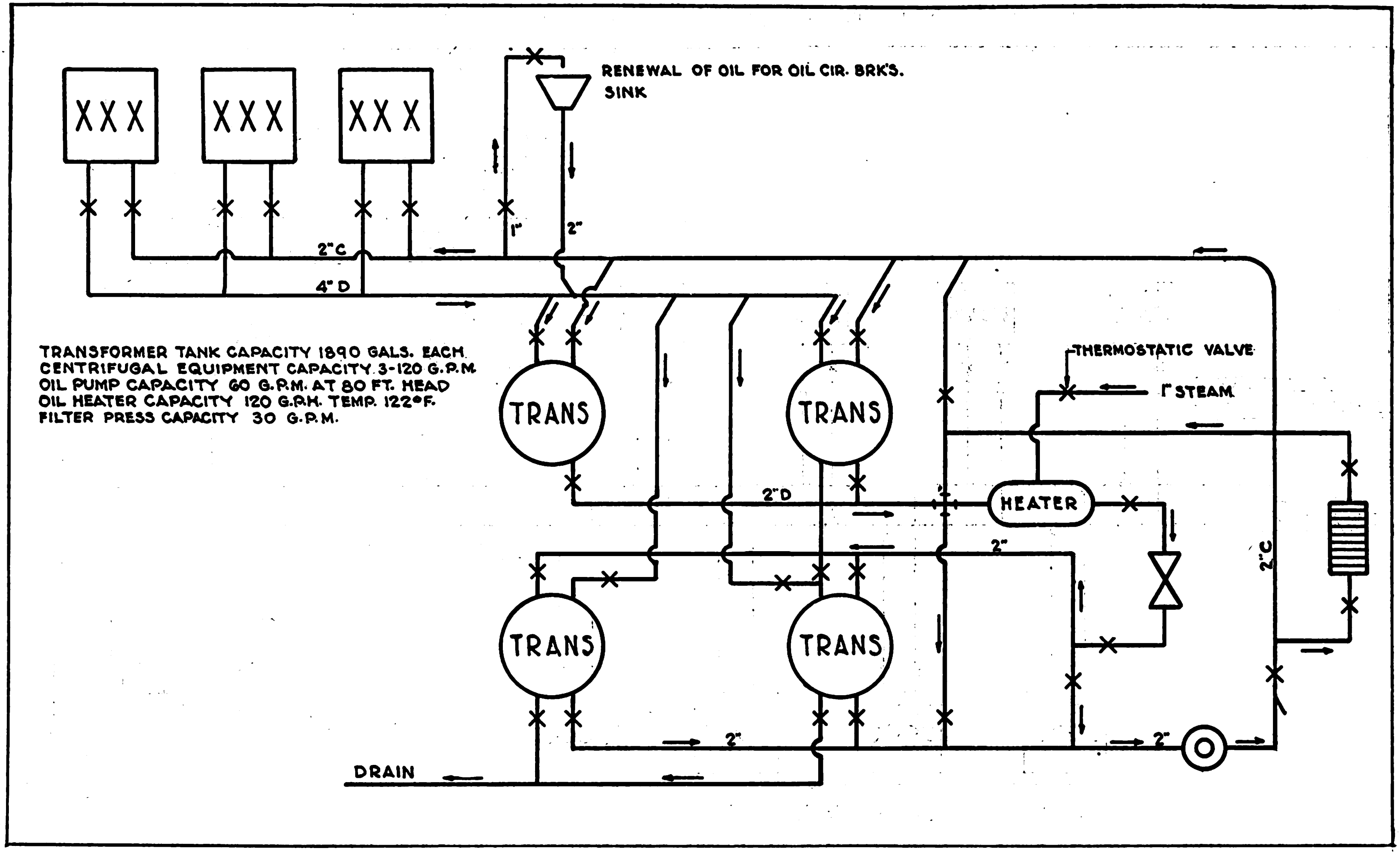
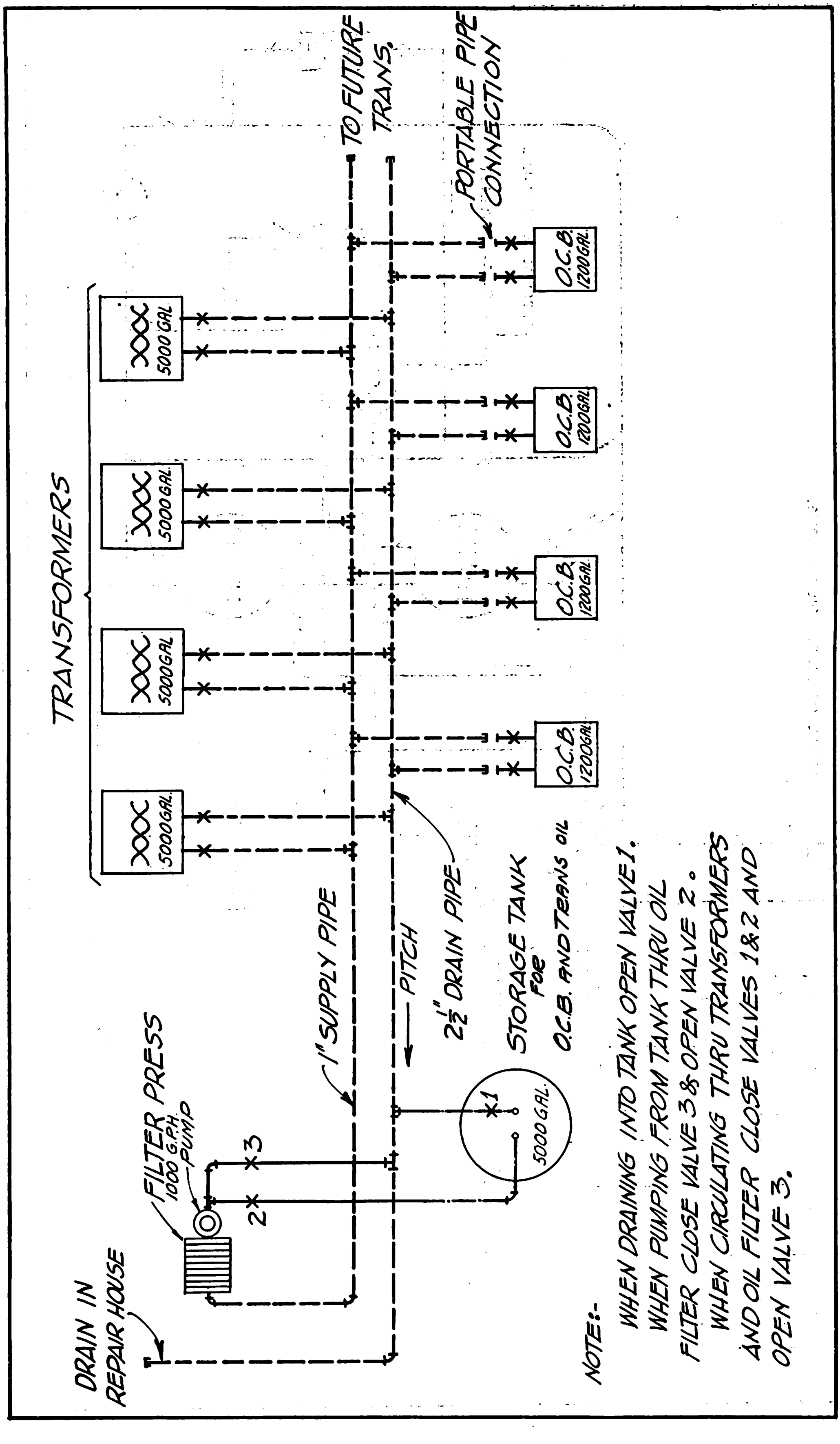

XXX
XXX
XXX
RENEWAL OF OIL FOR OIL CIR. BRK'S.
SINK
1"
2"
2"C
4"D
TRANSFORMER TANK CAPACITY 1890 GALS. EACH.
CENTRIFUGAL EQUIPMENT CAPACITY 3-120 G.P.M.
OIL PUMP CAPACITY 60 G.P.M. AT 80 FT. HEAD
OIL HEATER CAPACITY 120 G.P.H. TEMP. 122°F.
FILTER PRESS CAPACITY 30 G.P.M.
TRANS
TRANS
THERMOSTATIC VALVE
1" STEAM
2"D
HEATER
2"
2"C
TRANS
TRANS
2"
2"
DRAIN

FIG. 11—Power Station Reconditioning Plant—Day & Zimmermann, Inc.


DRAIN IN REPAIR HOUSE
FILTER PRESS
1000 G.P.H. PUMP
3
2
1
1" SUPPLY PIPE
PITCH
2½" DRAIN PIPE
STORAGE TANK FOR O.C.B. AND TRANS OIL
5000 GAL.
TRANSFORMERS
5000 GAL.
5000 GAL.
5000 GAL.
5000 GAL.
O.C.B. 1200 GAL.
O.C.B. 1200 GAL.
O.C.B. 1200 GAL.
O.C.B. 1200 GAL.
TO FUTURE TRANS.
PORTABLE PIPE CONNECTION

NOTE:-
WHEN DRAINING INTO TANK OPEN VALVE 1.
WHEN PUMPING FROM TANK THRU OIL FILTER CLOSE VALVE 3 & OPEN VALVE 2.
WHEN CIRCULATING THRU TRANSFORMERS AND OIL FILTER CLOSE VALVES 1&2 AND OPEN VALVE 3.

FIG. 12—Power Station Reconditioning Plant—The Milwaukee Electric Railway & Light Co.

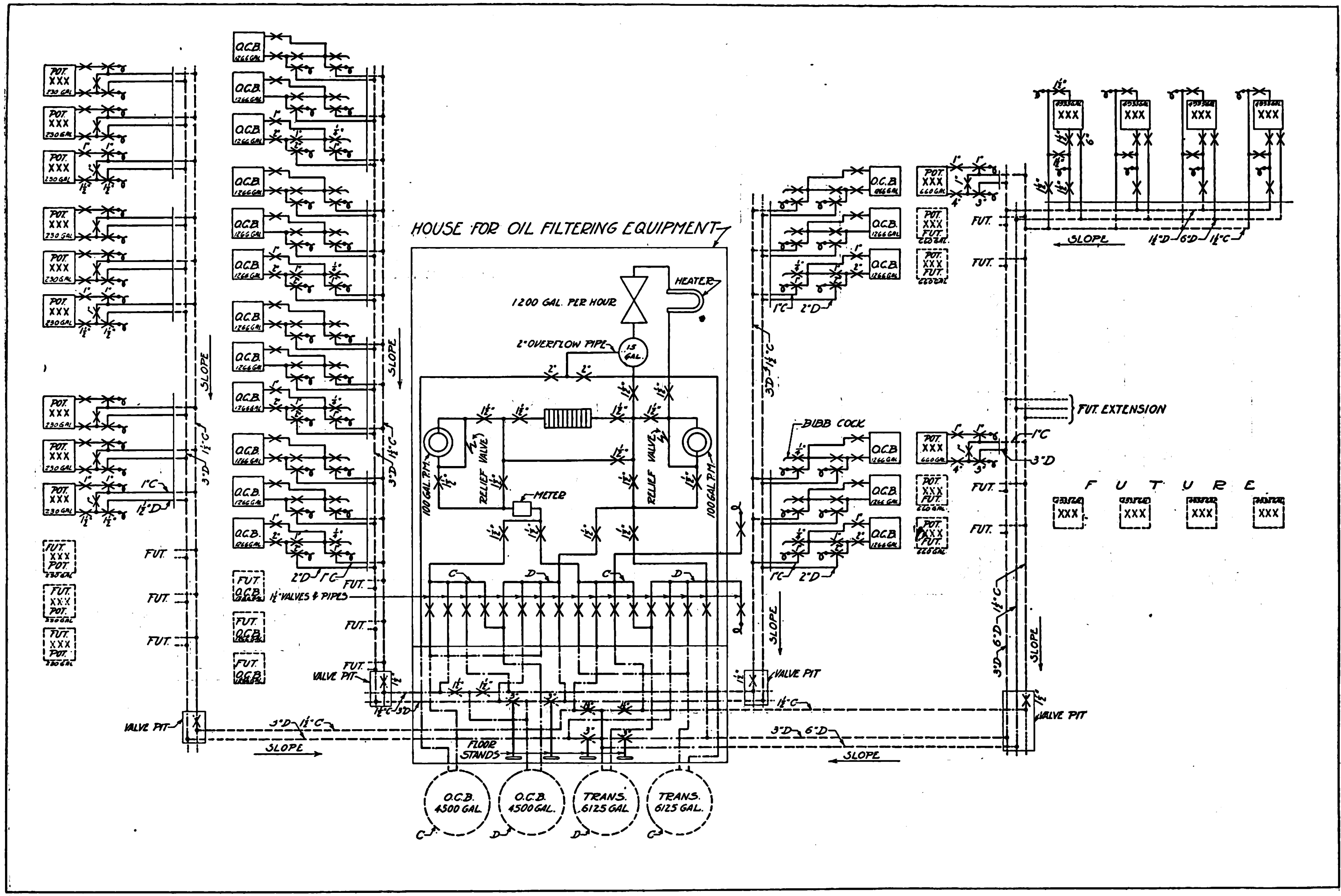

HOUSE FOR OIL FILTERING EQUIPMENT
HEATER
1200 GAL. PER HOUR
2" OVERFLOW PIPE
15 GAL.
100 GAL. P.M.
RELIEF VALVE
METER
RELIEF VALVE
100 GAL. P.M.
1½" VALVES & PIPES
FLOOR STANDS
O.C.B. 4500 GAL.
O.C.B. 4500 GAL.
TRANS. 6125 GAL.
TRANS. 6125 GAL.
O.C.B.
POT. XXX 230 GAL.
FUT. XXX POT.
FUT. O.C.B.
FUT.
SLOPE
VALVE PIT
3"D 1½"C
3"D 6"D
1½"D 6"D 1½"C
1"C 2"D
BIBB COCK
POT. XXX 660 GAL.
POT. XXX FUT. 660 GAL.
FUT. EXTENSION
1"C
3"D
F U T U R E
XXX

FIG. 13—POWER STATION RECONDITIONING PLANT—WAUKEGAN PLANT, PUBLIC SERVICE COMPANY OF NORTHERN ILLINOIS.

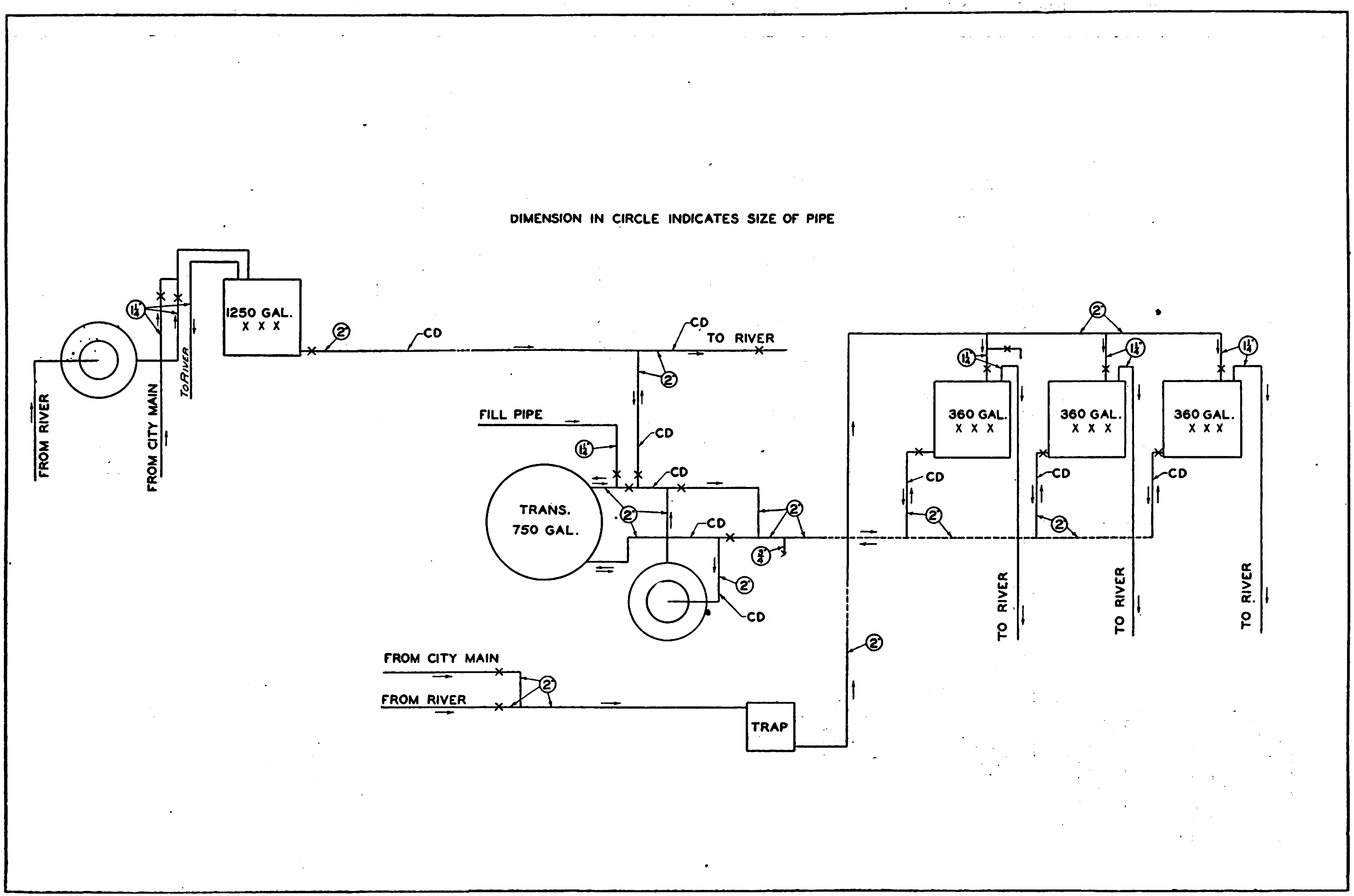

DIMENSION IN CIRCLE INDICATES SIZE OF PIPE
FROM RIVER
FROM CITY MAIN
To RIVER
1¼"
1250 GAL.
X X X
2"
CD
CD
TO RIVER
2"
FILL PIPE
1¼"
CD
CD
TRANS.
750 GAL.
2"
CD
2"
¾"
2"
CD
360 GAL.
X X X
360 GAL.
X X X
360 GAL.
X X X
1¼"
1¼"
1¼"
2"
CD
CD
CD
2"
2"
TO RIVER
TO RIVER
TO RIVER
2"
FROM CITY MAIN
FROM RIVER
2"
TRAP

FIG. 14—POWER STATION RECONDITIONING PLANT—STATION NO. 4, ROCHESTER GAS & ELECTRIC CO.

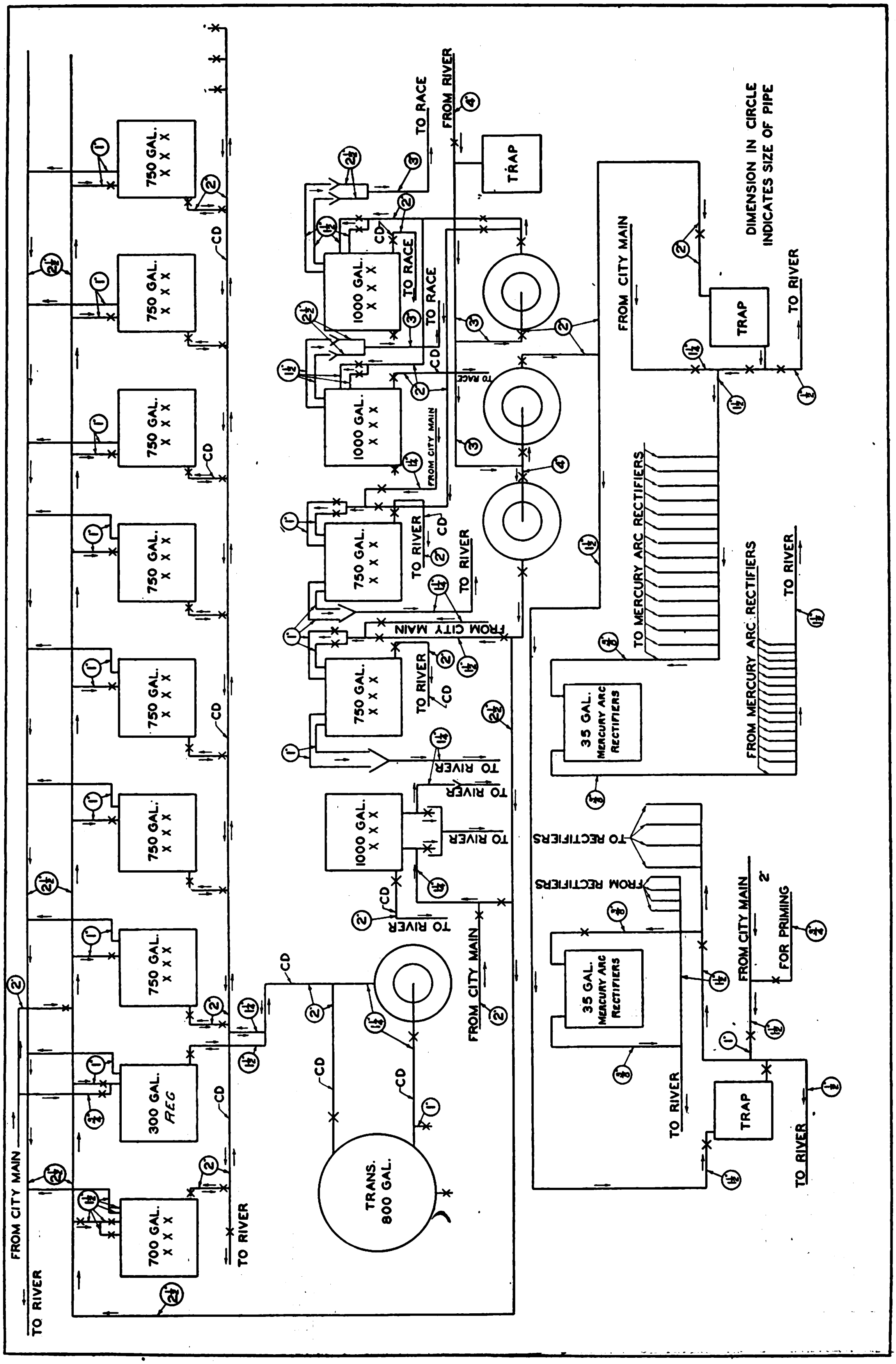

TO RIVER
FROM CITY MAIN
700 GAL. X X X
300 GAL. REG
750 GAL. X X X
1000 GAL. X X X
TRANS. 800 GAL.
CD
TO RACE
FROM RIVER
TRAP
FROM CITY MAIN
DIMENSION IN CIRCLE INDICATES SIZE OF PIPE
TO MERCURY ARC RECTIFIERS
FROM MERCURY ARC RECTIFIERS
35 GAL. MERCURY ARC RECTIFIERS
TO RECTIFIERS
FROM RECTIFIERS
FOR PRIMING
1"
1½
2
2"
2½
3
4
½
¾

FIG. 15—Power Station Reconditioning Plant—Station No. 6, Rochester Gas & Electric Co.

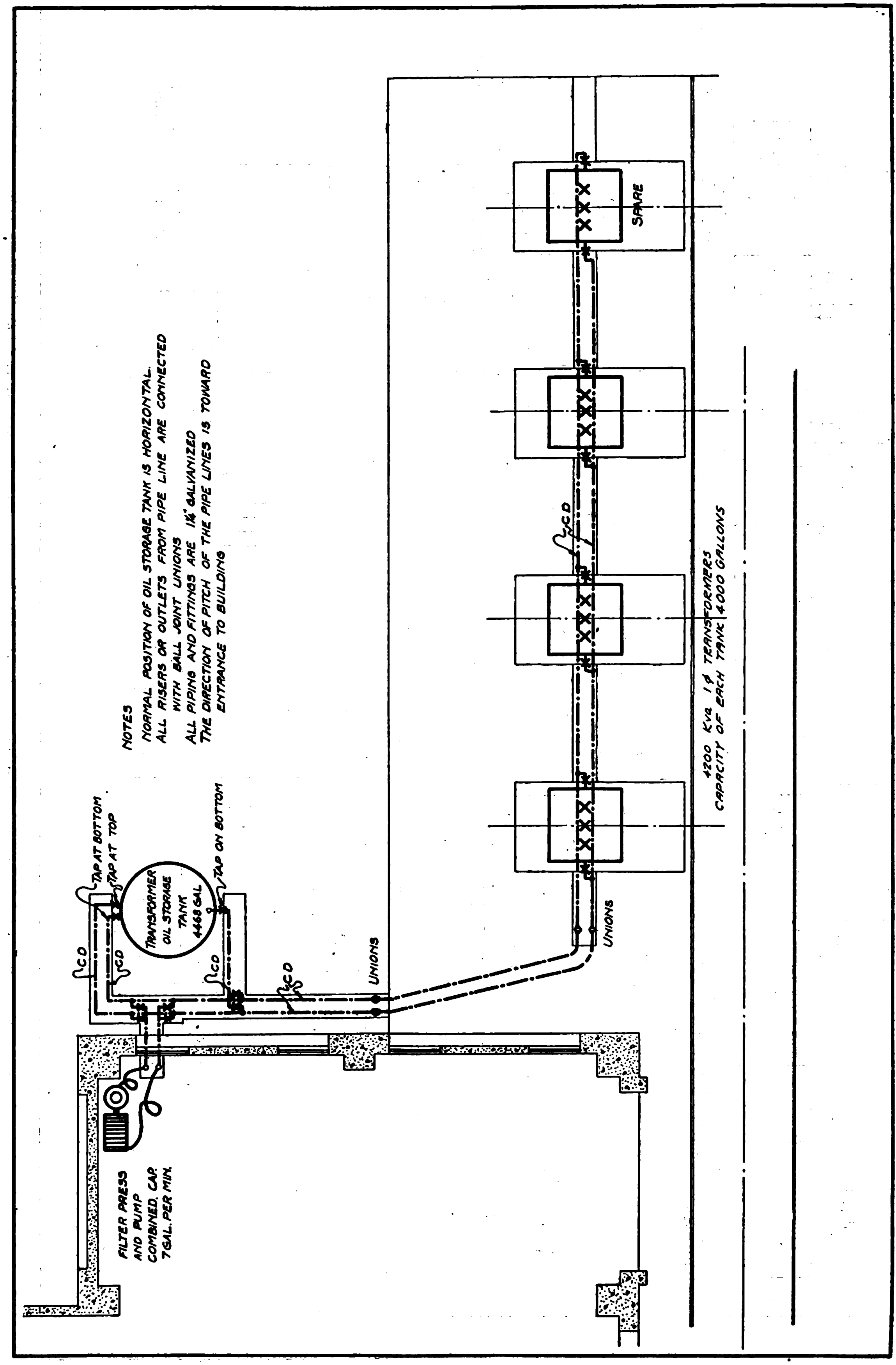

NOTES
NORMAL POSITION OF OIL STORAGE TANK IS HORIZONTAL.
ALL RISERS OR OUTLETS FROM PIPE LINE ARE CONNECTED WITH BALL JOINT UNIONS
ALL PIPING AND FITTINGS ARE 1¼" GALVANIZED
THE DIRECTION OF PITCH OF THE PIPE LINES IS TOWARD ENTRANCE TO BUILDING
TAP AT BOTTOM
TAP AT TOP
TRANSFORMER OIL STORAGE TANK 4468 GAL.
TAP ON BOTTOM
CD
CD
CD
CD
CD
UNIONS
UNIONS
SPARE
4200 Kva 1φ TRANSFORMERS
CAPACITY OF EACH TANK 4000 GALLONS
FILTER PRESS AND PUMP COMBINED CAP. 7 GAL. PER MIN.

FIG. 16—POWER STATION RECONDITIONING PLANT—POOLE PLANT, SOUTHERN SIERRAS POWER CO.

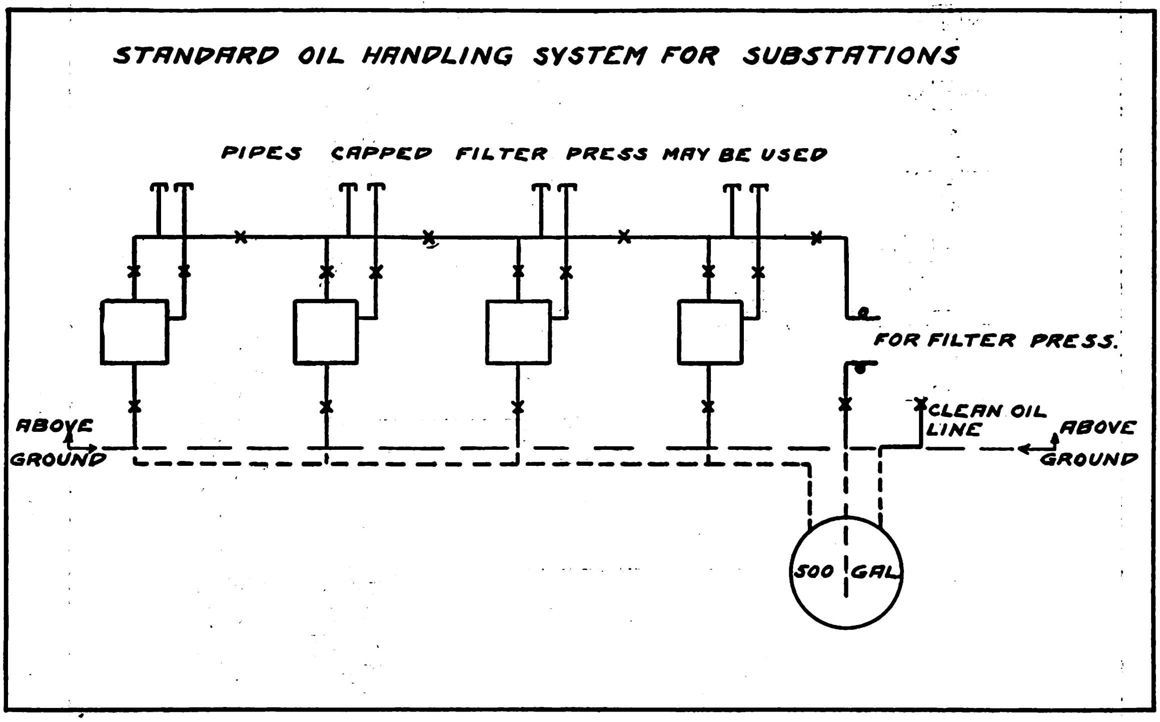

STANDARD OIL HANDLING SYSTEM FOR SUBSTATIONS
PIPES CAPPED FILTER PRESS MAY BE USED
FOR FILTER PRESS.
CLEAN OIL LINE
ABOVE GROUND
ABOVE GROUND
500 GAL

FIG. 17—Substation Reconditioning Plant—Brooklyn Edison Co.

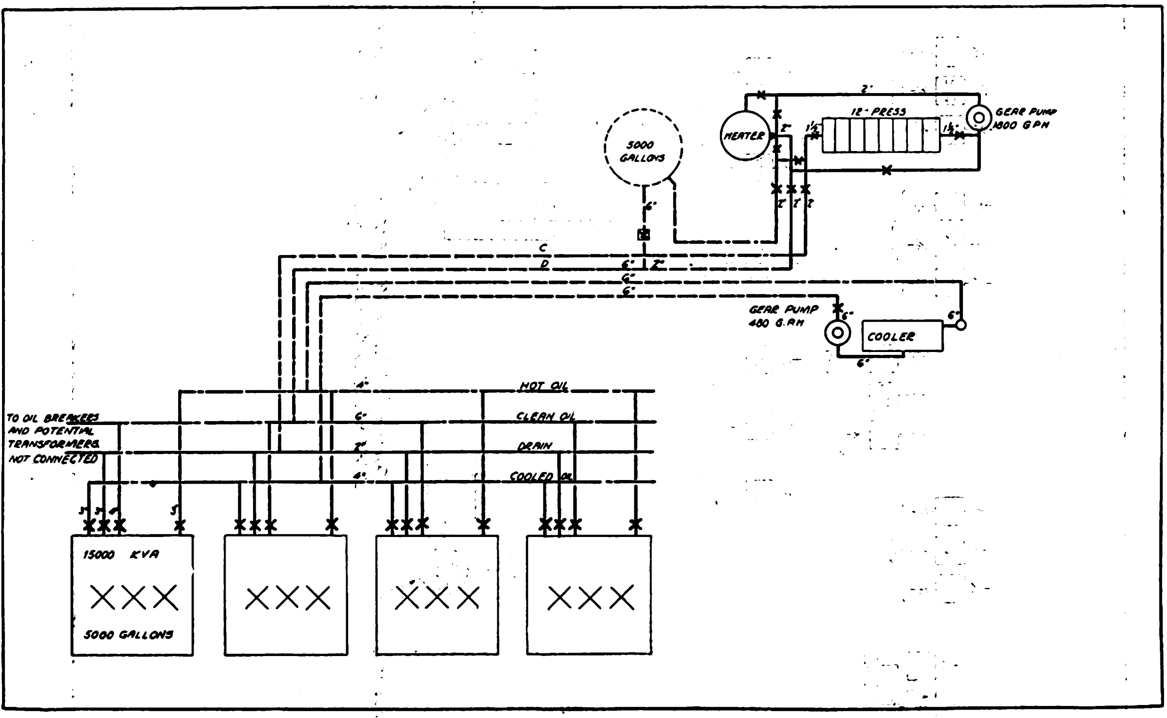

5000 GALLONS
HEATER
12" PRESS
GEAR PUMP 1800 GPM
2"
1½"
6"
C
D
GEAR PUMP 480 G.P.M
COOLER
HOT OIL
CLEAN OIL
DRAIN
COOLED OIL
4"
2"
TO OIL BREAKERS AND POTENTIAL TRANSFORMERS NOT CONNECTED
15000 KVA
5000 GALLONS
XXX
XXX
XXX
XXX

FIG. 18—Substation Reconditioning Plant—Commonwealth Edison Co.

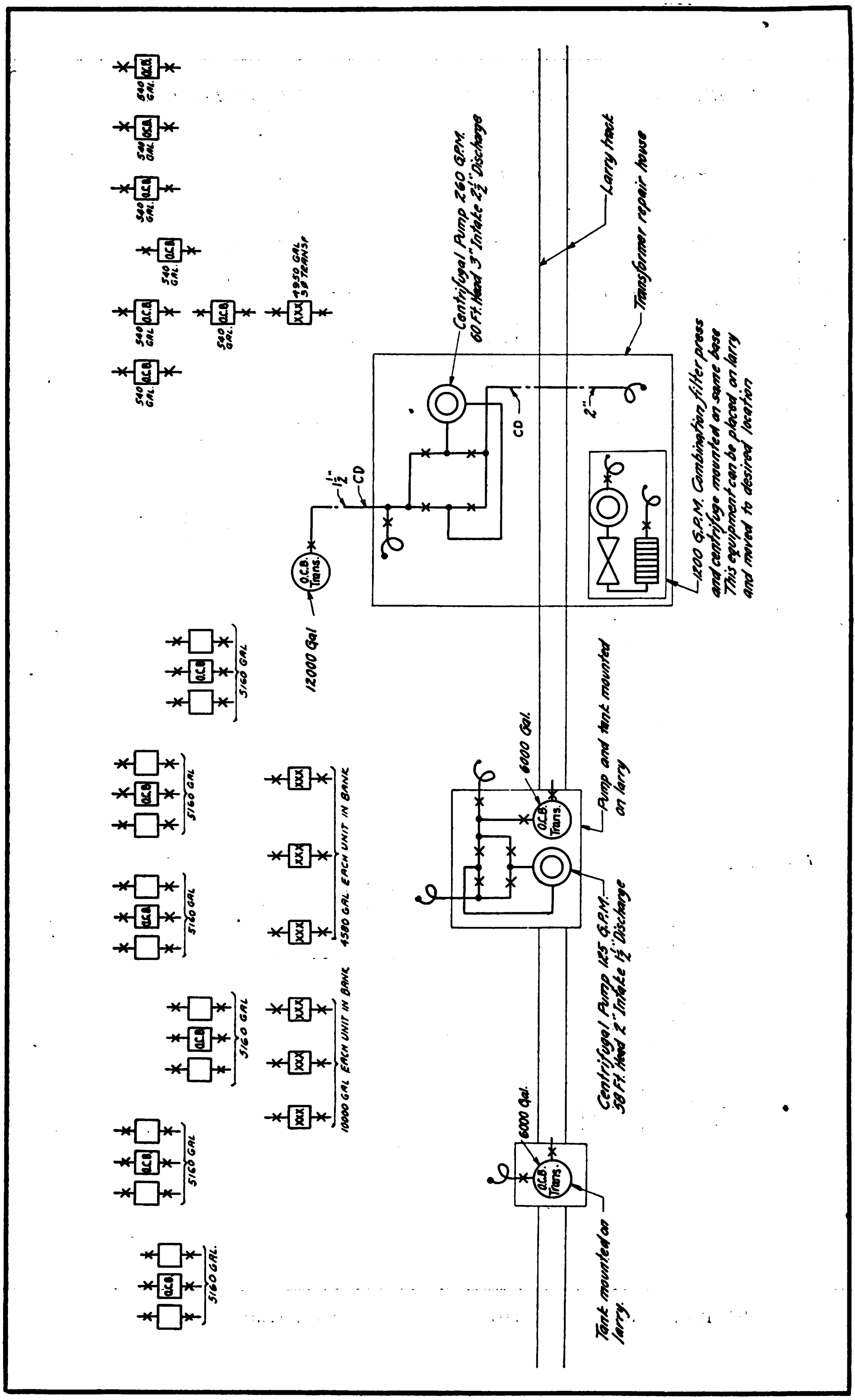

540 GAL.
O.C.B.
4950 GAL 3Ø TRANSF
Centrifugal Pump 260 G.P.M. 60 Ft. Head 3" Intake 2½" Discharge
Larry track
Transformer repair house
CD
2"
1½"
O.C.B. Trans.
12000 Gal
1200 G.P.M. Combination filter press and centrifuge mounted on same base This equipment can be placed on larry and moved to desired location
5160 GAL
4580 GAL. EACH UNIT IN BANK
10000 GAL. EACH UNIT IN BANK
XXX
6000 Gal.
Pump and tank mounted on larry
Centrifugal Pump 125 G.P.M. 38 Ft. Head 2" Intake 1½" Discharge
6000 Gal.
Tank mounted on larry.

FIG. 19—SUBSTATION RECONDITIONING PLANT—BLACKSTONE SUBSTATION, CONSUMERS POWER CO.

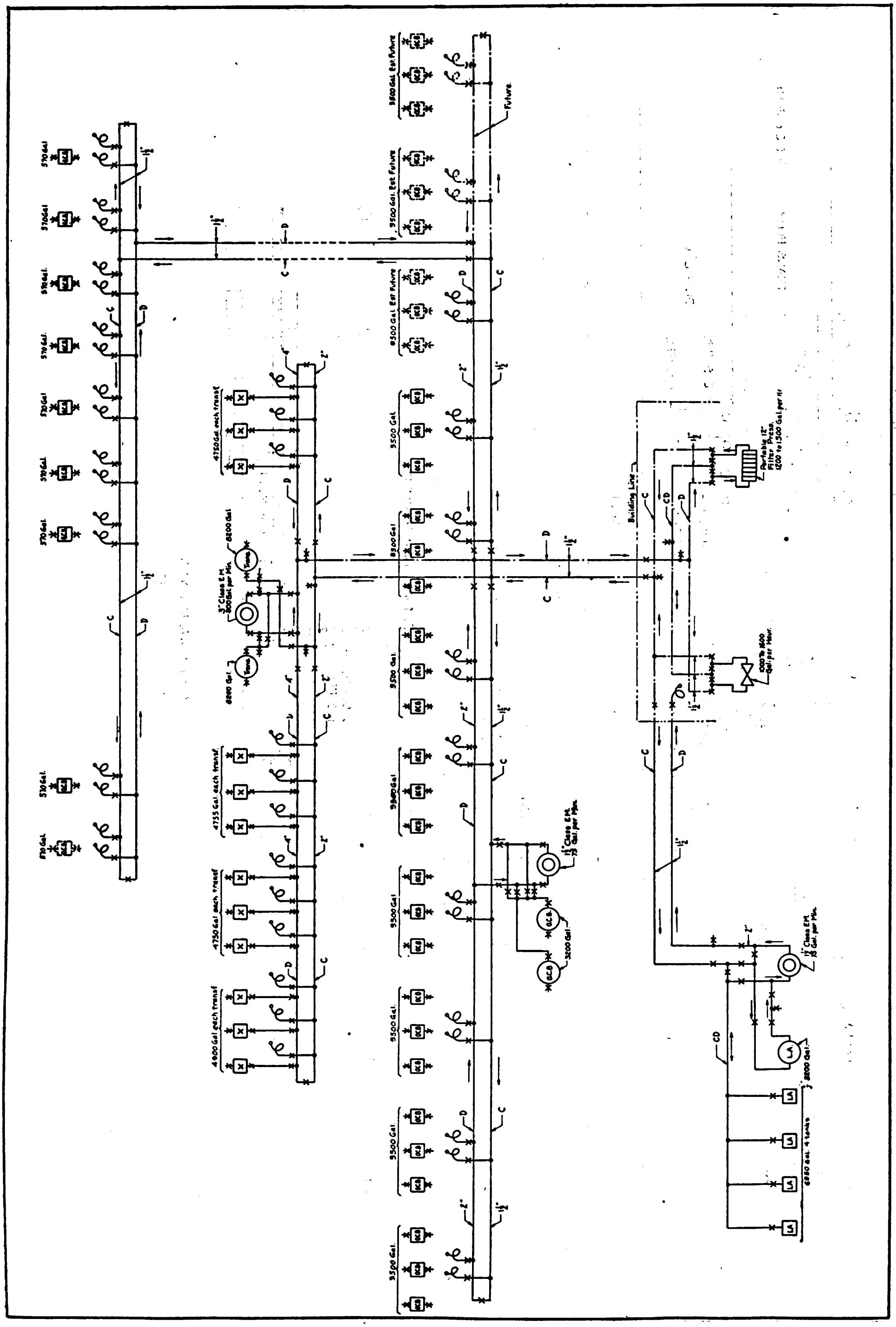

570 Gal.
4750 Gal. each transf.
4755 Gal. each transf.
4600 Gal. each transf.
3500 Gal.
3500 Gal. Est. Future
8500 Gal. Est. Future
Future
6800 Gal.
3" Class E.M. 300 Gal. per Min.
Building Line
Portable 12" Filter Press 1200 to 1500 Gal. per Hr.
1½" Class E.M. 75 Gal. per Min.
3200 Gal.
O.C.B.
2800 Gal.
6860 Gal. 4 tanks
C
D
CD
1½"
2"
4"

FIG. 20—SUBSTATION RECONDITIONING PLANT—GARFIELD AVENUE SUBSTATION, CONSUMERS POWER CO.

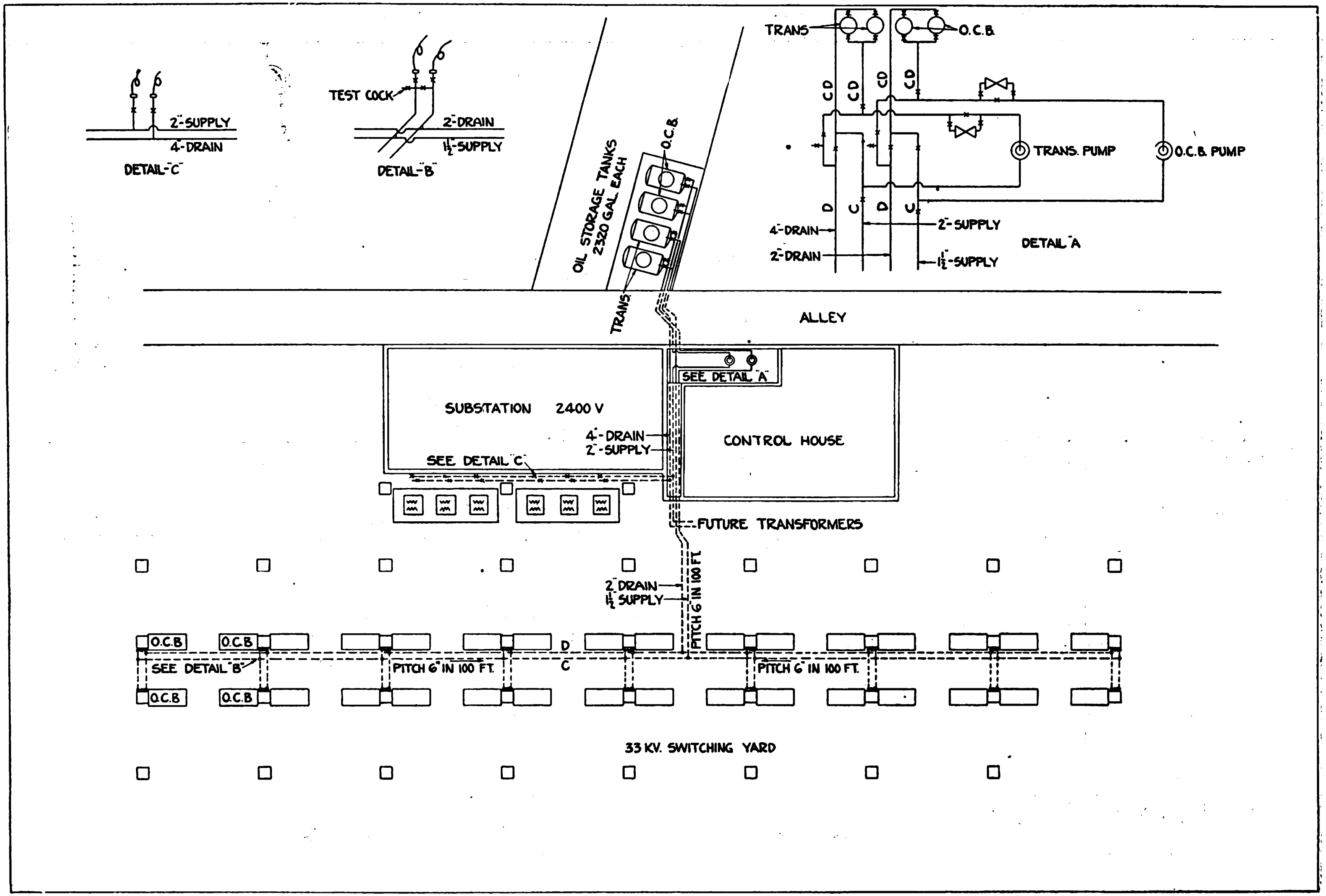
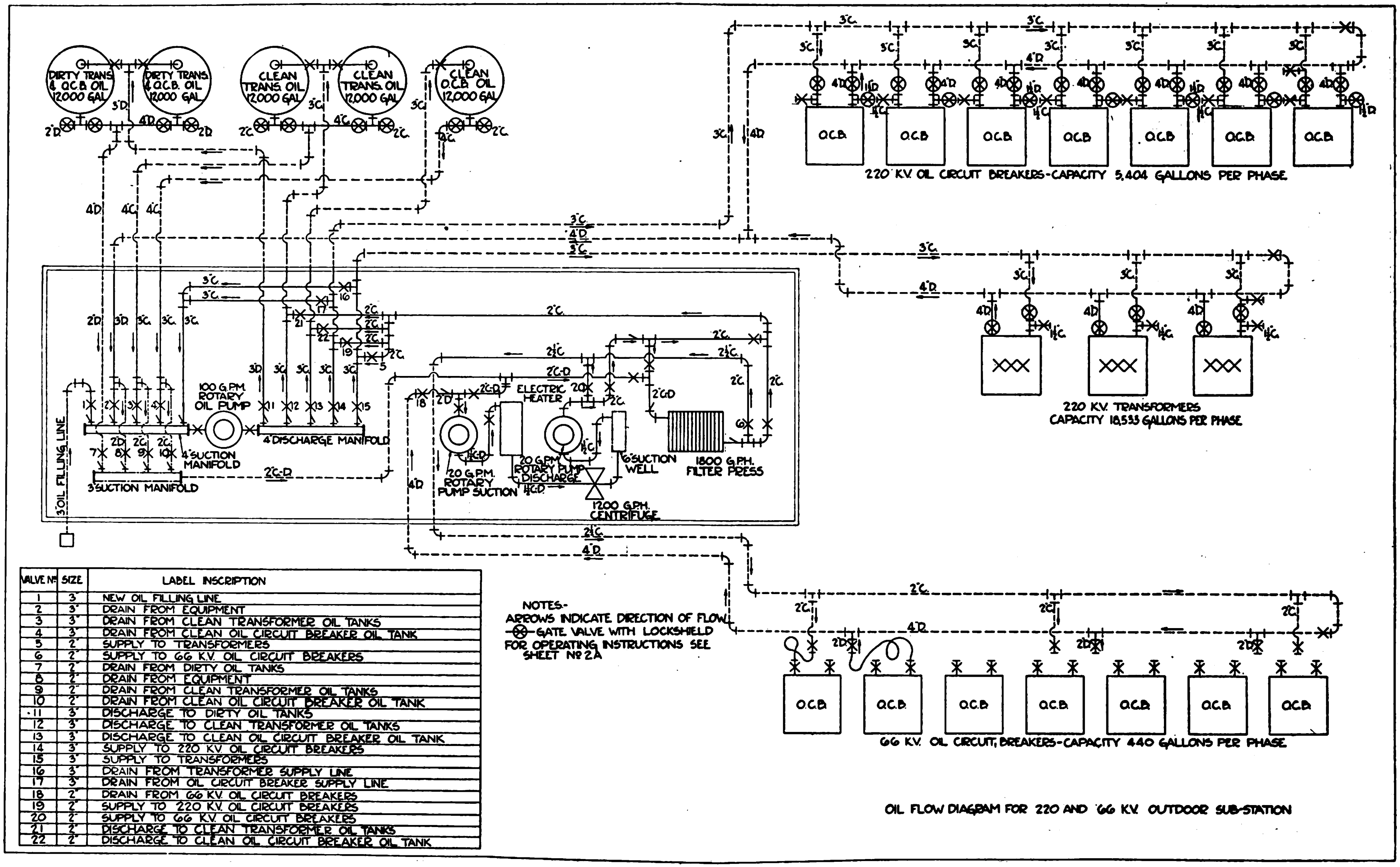
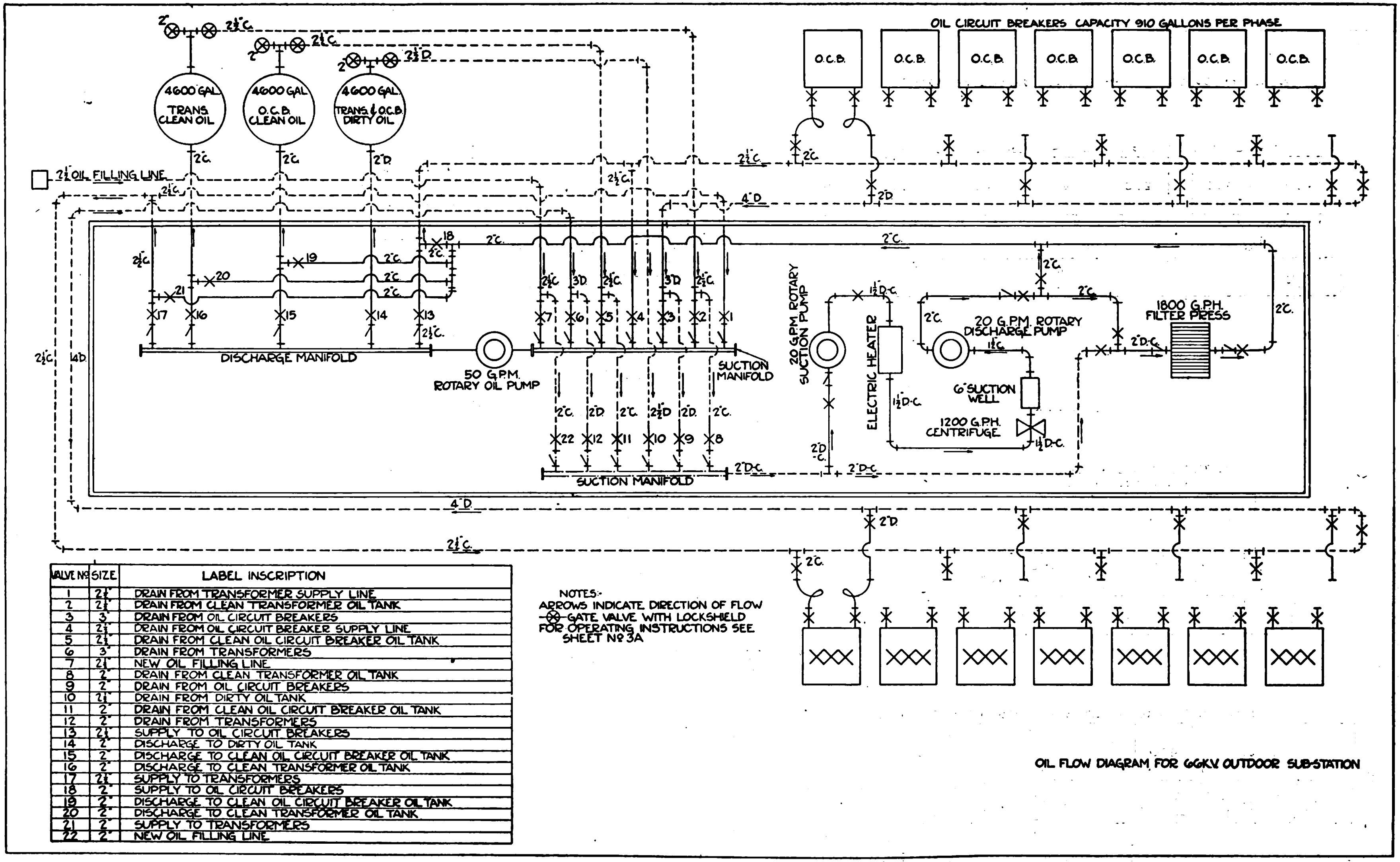

TRANS
O.C.B.
CD
CD
CD
CD
TRANS. PUMP
O.C.B. PUMP
D
C
D
C
4"-DRAIN
2"-DRAIN
2"-SUPPLY
1½"-SUPPLY
DETAIL "A"
2"-SUPPLY
4"-DRAIN
DETAIL "C"
TEST COCK
2"-DRAIN
1½"-SUPPLY
DETAIL "B"
OIL STORAGE TANKS
2320 GAL. EACH
O.C.B.
TRANS.
ALLEY
SEE DETAIL "A"
SUBSTATION 2400 V
4"-DRAIN
2"-SUPPLY
SEE DETAIL "C"
CONTROL HOUSE
FUTURE TRANSFORMERS
2" DRAIN
1½" SUPPLY
PITCH 6" IN 100 FT.
O.C.B.
O.C.B.
O.C.B.
O.C.B.
SEE DETAIL "B"
PITCH 6" IN 100 FT.
D
C
PITCH 6" IN 100 FT.
33 KV. SWITCHING YARD

FIG. 21—SUBSTATION RECONDITIONING PLANT—LOS ANGELES GAS & ELECTRIC CORP.


DIRTY TRANS. & O.C.B. OIL 12,000 GAL
DIRTY TRANS. & O.C.B. OIL 12,000 GAL
CLEAN TRANS. OIL 12,000 GAL
CLEAN TRANS. OIL 12,000 GAL
CLEAN O.C.B. OIL 12,000 GAL
100 G.P.M. ROTARY OIL PUMP
4" DISCHARGE MANIFOLD
4" SUCTION MANIFOLD
3" SUCTION MANIFOLD
3" OIL FILLING LINE
ELECTRIC HEATER
20 G.P.M. ROTARY PUMP SUCTION
20 G.P.M. ROTARY PUMP DISCHARGE
6" SUCTION WELL
1800 G.P.H. FILTER PRESS
1200 G.P.H. CENTRIFUGE
O.C.B.
220 KV. OIL CIRCUIT BREAKERS-CAPACITY 5,404 GALLONS PER PHASE
220 KV. TRANSFORMERS CAPACITY 18,533 GALLONS PER PHASE
66 KV. OIL CIRCUIT BREAKERS-CAPACITY 440 GALLONS PER PHASE
OIL FLOW DIAGRAM FOR 220 AND 66 KV. OUTDOOR SUB-STATION
NOTES-
ARROWS INDICATE DIRECTION OF FLOW
⊗ GATE VALVE WITH LOCKSHIELD
FOR OPERATING INSTRUCTIONS SEE SHEET No 2A

VALVE No.	SIZE	LABEL INSCRIPTION
1	3"	NEW OIL FILLING LINE
2	3"	DRAIN FROM EQUIPMENT
3	3"	DRAIN FROM CLEAN TRANSFORMER OIL TANKS
4	3"	DRAIN FROM CLEAN OIL CIRCUIT BREAKER OIL TANK
5	2"	SUPPLY TO TRANSFORMERS
6	2"	SUPPLY TO 66 K.V. OIL CIRCUIT BREAKERS
7	2"	DRAIN FROM DIRTY OIL TANKS
8	2"	DRAIN FROM EQUIPMENT
9	2"	DRAIN FROM CLEAN TRANSFORMER OIL TANKS
10	2"	DRAIN FROM CLEAN OIL CIRCUIT BREAKER OIL TANK
11	3"	DISCHARGE TO DIRTY OIL TANKS
12	3"	DISCHARGE TO CLEAN TRANSFORMER OIL TANKS
13	3"	DISCHARGE TO CLEAN OIL CIRCUIT BREAKER OIL TANK
14	3"	SUPPLY TO 220 KV. OIL CIRCUIT BREAKERS
15	3"	SUPPLY TO TRANSFORMERS
16	3"	DRAIN FROM TRANSFORMER SUPPLY LINE
17	3"	DRAIN FROM OIL CIRCUIT BREAKER SUPPLY LINE
18	2"	DRAIN FROM 66 K.V. OIL CIRCUIT BREAKERS
19	2"	SUPPLY TO 220 K.V. OIL CIRCUIT BREAKERS
20	2"	SUPPLY TO 66 K.V. OIL CIRCUIT BREAKERS
21	2"	DISCHARGE TO CLEAN TRANSFORMER OIL TANKS
22	2"	DISCHARGE TO CLEAN OIL CIRCUIT BREAKER OIL TANK

FIG. 22—Substation Reconditioning Plant—Plymouth Meeting Substation, Philadelphia Electric Co.


OIL CIRCUIT BREAKERS CAPACITY 910 GALLONS PER PHASE
O.C.B.
4600 GAL TRANS CLEAN OIL
4600 GAL O.C.B. CLEAN OIL
4600 GAL TRANS & O.C.B. DIRTY OIL
2½" OIL FILLING LINE
DISCHARGE MANIFOLD
50 G.P.M. ROTARY OIL PUMP
SUCTION MANIFOLD
20 G.P.M. ROTARY SUCTION PUMP
ELECTRIC HEATER
20 G.P.M. ROTARY DISCHARGE PUMP
6" SUCTION WELL
1200 G.P.H. CENTRIFUGE
1800 G.P.H. FILTER PRESS
4"D
2½"C.
2"D-C.
1½"D-C.
OIL FLOW DIAGRAM FOR 66KV OUTDOOR SUB-STATION

VALVE No	SIZE	LABEL INSCRIPTION
1	2½"	DRAIN FROM TRANSFORMER SUPPLY LINE
2	2½"	DRAIN FROM CLEAN TRANSFORMER OIL TANK
3	3"	DRAIN FROM OIL CIRCUIT BREAKERS
4	2½"	DRAIN FROM OIL CIRCUIT BREAKER SUPPLY LINE
5	2½"	DRAIN FROM CLEAN OIL CIRCUIT BREAKER OIL TANK
6	3"	DRAIN FROM TRANSFORMERS
7	2½"	NEW OIL FILLING LINE
8	2"	DRAIN FROM CLEAN TRANSFORMER OIL TANK
9	2"	DRAIN FROM OIL CIRCUIT BREAKERS
10	2½"	DRAIN FROM DIRTY OIL TANK
11	2"	DRAIN FROM CLEAN OIL CIRCUIT BREAKER OIL TANK
12	2"	DRAIN FROM TRANSFORMERS
13	2½"	SUPPLY TO OIL CIRCUIT BREAKERS
14	2"	DISCHARGE TO DIRTY OIL TANK
15	2"	DISCHARGE TO CLEAN OIL CIRCUIT BREAKER OIL TANK
16	2"	DISCHARGE TO CLEAN TRANSFORMER OIL TANK
17	2½"	SUPPLY TO TRANSFORMERS
18	2"	SUPPLY TO OIL CIRCUIT BREAKERS
19	2"	DISCHARGE TO CLEAN OIL CIRCUIT BREAKER OIL TANK
20	2"	DISCHARGE TO CLEAN TRANSFORMER OIL TANK
21	2"	SUPPLY TO TRANSFORMERS
22	2"	NEW OIL FILLING LINE

NOTES:-
ARROWS INDICATE DIRECTION OF FLOW
-⊗- GATE VALVE WITH LOCKSHIELD
FOR OPERATING INSTRUCTIONS SEE SHEET No 3A

FIG. 23—SUBSTATION RECONDITIONING PLANT—WESTMORELAND SUBSTATION, PHILADELPHIA ELECTRIC CO.

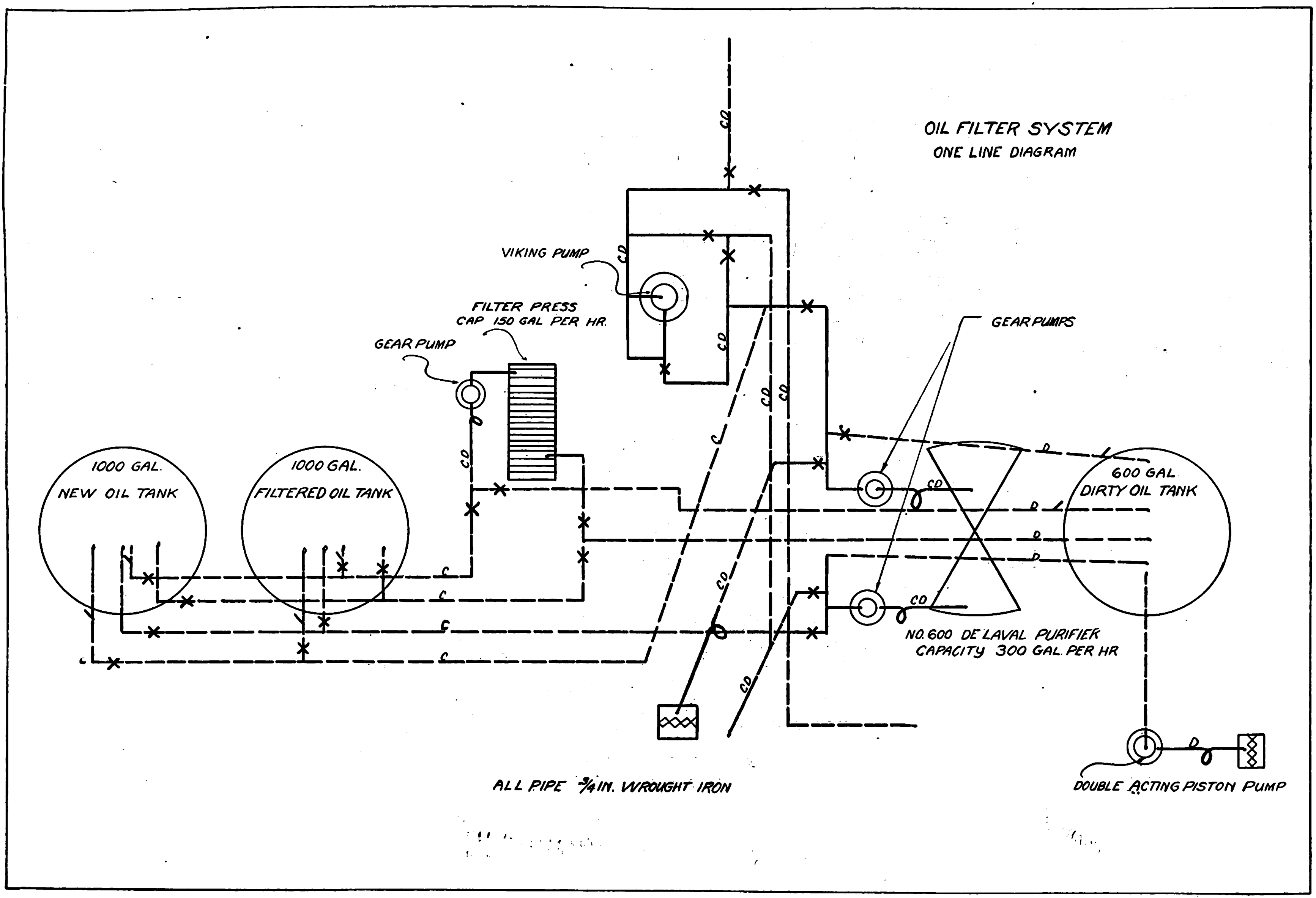

OIL FILTER SYSTEM
ONE LINE DIAGRAM
VIKING PUMP
FILTER PRESS
CAP 150 GAL PER HR.
GEAR PUMP
GEAR PUMPS
1000 GAL.
NEW OIL TANK
1000 GAL.
FILTERED OIL TANK
600 GAL
DIRTY OIL TANK
NO. 600 DE LAVAL PURIFIER
CAPACITY 300 GAL. PER HR
DOUBLE ACTING PISTON PUMP
ALL PIPE ¾ IN. WROUGHT IRON
CD
C
D

FIG. 24—SUBSTATION RECONDITIONING PLANT—SAN DIEGO CONSOLIDATED GAS & ELECTRIC CO.

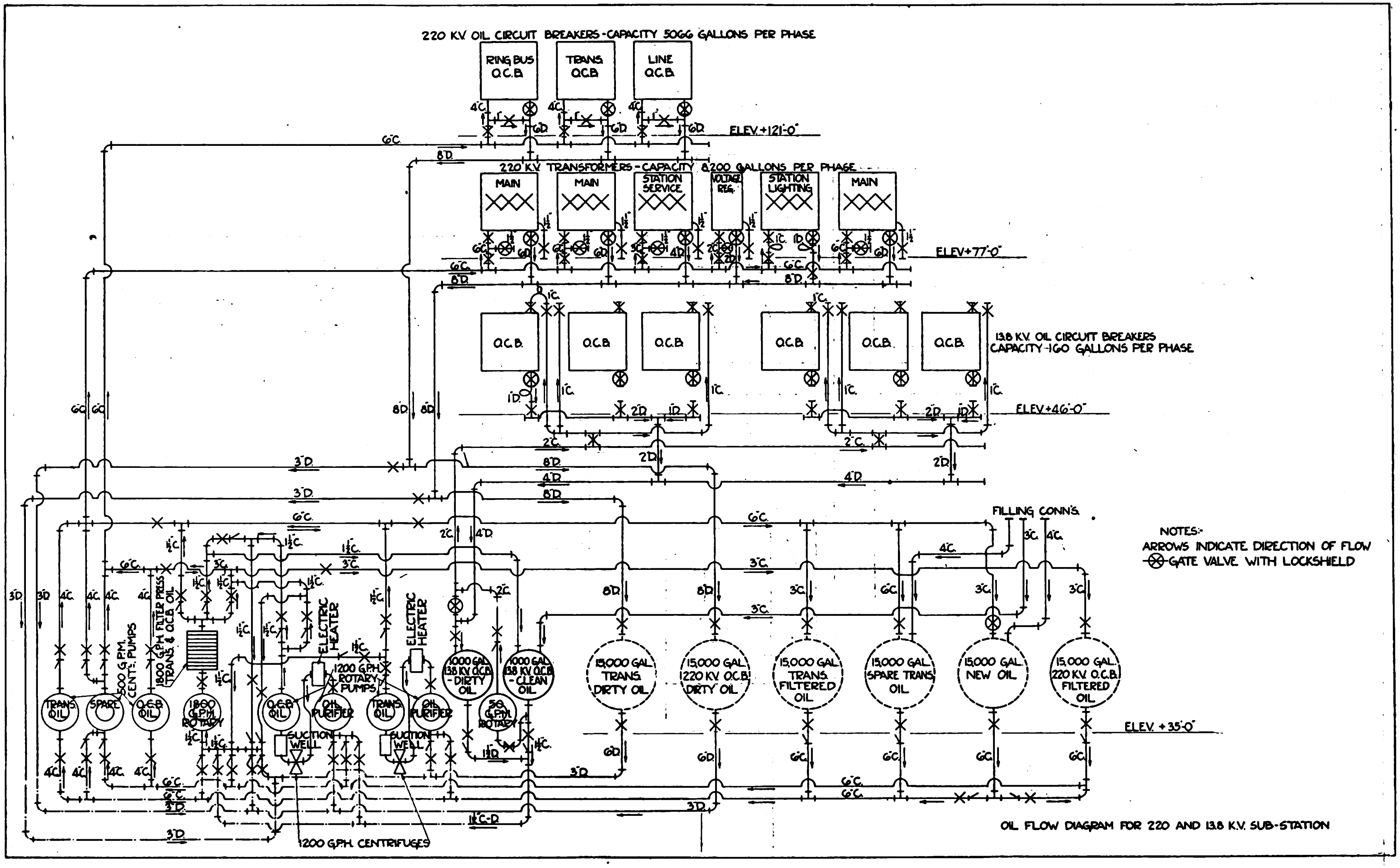

220 K.V. OIL CIRCUIT BREAKERS-CAPACITY 5066 GALLONS PER PHASE
RING BUS O.C.B.
TRANS O.C.B.
LINE O.C.B.
ELEV.+121-0"
220 K.V. TRANSFORMERS-CAPACITY 8200 GALLONS PER PHASE
MAIN
MAIN
STATION SERVICE
VOLTAGE REG.
STATION LIGHTING
MAIN
ELEV+77'-0"
O.C.B.
O.C.B.
O.C.B.
O.C.B.
O.C.B.
O.C.B.
13.8 K.V. OIL CIRCUIT BREAKERS CAPACITY-160 GALLONS PER PHASE
ELEV+46'-0"
FILLING CONN'S.
NOTES:-
ARROWS INDICATE DIRECTION OF FLOW
⊗ GATE VALVE WITH LOCKSHIELD
500 G.P.M. CENT'L. PUMPS
1800 G.P.H. FILTER PRESS TRANS. & O.C.B. OIL
ELECTRIC HEATER
1200 G.P.H. ROTARY PUMPS
ELECTRIC HEATER
1000 GAL. 13.8 KV O.C.B. - DIRTY OIL
1000 GAL. 13.8 KV O.C.B. - CLEAN OIL
15,000 GAL. TRANS. DIRTY OIL
15,000 GAL. 220 KV. O.C.B. DIRTY OIL
15,000 GAL. TRANS. FILTERED OIL
15,000 GAL. SPARE TRANS. OIL
15,000 GAL. NEW OIL
15,000 GAL. 220 KV. O.C.B. FILTERED OIL
ELEV. +35-0"
TRANS. OIL
SPARE
O.C.B. OIL
1800 G.P.H. ROTARY
O.C.B. OIL
OIL PURIFIER
TRANS. OIL
OIL PURIFIER
50 G.P.H. ROTARY
SUCTION WELL
SUCTION WELL
1200 G.P.H. CENTRIFUGES
OIL FLOW DIAGRAM FOR 220 AND 13.8 K.V. SUB-STATION

FIG. 25—SUBSTATION RECONDITIONING PLANT—CONOWINGO SUBSTATION, SUSQUEHANNA POWER CO.

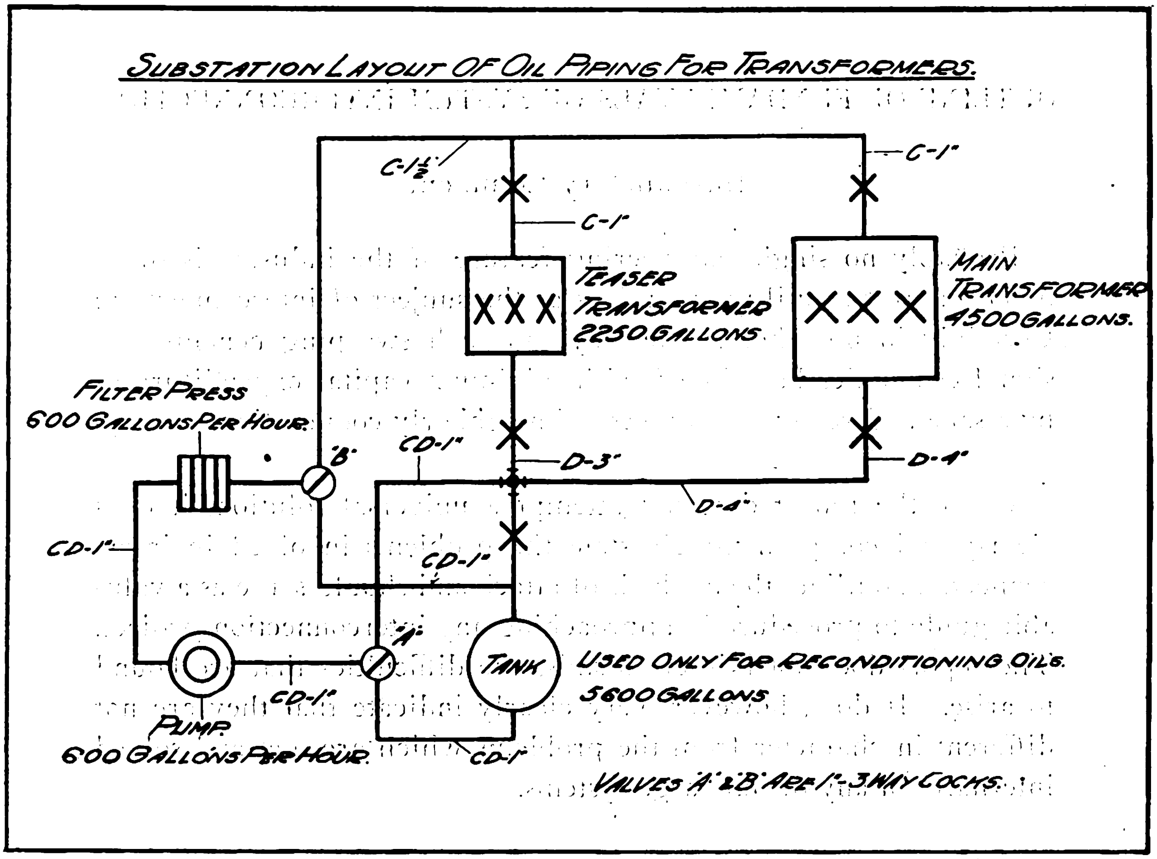

SUBSTATION LAYOUT OF OIL PIPING FOR TRANSFORMERS.
C-1½"
C-1"
C-1"
TEASER
TRANSFORMER
2250 GALLONS
MAIN
TRANSFORMER
4500 GALLONS.
FILTER PRESS
600 GALLONS PER HOUR.
"B"
CD-1"
D-3"
D-4"
D-4"
CD-1"
CD-1"
"A"
TANK
USED ONLY FOR RECONDITIONING OILS.
5600 GALLONS
CD-1"
PUMP
600 GALLONS PER HOUR.
CD-1"
VALVES "A" & "B" ARE 1"-3 WAY COCKS.

FIG. 26—SUBSTATION RECONDITIONING PLANT—UNITED ELECTRIC LIGHT & POWER CO.

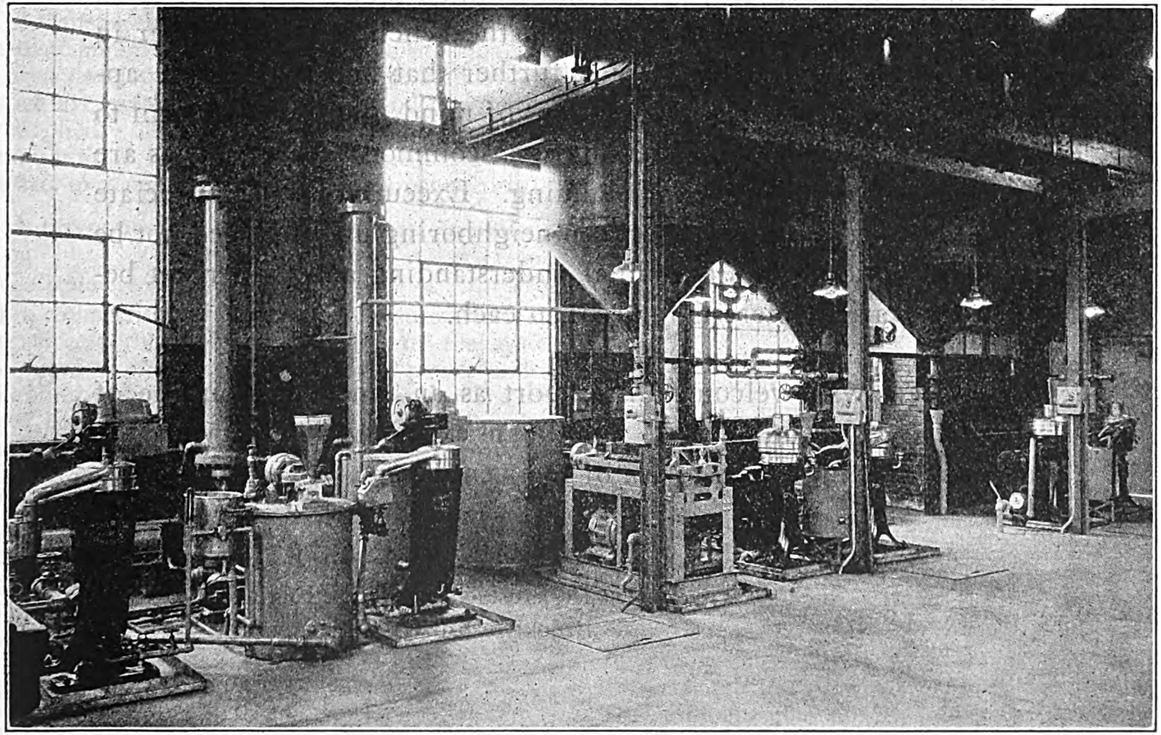


FIG. 27—CENTRAL RECONDITIONING PLANT OF DUQUESNE LIGHT CO.

OUTLINE OF FUNDAMENTALS OF SYSTEM INTERCONNECTION

Introductory Comment

Probably no single engineering feature of the industry is of so much interest to utility executives as the subject of interconnection. Certainly in no other single way can such sweeping benefits and signal economies be effected with minimum capital expenditure as by a sane and reasonable process of neighborly cooperation.

While the report does not attempt a universal solution, it does clearly and comprehensively state the problems involved in interconnection, outlines the methods of attack and should serve as a valuable guide to procedure in approaching any interconnection project. The report does not blithely dismiss the difficulties that are bound to arise. It does, however, very clearly indicate that they are not different in character from the problems which are met and solved internally in any of our large systems.

It is suggested in the report that it is possible to operate utilities under separate ownership to effect the same economies that would result were the ownership common. Granted that both parties to an interconnection must benefit and that the benefits may be either in dollars or "in kind," and granted further that both parties are approaching the problem with openness of mind, there would seem to be no essential difficulty in making such common adjustments as are necessary to contractual understanding. Executives will appreciate that a meeting of minds as between neighboring utilities need not be any more difficult than is mutual understanding and agreement between the varied interests internal to each.

Engineers will welcome this report as an index and outline of procedure. Executives will find it an excellent summary of the questions they may wish to ask of their engineers.

JOHN C. PARKER
Vice-President in Charge Engineering
Brooklyn Edison Company, Inc.

OUTLINE OF FUNDAMENTALS OF SYSTEM INTERCONNECTION

STATUS OF PROBLEM—ITS IMPORTANCE

The purpose of this report is to present the general considerations involved in the planning and execution of system interconnections. Interconnection standards, commercial and accounting as well as technical, have not been formulated as a whole, and it is desirable that they be developed in order to provide for coordinated power development and distribution. The increasing dependence of industrial and community life on electric utility service makes reliability of supply a prime consideration. The added protection from possible interruption to service by a considered policy of interconnection is correlated with the growth of systems and economical use of capital funds. The diverse ownership and control of utility properties should not interfere with a proper interweaving of independent power systems, where this can be brought about by a clearer understanding of the problem and the adoption of cooperative policies.

I—NATURE AND PURPOSE OF INTERCONNECTION

Interconnection as Distinguished from Transmission

Interconnection is the joining together of separate power systems in order to provide for interchange of power, to the end that mutual protection of service and greater combined economy of operation may be obtained.

The transmission of electric power from the source to a distribution center by direct transmission lines has been developed to the point where standards of practice are quite generally understood and reasonably applied. This is not classified as an interconnection in this report, although transmission practices are, in general, applicable to interconnection.

Interconnection—Normal Operation and Emergency Use

1. For Continuity of Service

If a connection is proposed to insure continuity of service, a thorough investigation of the system is required to determine the need of power and its availability. An interconnection made for the reason of continuity of service is usually of the emergency type and may be made either for protecting the system as a whole, or for protection of a portion of the system which is not otherwise adequately supported. For instance, two densely loaded areas, which are very close to each other and without appreciable diversity, desire insurance in the form of a high capacity tie against such a catastrophe as the loss of several large units at once. This tie should be terminated at high capacity buses in each system, or at load centers where the required amount of power could be readily absorbed. Another example would be a lightly loaded substation fed by a single transmission line and located closer to another system than to its own source of supply. A small capacity tie from the other system gives emergency service. If the two systems are not already in synchronism, the emergency tie should normally be operated open.

2. For Reduction of Fixed Charges

In order to determine whether an interconnection is justifiable on the grounds that it results in a reduction of the fixed charges in either or both systems, an investigation of the load diversity, generator reserve diversity, transmission reserve diversity, construction program diversity and financial diversity is required. The connection may be justified on any one or all of these items.

(a) *Load Diversity.* A careful estimate of load diversity should be obtained by making a comparison of the existing and future loads of the systems to be connected and by investigating the hourly, weekly and seasonal saving in generating capacity comparable with the cost of the interconnection.

(b) *Generator Reserve Diversity.* While the proper amount of spare generating capacity varies greatly in different localities, a detailed study might result, for instance, in a decision by the engineers representing the two systems to maintain only 12 per cent spare generator capacity after interconnection, where before 15 per cent was maintained. Obviously, there is a critical limit to this diversity, and the proper value will be determined only by experience.

(c) *Transmission Reserve Diversity.* Occasionally two systems are so located geographically that a tie between them will act as a transmission spare to a portion of either. In such a connection, synchronizing capacity should be very carefully investigated.

(d) *Construction Program Diversity.* This type of diversity becomes of importance through the greater economy of an extensive construction program which can be planned and carried out with less disturbance to operating routine. A typical example of construction program diversity is the case where companies A and B each grow at the rate of 10,000 kw. a year and find that the most economical generator unit for the combined systems is 20,000 kw. They interconnect, A installing generating capacity one year, and B the next year.

(e) *Financial Diversity.* Occasionally two contiguous systems may be interconnected to obtain the financial advantage which may accrue through the ability of one company to supply the necessary construction at lower cost.

Publication No. 289-60, Serial report, Electrical Apparatus Committee.

3. Reduction of Operating Costs

Besides the reduction of operating costs arising from less installed capacity, it is necessary to determine whether at times one system will have available more economical generating equipment than another system would normally be operating at that time. If so, an additional reduction in operating costs can be obtained through interchange. Such interchange connections find their greatest use in systems composed of both all-steam and all-hydro stations, although variations in the costs of either all-steam or all-hydro systems may establish such a connection. Diversities as between water supply, either condensing or water power, coal supply, etc., are likely to enter into the analysis of this problem.

4. Complications of Interconnection

(a) *Operating Routine and Divided Responsibility.* As an offset to these benefits of interconnection, there are the disadvantages of greater complication in operating routine and divided responsibility which can only be reduced to a minimum by agreement between the different companies and by unified control.

(b) *Operating Disturbances.* The possibility of operating disturbances affecting a much larger territory than with independent operation must also be taken into account, and methods adopted by automatic and manual control to prevent any jeopardizing of continuity of supply to the entire region served.

(c) *Reliability of Interconnection Facilities.* Any saving of generator capacity resulting from interconnection involves a partial dependence of one system on the other. The reliability of the interconnection facilities must be such that they do not introduce a net hazard.

II—CONTRACTUAL RELATIONS

Operating and Engineering Agreement

Agreement as to the engineering features of the interconnection, the division of costs and charges of the actual interconnection facilities as well as costs of reinforcing existing facilities, contingent items, the construction forces to be employed and responsibility for the work should be definitely established. The form of contract will, of course, be dependent upon local conditions and may vary considerably due to variations of the fundamental factors underlying the interconnection; for example, an operating agreement, when made to provide for more reliable service, must differ considerably from a contract which has as its basis a reduction in fixed charges. Operating and maintenance plans for normal and emergency service as affecting the different companies interested may form a part of such a contract, or be covered by separate agreements.

Load Dispatching

Complete understanding and authority to insure effective cooperation must be set up in the arrangements for load dispatching which should preferably be centralized.

Adjustment of Interests

The agreement must be sufficiently inclusive to provide for a harmonious adjustment of conflicting interests and flexible enough to permit adjustment of these differences when they develop, with provision for arbitration. This may be obtained by an operating committee with a personnel having authority to settle disputed questions. It may be found advisable, if daily power interchange is contemplated, to incorporate an independent operating company, under the control of the contracting companies, to control and operate the combined interconnection facilities, to supervise the interchange of power and in general to serve as a coordinating medium.

Records

The agreement should provide for uniform systems of records pertaining to the execution of the contract.

III—ORGANIZATION FOR COOPERATIVE ANALYSIS

To investigate a proposed connection, it is advisable to have an organization set up which has in mind the joint responsibility of the companies and the broad scope of the work to be accomplished. This can usually be effected by dividing the work into two portions and forming a committee or group to handle each.

The first group would study the loads and diversities, existing and forecast, of the systems to be interconnected, the economies to be obtained through the interconnection, and the general benefits to be derived.

The second group is primarily interested in the design of the physical plant needed to accomplish the purposes enumerated by the load and diversity group. Its chief interest would lie in such things as the design of the substations and transmission lines; the selection of line routes; the determination of the regulation of the lines, the means for controlling the flow of power, the synchronizing power required to keep the two systems in parallel operation, and the protection needed; and the calculation of short circuit values so that equipment adequate for future use may be provided. Complete construction and operating cost estimates on this initial interconnection program must be made with due regard to the effect on these costs of future additions to the interconnection plant.

IV—IMPORTANT ENGINEERING PROBLEMS INVOLVED IN INTERCONNECTION

Load Forecasting, Peak Loads and Load Factors

The first technical step in the consideration of a proposed interconnection project is the analysis of the system loads, regional and local, over a period of past years with a forecast of the expected growth of each section of the region to be served. The economic factors affecting the growth of the different industries and communities served would be considered, and the anticipated loads for successive future years would be drawn up. The division of load between power sources, transmission lines and substations, with predicted peaks, power factors and load factors, would then be studied and the effect on station operating costs determined. The interconnection and future construction program would be based on the derived load curves. Operating costs and fixed charges for successive future years would be set up to show development under an interconnected program as compared with the independent development of present systems.

System Stabilty

A study of system stability, often one of the most important fundamentals to be considered in the development of interconnected systems, should be made for both static and transient conditions.

The static stability or the operation of the system under normal steady load conditions can be calculated with reasonable accuracy from machine, transformer and line characteristics and a study of the voltage regulator, machine governor and exciter operation. The static power limit may be increased by changes in these automatic controls and by the use of low reactance synchronous machines. The operating limitations due to static stability are important only in considering the system under conditions of transmission line outages impairing the strength of the combined system ties.

The transient stability under fault conditions, and load relations under the various system disturbances which may occur due to switching operations and breakdowns in apparatus and lines, should be studied carefully in its functioning. Considerable experimental and operating data have been obtained from present interconnected systems and artificial test systems, which indicate new methods of approach in making such a study. The subject of stability is so important, involves so many considerations, and its state of development is such that expert advice should be obtained with a view to determining the effect on stability of such factors as:

Switching operations.
Normal and abnormal variations in load.
The nature of the load.
The nature, frequency, duration and location of faults.
Ground resistance.
Reactance in the system.
Excitation characteristics.
Time characteristics of relays and circuit breakers.

Load Control

The interchange of load over interconnection ties necessitates the ability to control the transmission of load at will, in either direction, and at any hour of the day. The problem of load control increases in complexity with the increase in diversity of interconnecting tie characteristics. The importance of this problem is emphasized as careful study is required to assure proper load control, particularly where the interconnection involves more than one point of tie.

The question of variation in voltage levels between the different parts of the system where tie lines are interconnected, and the differences in electrical constants of multiple tie lines, must be studied in relation to the circulating and charging currents, and a proper solution found for the conditions imposed. The use to be made of voltage regulators, transformers with tap changers, reactors, etc., must be determined in order to obtain satisfactory operating conditions and load control. The introduction at the proper location on the system of synchronous condensers of the required capacity must be studied, together with the use of auto transformers with tap changers, induction regulators or synchronous boosters.

The general solution of these problems is now being found in the solution of similar problems in present individual power systems. These internal system interconnections may be of a more complicated nature than interconnections between large systems.

Protection Schemes

When systems differ radically in their protective features, such as relay methods, reactors and methods of grounding, it may be necessary to make changes to bring the systems into harmony with each other before interconnection for other than emergency service can be made effective.

The requirements of the protective system of an interconnection are, in general, as follows:

It should clear faults quickly to prevent loss of synchronism; must afford protection in case of single line as well as parallel line operation; and must afford proper protection for power flow in either direction.

It should permit flexibility of operation, use of transfer breakers, dual switching, etc.; must permit complex system connection without necessitating system revisions; should afford bus protection: and must be reasonably economical.

In most protective schemes time delay is objectionable and should be reduced to a minimum or eliminated, where possible. Therefore, some form of balanced or differential protection may be the solution. Relays of the usual overload type, such as are used with selective settings, on the fringe of the system, cannot be used for the major positions because of excessive time delay.

Balanced protection may be divided into two groups; namely, balanced current and balanced power. The current differential may be a series balance involving pilot wires or a parallel balance where multiple circuits are concerned. Balanced power may, likewise, appear as parallel balance for multiple lines, or a series balance using pilot wire or its equivalent, such as carrier current, which is still in the experimental stage. Balanced protection has its limitations with respect to bus protection, flexibility of system operation, and the condition of a single line in operation. Moreover, it places limitations on system connections. There are cases, however, in which it must be used.

A very promising solution, as far as clearing of fault is concerned, lies in the use of differential bus protection and pilot wire line protection. Practically, however, the latter can be applied only to the shortest sections.

Where time must be relied upon for selectivity, the inverse characteristic is preferable. This is now more or less universal in this country. The ohmic or impedance relays, which have their inverse nature accentuated by the drop in voltage, appear to meet the requirements more closely than any other available device. Bus protection, quick clearing of faults and single line protection are secured. As the system grows more complex, increased time for operation is not required, nor does the relay place limitations on the system connections. The time required for clearing faults does not become cumulative. However, on very short lines with high impedance to the sources of power, discrimination cannot be secured by the impedance relay and pilot wire or balanced protection must be used.

Load Dispatching Facilities

Successful joint operation requires that adequate facilities be provided for load dispatching. It is necessary for the load dispatcher to know, or be in a position to ascertain, at all times, the loads and available generating capacities of each system and, in some cases, of each station and substation. He must know the loading and physical condition of the circuits and those which are out of service. This implifies unified control and authority in matters of generation and transmission of power. However, in some cases, authority will be preferably divided between the dispatchers of the systems involved. Adequate communication facilities, both normal and reserve, in the form of telephone lines, radio or carrier current communicating routes, must be provided.

The load dispatcher should have as complete information as possible on weather forecasts over the different parts of the system, on construction and repair programs which affect operation of generating plants and lines, and on abnormal loads to be expected on different parts of the system.

Metering and Apportionment of Losses

The metering of power, together with recording of kilowatts, volts and kilovolt-amperes, to show the interconnection interchange of loads and characteristics, must be studied carefully and responsibility for meter accuracy assigned. A plan for apportioning losses between the different systems should be decided upon.

Standardization of Engineering Practice Prior to Interconnection

1. VOLTAGE

The question of voltage standardization has been taken up actively in this country, and progress is being made to obtain the many economic advantages which reasonable standardization will procure. It is particularly important as a fundamental in connection with the development of interconnection to analyze carefully the many conflicting influences which bear on this question of voltage standardization.

The simplification of the interconnected systems by reducing the variation in voltage levels to a minimum must be realized to prevent interference with flexibility in transmission, regulation and load control. This is particularly necessary in this country where transmission distances are increasing as more of our available water powers are developed.

2. PHASE ANGLE

It is desirable from the standpoint of future interconnection for neighboring systems to establish a definite policy in star to delta transformations. The policy of making the connection with the delta 30 deg. lagging relative to the star seems to offer the greater advantage on account of facility in starting up synchronous apparatus.

3. PROTECTION

Reasonable standardization in system protective features, such as relay systems, reactors, and methods of grounding, at the present time, will permit power systems to gradually apply these standards at a nominal cost while additions and changes are made, and thus avoid excessive changes and expense when interconnection is found to be desirable. This standardization should not be difficult, nor should it interfere with flexibility in the development of power systems.

4. CONSTRUCTION DETAILS

The standardization of construction details is desirable from the standpoint of reducing manufacturing costs and in keeping maintenance and emergency stock at a minimum. It assists operation by familiarizing the operating and maintenance forces with standard arrangements of equipment. Transmission line crossings over telephone and telegraph lines, power lines and railroad rights-of-way are usually built in accordance with accepted practice and, in general, more rugged construction is secured. This increases the reliability of the system, as a whole, after interconnection is accomplished.

V—SYSTEM PLANNING PRIOR TO INTERCONNECTION

It is desirable that, so far as practicable, interchange of ideas should be accomplished between companies so located that their future relations will probably involve interconnections, although such interconnections may not be imminent nor even a seriously considered problem at present. This interchange of ideas may take the form of very informal conferences between the responsible engineers of the adjacent companies or through a somewhat formal joint system planning committee, or through regional groups who meet for the general study of engineering problems without relation to specific interconnection problems. An example of the advantage of such cooperation is that of companies in contiguous territory, perhaps having no immediate justification for considering interconnection, but each developing a new transmission system of its own, one say at 110,000 volts and the other at 132,000 volts. This would lead to a voltage difficulty when interconnection is seriously complicated, whereas joint system planning conferences might have prevented such a situation.

D. C. SUBSTATION DESIGN PRACTICE

This report presents in a condensed form the principal features of design of twenty-seven direct-current substations supplying Edison or railway loads. The data are presented along the general lines found useful in two preceding reports on alternating-current substation design, "A. C. Substation Design Practice," Publication No. 25-44, *issued in July,* 1925, *and "A. C. Substation Design Practice—*1927,*" Publication No.* 278-39, *issued in April,* 1928.

The report is divided into four sections: (1) *Automatic Edison Substations,* (2) *Non-Automatic Edison Substations,* (3) *Automatic Railway Substations, and* (4) *Non-Automatic Railway Substations.*

The report includes simplified plans, cross-sections, single line diagrams, cuts of electrical equipment and building exteriors, and tabulations of substation details.

Purpose and Conclusions

The d-c. substation is an extremely important part of the central station power system. While it is probable that the number of Edison systems may decrease rather than increase in the future, the Edison type of substation is, and will be for a number of years, of prime importance in many systems, and it is generally recognized that railway substations will assume increasing importance, particularly in steam railroad electrification zones. For these reasons and as a result of the interest manifested in two previous serial reports on A. C. Substation Design Practice (Publication No. 25-44 and 278-39), this similar report on D. C. Substation Design Practice is presented. These reports, summarizing the latest designs of various companies, enable the designing engineer to keep abreast of new developments and practices making for added reliability and economy, many of which he may find useful in reaching satisfactory solutions to his own problems.

This report presents design data on twenty-seven d-c. substations as follows:

Edison Substations	
Automatic	2
Non-automatic	9
Railway Substations	
Automatic	9
Non-automatic	6
Combined Edison and Railway Substation	
Non-automatic	1

Conversion equipment in these substations includes synchronous converters, motor-generator sets, and mercury-arc rectifiers. The synchronous converter is, as would be expected, the preferred type of apparatus, 49 or 71 per cent of the sixty-nine conversion units reported being of this type. The preference for synchronous converters is slightly more pronounced in railway substations than in Edison substations. Two of the sixty-nine conversion units are mercury-arc rectifiers, one a 3000-kw. unit installed in a 600-volt automatic railway station and the other a 1500-kw. unit installed in a non-automatic station supplying an electrified steam railroad. Since the mercury-arc rectifier is a comparatively recent development in American practice, these figures are not indicative of its true worth, and it seems probable that it will supplant the synchronous converter to a larger extent in the future.

A preference for units of fairly high capacity is indicated, particularly in Edison substations. The capacity of individual machines in the Edison stations varies from 1500 to 4200 kw., with an average of approximately 3000 kw. for synchronous converters, and from 750 to 3000 kw., with an average of about 1600 kw. for motor-generator sets. The largest conversion unit in the railway substations is the 3000-kw. mercury-arc rectifier. The rating of synchronous converters in these stations ranges from 500 to 1500 kw., averaging 1000 kw., while the capacity of motor-generator sets varies from 1000 to 1500 kw., averaging 1250 kw.

Agreement is general on the synchronous motor for driving motor-generator sets in both Edison and railway substations.

The trend toward automatic substations, as indicated by the stations covered in this report is much more marked in the case of railway stations than in Edison stations. Whereas all but two of the twelve substations supplying Edison service are non-automatic, nine of sixteen substations serving railway loads are automatic. It will be noted that automatic control has been applied in these cases to several units of 1500 kw. capacity, and to one rated at 1875 kw., indicating the suitability of automatic equipment for the control of large units.

The necessity for the utmost reliability of service consistent with reasonable investment has a determining influence on the station layouts, particularly in Edison substations. In practically every case two or more incoming lines are provided, and in many cases it has been found necessary to provide duplicate high- and low-voltage buses with adequate sectionalizing facilities. An isolated-phase a-c. structure has been adopted for one Edison substation, and in several of the Edison stations system standby storage batteries, floating on the bus, have been installed. In contrast with this practice, several companies have found it possible to simplify their designs to a large extent, with the elimination of buses, oil circuit breakers, etc.

The limited space available for substation locations in congested downtown urban areas is also reflected in the layouts. Examples are included in the report of four- and five-story substation buildings with basement and sub-basement, and of other buildings of restricted dimensions, irregular in shape. Some companies have overcome this difficulty by installing their equipment in leased space in the basement of office buildings, and several examples of this kind are also included in the report.

Publication No. 289-82. Serial Report, Electrical Apparatus Committee.

SECTION I

AUTOMATIC EDISON SUBSTATIONS

Kansas City Power and Light Co., Kansas City, Mo. Substation "T"

This company is operating five fully automatic d-c. substations, each station equipped with two rotary converters with transformers and the necessary control equipment to make them fully automatic. These ten equipments supply the entire Edison system with power. The equipment of the four of the substations is identical and in the fifth the control is the same as in the other four, but the rotary converters are larger.

The five stations are supplied with power from three cables direct from Northeast Generating Station, and there is one normal and one emergency cable for each machine.

The machines are so arranged that any one of the three cables may be out of service, and all machines will still operate on either their normal or their emergency position, and neither of the other two cables will be overloaded. The ordinary safety devices are provided for the machines, including single-phase starting, a-c. under-voltage, wrong position of brushes, incomplete start, underspeed field failure, wrong polarity, low d-c. voltage when closing on the bus, reverse power, overload on transformer or on rotary converter, hot bearings, d-c. flashover, low water in load limiting resistors, d-c. overload, high d-c. voltage, overspeed, and poor power factor.

On the d-c. side the machines do not trip off from overload, but water-cooled resistors are inserted when the load reaches a certain point. These water-cooled resistors have a capacity much greater than the output of the machine, and cooling water is supplied from the city mains when the temperature reaches a certain point so that they may continue in service indefinitely.

The system of operation used in the automatic equipment consists in bringing on a machine when the voltage on its bus drops to a certain point. The machine starts and comes on the line, and the voltage is then regulated to maintain a certain predetermined value in a selected manhole in the district. The machine operates until the load drops below a certain point, when it is shut down.

These five substations are all located in basements or sub-basements of large down-town buildings, and in every case are located below the street and alley level.

The building in which Substation T is located is a ten-story office building, situated on the southwest corner of the intersection of Tenth and Walnut Streets. The machinery entrance and air intake is located in the sidewalk on the Walnut Street front, and the traffic over the grating is very heavy for a large part of the day. Being below street grade, artificial ventilation is necessary; and as it is the practice of this company to make all equipment fully automatic, it was necessary to provide automatic control for the fans as well as for the louvers. The control for this substation provides the following operation:

Two fans are provided for the substation, one of which is controlled by each of the machines. This control starts the fan when the rotary converter is closed onto the d-c. bus, provided the temperature in the substation is above a certain point. If the temperature is low, the fan motor is not energized until the station warms up. In cold weather, after the fan starts, to prevent one end of the substation being very cold while the other end is still warm, a recirculating duct, which connects the exhaust with the intake, was built along the ceiling near one side.

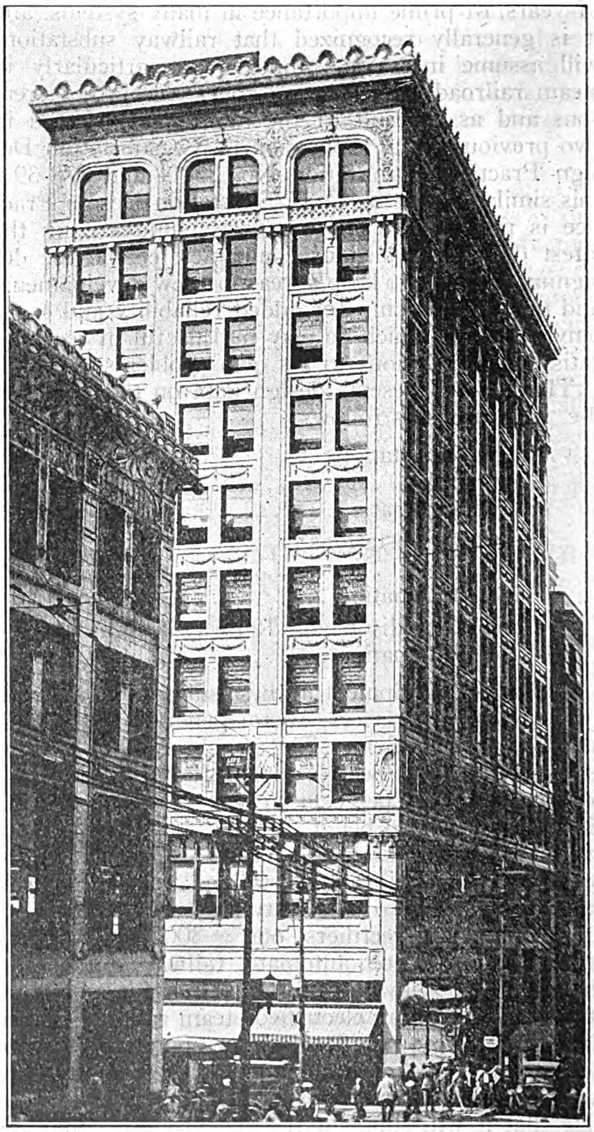


FIG. 1—EXTERIOR VIEW OF OFFICE BUILDING IN WHICH SUBSTATION "T" IS LOCATED.

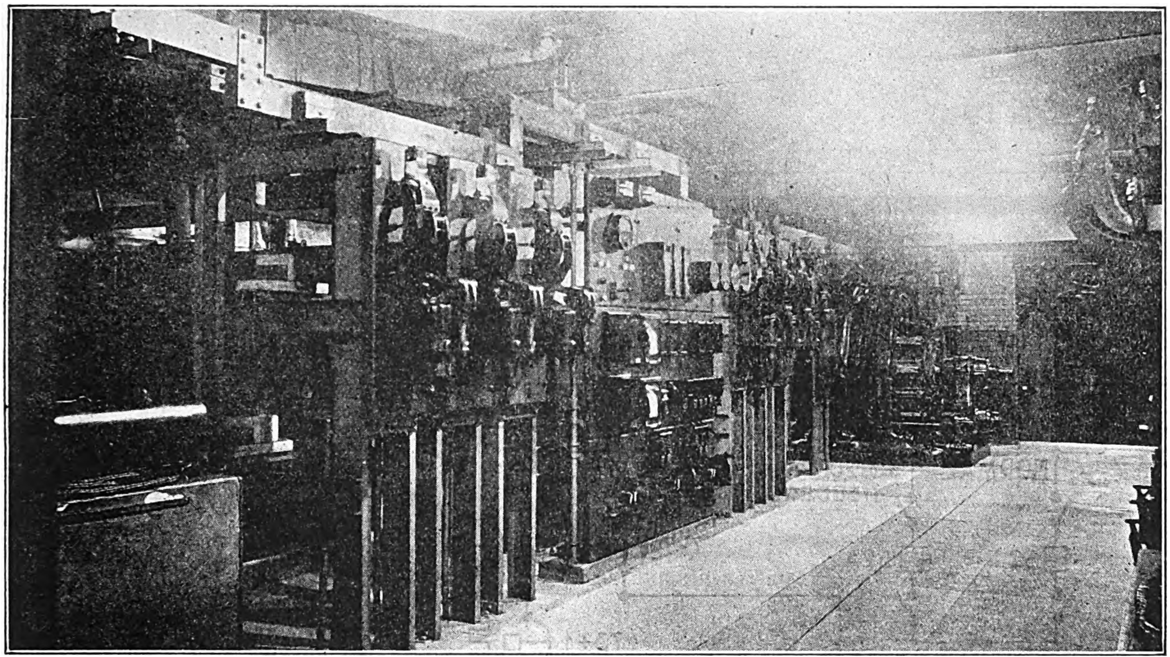


FIG. 2—GENERAL INTERIOR, SUBSTATION "T."

This recirculating duct is closed by automatic louvers which open sufficiently to keep the temperature of the substation nearly constant. Steam heating equipment is also provided to prevent the temperature going too low when the station is down. An automatic valve is provided to turn on the steam when it is needed.

The air intake being located in the sidewalk, a very large amount of dirt, much of it very fine, is taken in with the cooling air. To prevent this dirt and dust entering the equipment, dry or viscous type air filters are provided between the intake and the substation. These filters are made up in unit cells and effectively prevent all dirt and dust from getting into the substation.

In order to forestall complaints in summer due to discharging hot air where it could enter other buildings, a duct was installed, extended from the fan exhausts to the roof of the building, a distance of 138 ft.

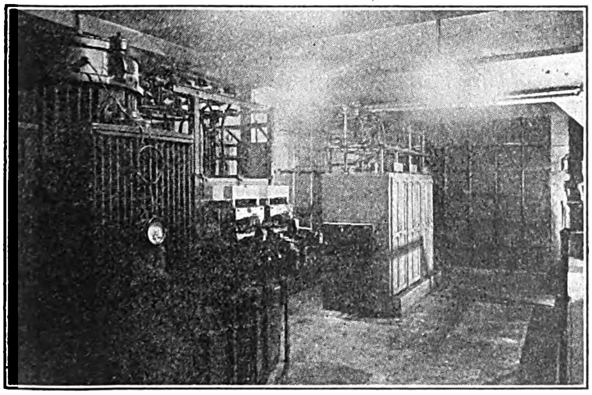


FIG. 3—INTERIOR, SUBSTATION "T."

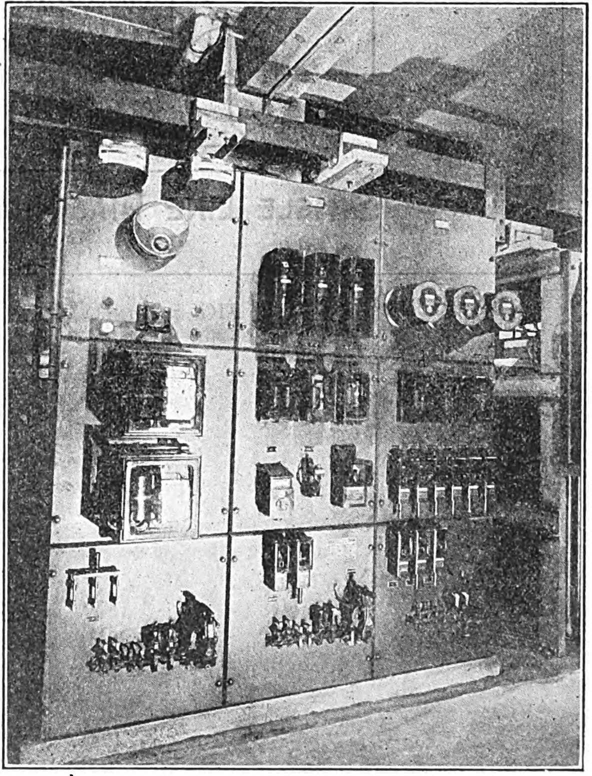


FIG. 4—INTERIOR, SUBSTATION "T."

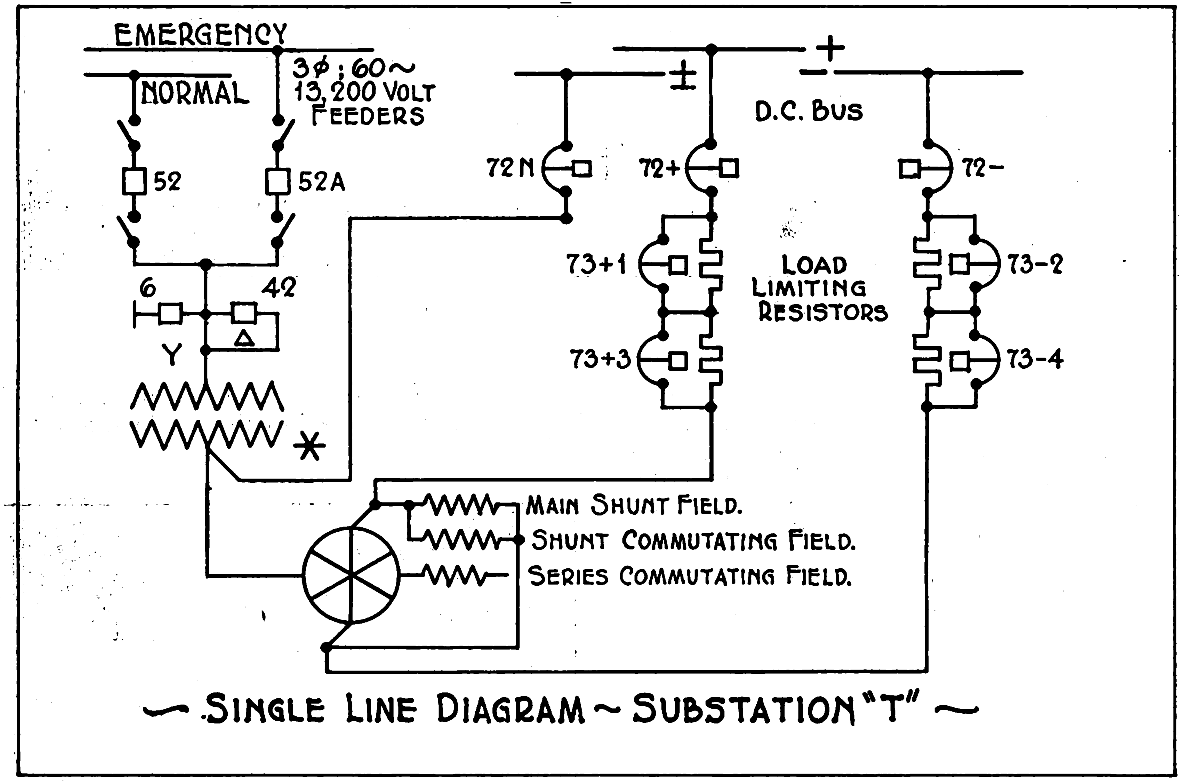

EMERGENCY
NORMAL
3φ; 60~
13,200 VOLT
FEEDERS
52
52A
6
42
Y
Δ
72N
72+
±
+
−
D.C. BUS
72−
73+1
73+3
73−2
73−4
LOAD
LIMITING
RESISTORS
MAIN SHUNT FIELD.
SHUNT COMMUTATING FIELD.
SERIES COMMUTATING FIELD.
SINGLE LINE DIAGRAM ~ SUBSTATION "T"

FIG. 5—SINGLE LINE DIAGRAM, SUBSTATION "T."

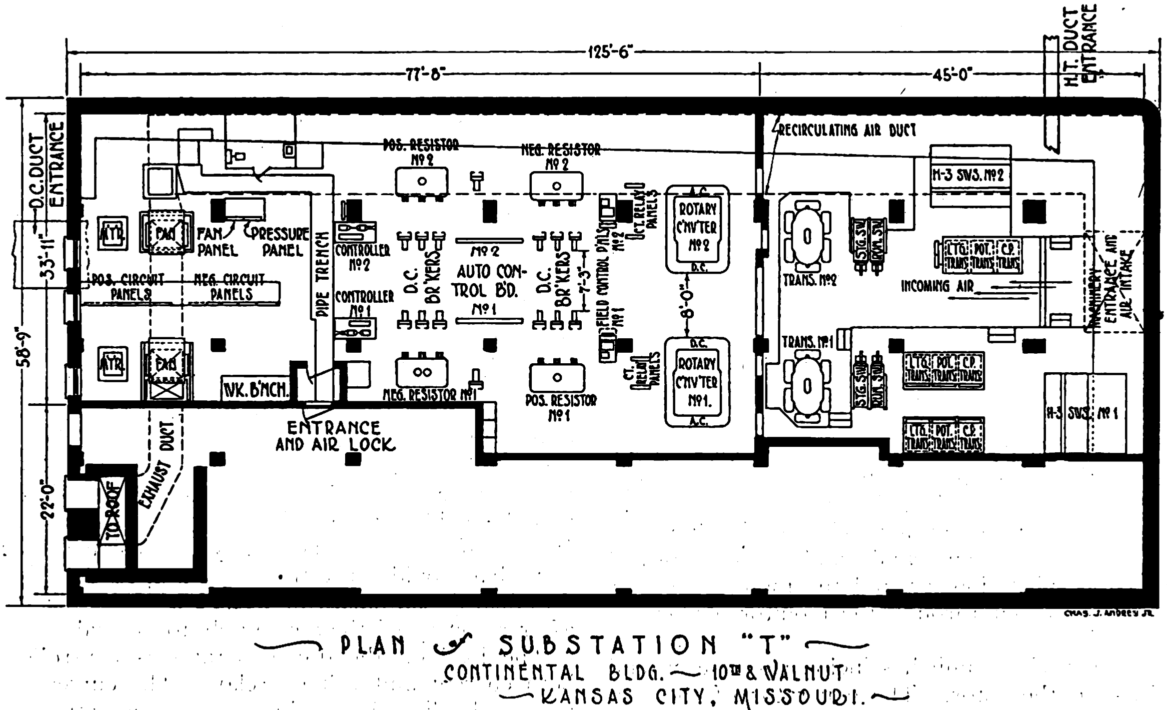

125'-6"
77'-8"
45'-0"
H.T. DUCT ENTRANCE
D.C. DUCT ENTRANCE
33'-11"
58'-9"
22'-0"
RECIRCULATING AIR DUCT
POS. RESISTOR No 2
NEG. RESISTOR No 2
H-3 SWS. No 2
FAN PANEL
PRESSURE PANEL
PIPE TRENCH
CONTROLLER No 2
CONTROLLER No 1
D.C. BR'KERS
No 2 AUTO CONTROL BD. No 1
D.C. BR'KERS
FIELD CONTROL P'N'LS No 2 No 1
CT. RELAY PANELS
ROTARY CNV'TER No 2
ROTARY CNV'TER No 1
8'-0"
7'-3"
TRANS. No 2
TRANS. No 1
INCOMING AIR
LTG. TRANS
POT. TRANS
C.P. TRANS
MACHINERY ENTRANCE AND AIR INTAKE
POS. CIRCUIT PANELS
NEG. CIRCUIT PANELS
WK. B'NCH.
NEG. RESISTOR No 1
POS. RESISTOR No 1
H-3 SWS. No 1
ENTRANCE AND AIR LOCK
EXHAUST DUCT
TO ROOF
CHAS. J. ANDREW JR.
PLAN of SUBSTATION "T"
CONTINENTAL BLDG. 10th & WALNUT
KANSAS CITY, MISSOURI.

FIG. 6—PLAN, SUBSTATION "T."

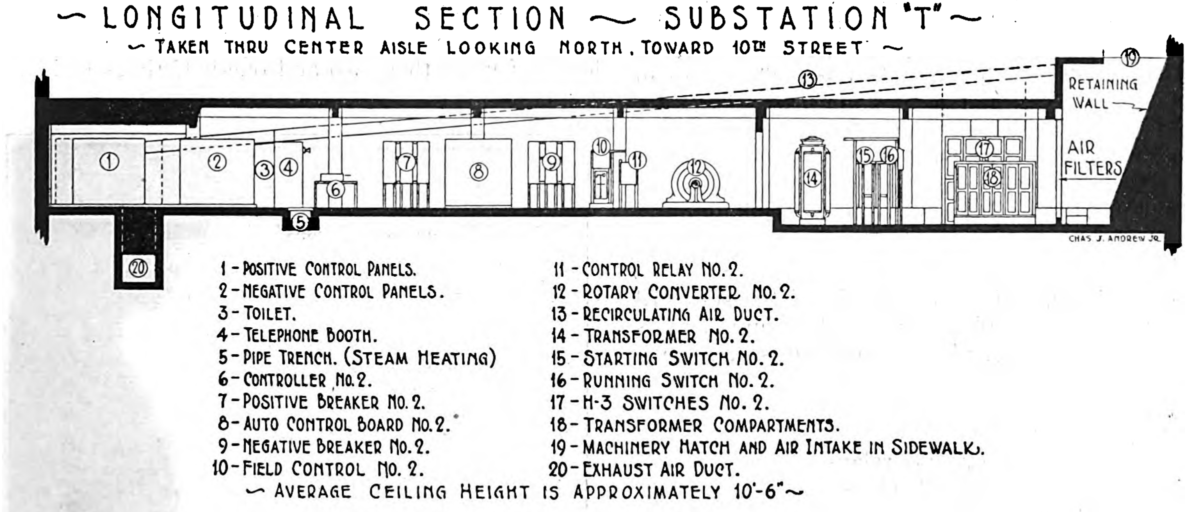

LONGITUDINAL SECTION — SUBSTATION "T"
TAKEN THRU CENTER AISLE LOOKING NORTH, TOWARD 10th STREET
RETAINING WALL
AIR FILTERS
CHAS. J. ANDREW JR.
1 - POSITIVE CONTROL PANELS.
2 - NEGATIVE CONTROL PANELS.
3 - TOILET.
4 - TELEPHONE BOOTH.
5 - PIPE TRENCH. (STEAM HEATING)
6 - CONTROLLER No. 2.
7 - POSITIVE BREAKER No. 2.
8 - AUTO CONTROL BOARD No. 2.
9 - NEGATIVE BREAKER No. 2.
10 - FIELD CONTROL No. 2.
11 - CONTROL RELAY No. 2.
12 - ROTARY CONVERTER No. 2.
13 - RECIRCULATING AIR DUCT.
14 - TRANSFORMER No. 2.
15 - STARTING SWITCH No. 2.
16 - RUNNING SWITCH No. 2.
17 - H-3 SWITCHES No. 2.
18 - TRANSFORMER COMPARTMENTS.
19 - MACHINERY HATCH AND AIR INTAKE IN SIDEWALK.
20 - EXHAUST AIR DUCT.
AVERAGE CEILING HEIGHT IS APPROXIMATELY 10'-6"

FIG. 7—SECTION, SUBSTATION "T."

Union Gas & Electric Company, Cincinnati, Ohio—Jackson Street Substation*

General Description

This substation is located in the downtown section of Cincinnati, on Jackson Street between Twelfth and Thirteenth Streets. The building itself is constructed of red wire-cut brick and contains one story and a basement. In order to cut down noise of operation and fire hazard, the station has no windows. This substation is entirely automatic in operation.

In the basement are located the ventilating filters, the switch positions, the starting reactors, the switchboard, and the 125-volt control battery. The first floor contains the 1875-kw. motor-generator set with enough additional space for a second unit. The motor-generator set has a direct connected exciter on the shaft of the machine. In the roof of the building are monitor air outlets.

Ventilating System

The ventilating system of the Jackson Street Substation is of the natural draft type. The air enters the substation through an airshaft and air filters, located in the basement wall, and passes upward through the substation, around the motor-generator set, and thence out through the monitor air outlets in the roof.

The motor of the unit has inclosures on each end and fans on the rotor. The generator of the unit has inclosure on rear end with commutator end open. Fans are provided on the rear end of the generator rotor only. When the motor-generator set is in service it is possible to move approximately 19,600 cu. ft. of air per minute with this system.

A system of baffling has been installed in the substation to reduce the amount of noise going out through air inlet and outlet openings. The baffles consist of "V" shaped pieces of sheet steel covered on all sides with ½ in. of hair felt. These are in a series slightly overlapping one another. They are installed in the discharge and inlet openings. It is estimated that the installation of the baffles has reduced the noise getting out of the substation to 25 per cent of what it was before their installation.

Relaying

The relaying at this substation is of the standard type for automatic substations. The equipment is fully protected against all types of faults, as shown by the following:

Motor-Generator Set:

1. Overload and ground relays.
2. Thermostat overload relays.
3. Under-voltage relays.
4. Bearing temperature relays.
5. Speed limit relays.
6. Flash relays (connected between base plate and ground).
7. Reverse phase relays.

Automatic Motor-Generator Set Control

The 1875-kw. automatic motor-generator set ha fully automatic control. The machine is used to supply direct current to the Edison system of the Unio Gas & Electric Co. in Cincinnati, Ohio. The motor of the machine is wound for 13,200 volts, 3-phase, 60-cycle alternating current. The generator delivers direct current at 230 to 280 volts, two-wire.

The machine is supplied by two incoming 13,200-volt lines, one designated at the preferential source and the second as the emergency source. The emergency source is kept energized at all times. In case of failure of the preferential source the motor-generator circuit is automatically transferred to the emergency source.

The machine can be arranged to start by energizing the supply feeder at a nearby a-c. substation which has an attendant, or by use of a pilot wire.

Starting the motor-generator is accomplished by a time switch which closes the 13,200-volt line oil circuit breaker. The set starts through series reactors, and when it comes up to speed the reactors are short circuited by another oil circuit breaker, and the field is automatically applied to the motor. In case of a momentary a-c. system voltage disturbance that would cause the motor to pull out of step, the field is automatically removed and reinstalled after recovery of the a-c. supply to normal.

The load on the d-c. generator is controlled by both current and voltage relays. The current relay permits loading the machine on a temperature basis. The voltage relay limits machine voltage and, in turn, the load during light-load periods.

In the case of sudden overloads due to adjacent substations dropping out during full load or in the case of energizing a dead Edison system, current limitation is accomplished by a differential field winding. This winding is normally short-circuited by a breaker which trips on application of sudden overloads of more than two and one-half times rating.

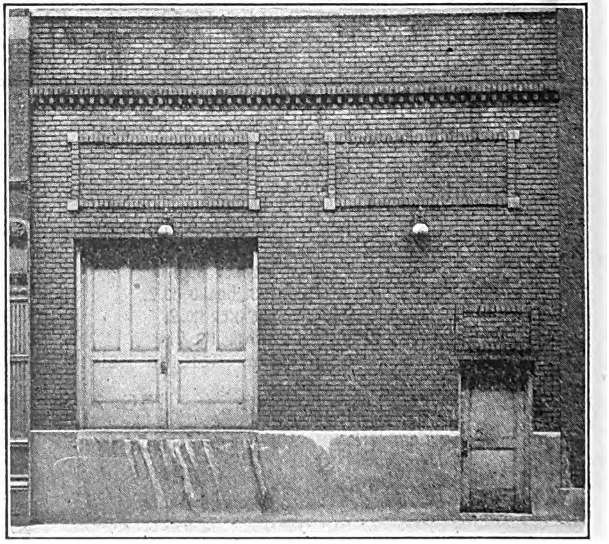


FIG. 8—EXTERIOR VIEW, JACKSON STREET SUBSTATION.

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*For a general description of d-c. substation practice in Cincinnati, see first paragraph under Baker Alley Substation.

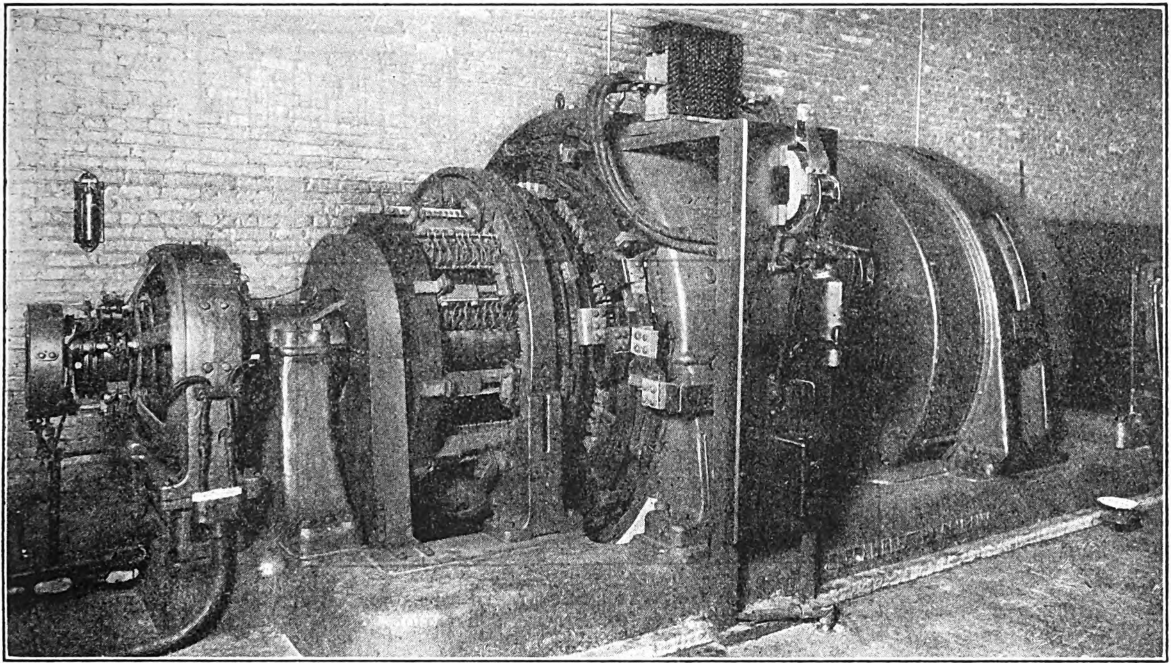


FIG. 9—1875-KW. MOTOR-GENERATOR SET, JACKSON STREET SUBSTATION.

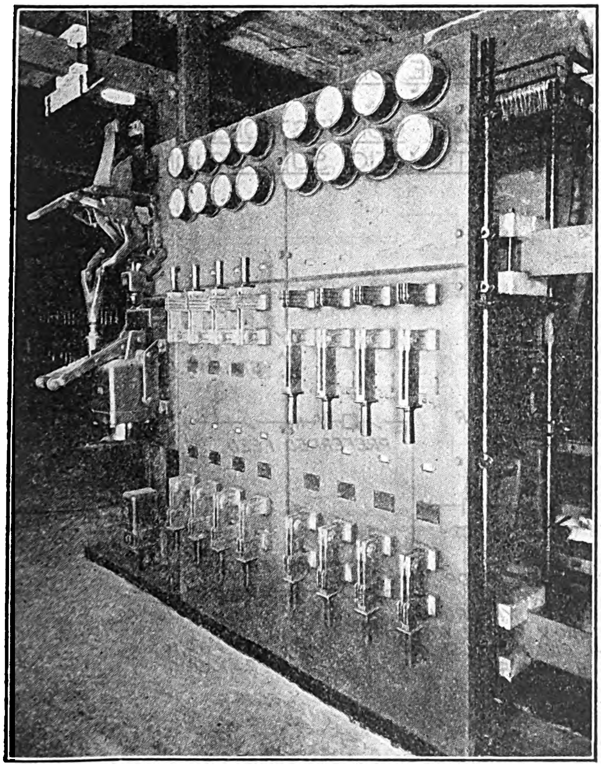


FIG. 10—DIRECT-CURRENT SWITCHBOARD, JACKSON STREET SUBSTATION.

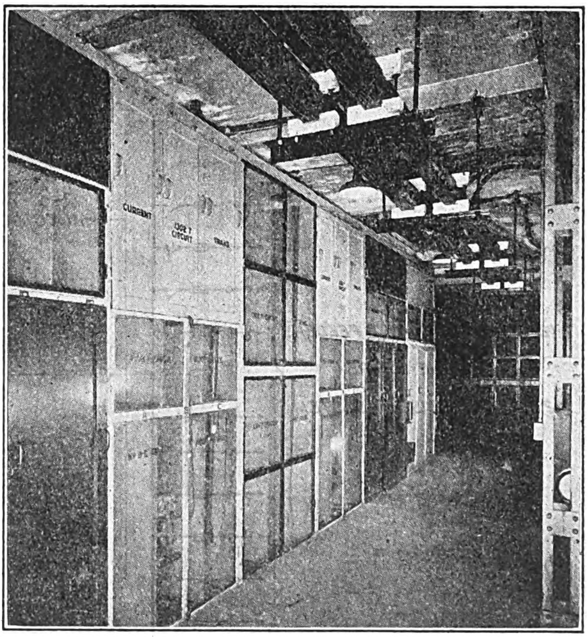


FIG. 11—13,200-VOLT BUS STRUCTURE, JACKSON STREET SUBSTATION.

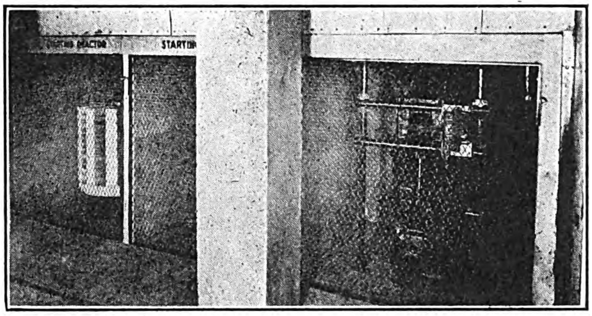


FIG. 12—MOTOR GENERATOR SET STARTING REACTORS AND BREAKER, JACKSON STREET SUBSTATION.

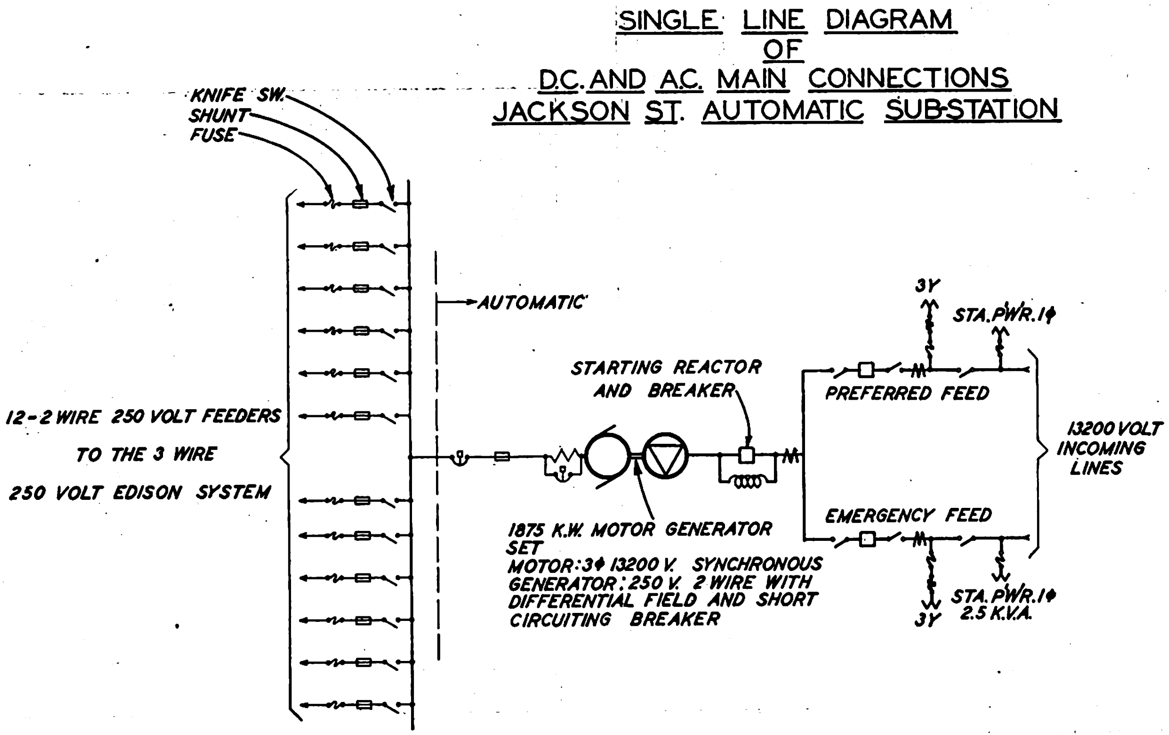
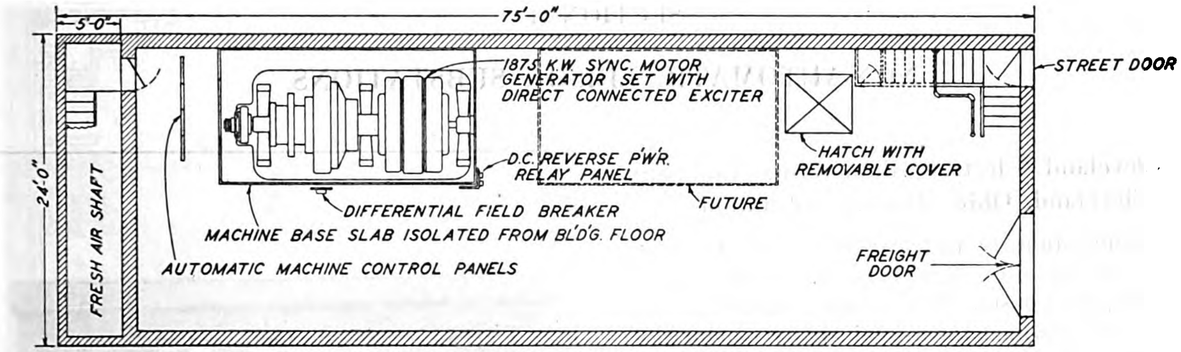
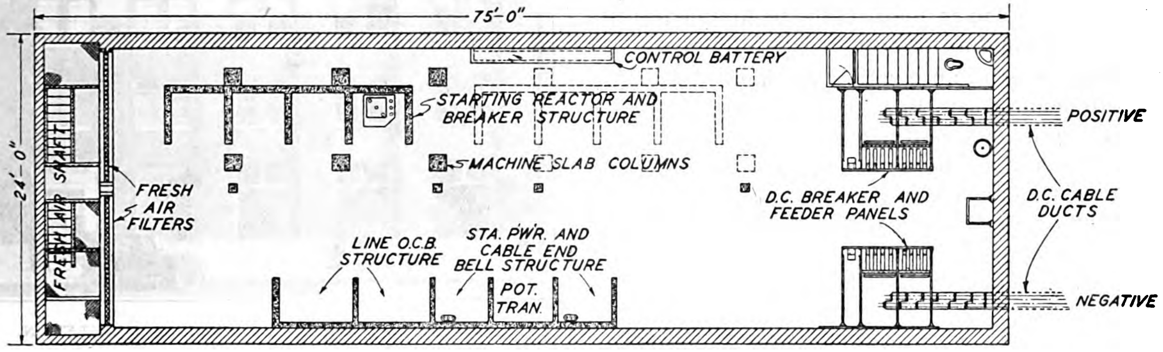

SINGLE LINE DIAGRAM
OF
D.C. AND A.C. MAIN CONNECTIONS
JACKSON ST. AUTOMATIC SUB-STATION
KNIFE SW.
SHUNT
FUSE
AUTOMATIC
12-2 WIRE 250 VOLT FEEDERS
TO THE 3 WIRE
250 VOLT EDISON SYSTEM
STARTING REACTOR
AND BREAKER
3Y
STA. PWR. 1φ
PREFERRED FEED
13200 VOLT
INCOMING
LINES
EMERGENCY FEED
1875 K.W. MOTOR GENERATOR
SET
MOTOR: 3φ 13200 V. SYNCHRONOUS
GENERATOR: 250 V. 2 WIRE WITH
DIFFERENTIAL FIELD AND SHORT
CIRCUITING BREAKER
3Y
STA. PWR. 1φ
2.5 K.V.A.

FIG. 13—SINGLE LINE DIAGRAM, JACKSON STREET SUBSTATION.


75'-0"
5'-0"
24'-0"
FRESH AIR SHAFT
1875 K.W. SYNC. MOTOR GENERATOR SET WITH DIRECT CONNECTED EXCITER
D.C. REVERSE PWR. RELAY PANEL
DIFFERENTIAL FIELD BREAKER
MACHINE BASE SLAB ISOLATED FROM BL'D'G. FLOOR
AUTOMATIC MACHINE CONTROL PANELS
FUTURE
HATCH WITH REMOVABLE COVER
STREET DOOR
FREIGHT DOOR

MAIN FLOOR

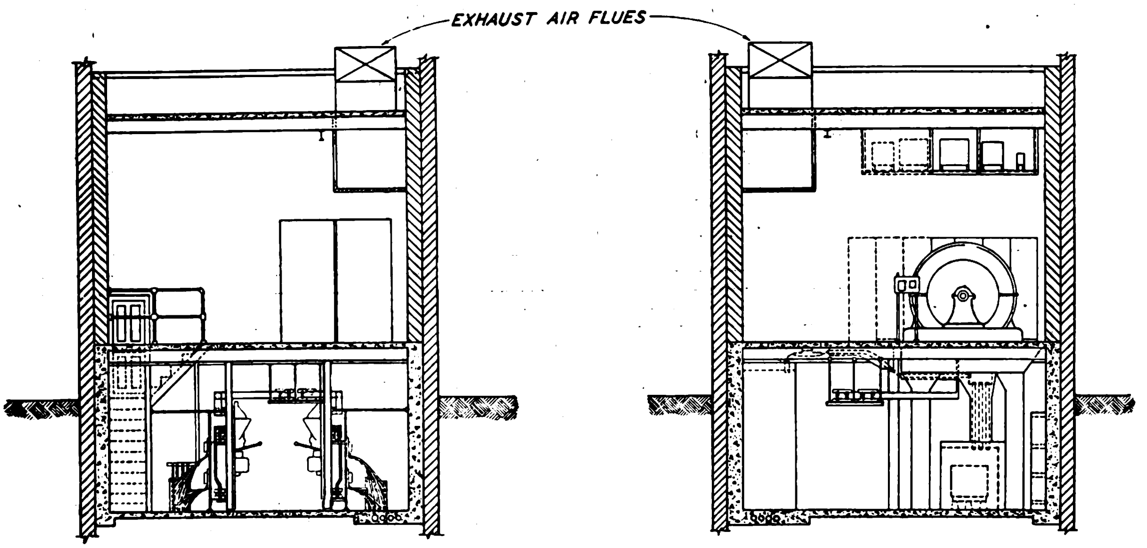
MACHINE ROOM


75'-0"
24'-0"
FRESH AIR SHAFT
CONTROL BATTERY
STARTING REACTOR AND BREAKER STRUCTURE
MACHINE SLAB COLUMNS
FRESH AIR FILTERS
LINE O.C.B. STRUCTURE
STA. PWR. AND CABLE END BELL STRUCTURE
POT. TRAN.
D.C. BREAKER AND FEEDER PANELS
D.C. CABLE DUCTS
POSITIVE
NEGATIVE

BASEMENT

13200 VOLT SWITCHING AND D.C. FEEDER ROOM

FIG. 14—Plan Views, Jackson Street Substation.


EXHAUST AIR FLUES

VIEW LOOKING TOWARD FRONT OF STATION

VIEW LOOKING TOWARD REAR OF STATION

FIG. 15—Sectional Views, Jackson Street Substation.

SECTION II

NON-AUTOMATIC EDISON SUBSTATIONS

The Cleveland Electric Illuminating Company, Cleveland, Ohio—Bolivar Substation

This substation is the one most recently constructed in the d-c. district of Cleveland. Three 13,000-ampere booster type rotaries are in service, and space is provided for a total of five machines of this rating. Incoming supply is from 11,000-volt underground cables. A storage battery of approximately 10,000 ampere-hr. capacity (one-hour rating) is located on an upper floor. The front portion of the substation building is occupied by offices.

Switching is semi-automatic. A single operation by the attendant starts up a rotary and puts it on the line at light load. Adjustments of load, voltage and power factor are by manual control only. Load limiting resistors are cut in automatically at or above 50 per cent overload. When the station reaches its ultimate development it should be able to pick up a dead system without the aid of the storage batteries.

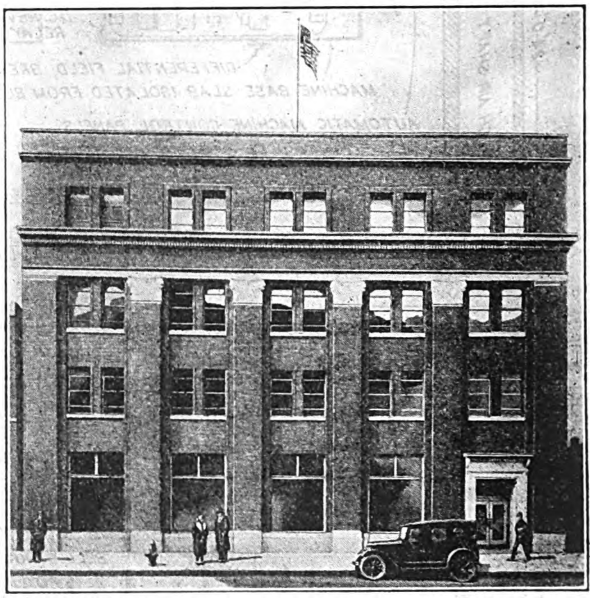


FIG. 16—EXTERIOR VIEW, BOLIVAR SUBSTATION.

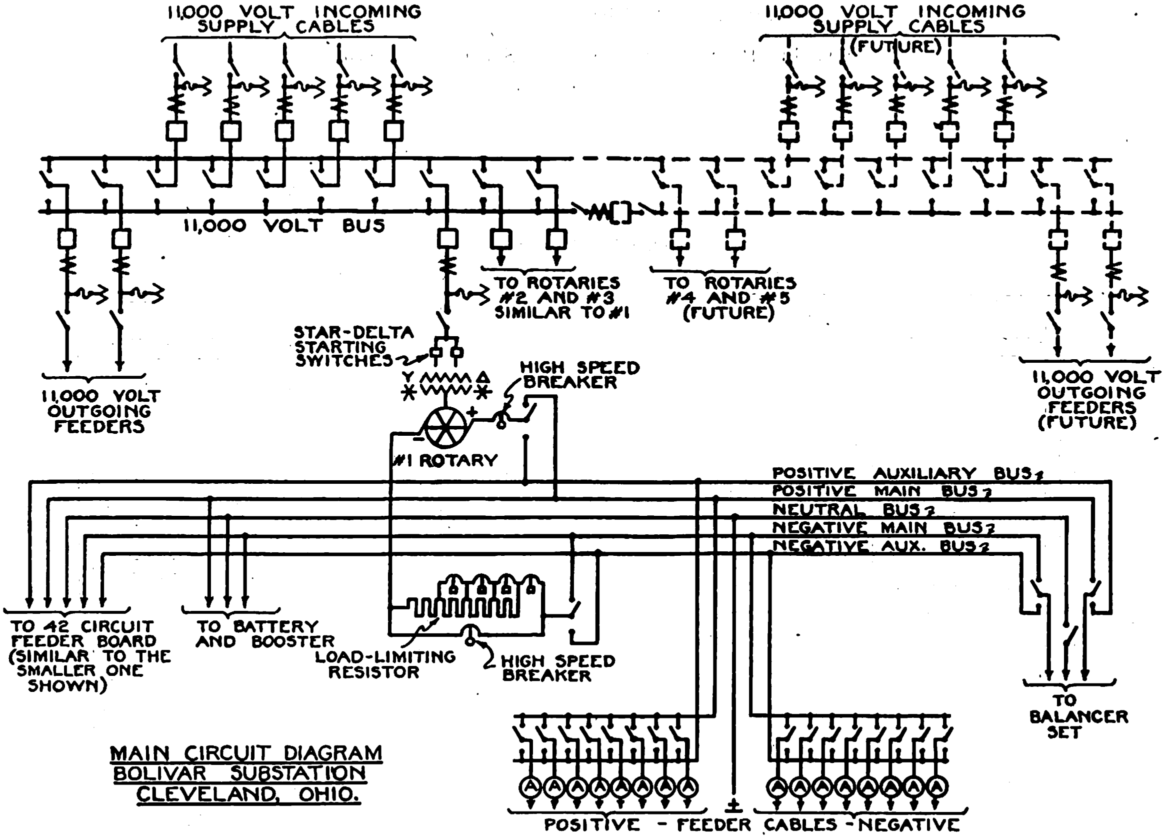

11,000 VOLT INCOMING SUPPLY CABLES
11,000 VOLT INCOMING SUPPLY CABLES
(FUTURE)
11,000 VOLT BUS
TO ROTARIES #2 AND #3 SIMILAR TO #1
TO ROTARIES #4 AND #5 (FUTURE)
STAR-DELTA STARTING SWITCHES
Y Δ
HIGH SPEED BREAKER
11,000 VOLT OUTGOING FEEDERS
11,000 VOLT OUTGOING FEEDERS (FUTURE)
#1 ROTARY
POSITIVE AUXILIARY BUS
POSITIVE MAIN BUS
NEUTRAL BUS
NEGATIVE MAIN BUS
NEGATIVE AUX. BUS
TO 42 CIRCUIT FEEDER BOARD (SIMILAR TO THE SMALLER ONE SHOWN)
TO BATTERY AND BOOSTER
LOAD-LIMITING RESISTOR
HIGH SPEED BREAKER
TO BALANCER SET
MAIN CIRCUIT DIAGRAM BOLIVAR SUBSTATION CLEVELAND, OHIO.
POSITIVE - FEEDER CABLES - NEGATIVE

FIG. 17—SINGLE LINE DIAGRAM, BOLIVAR SUBSTATION.

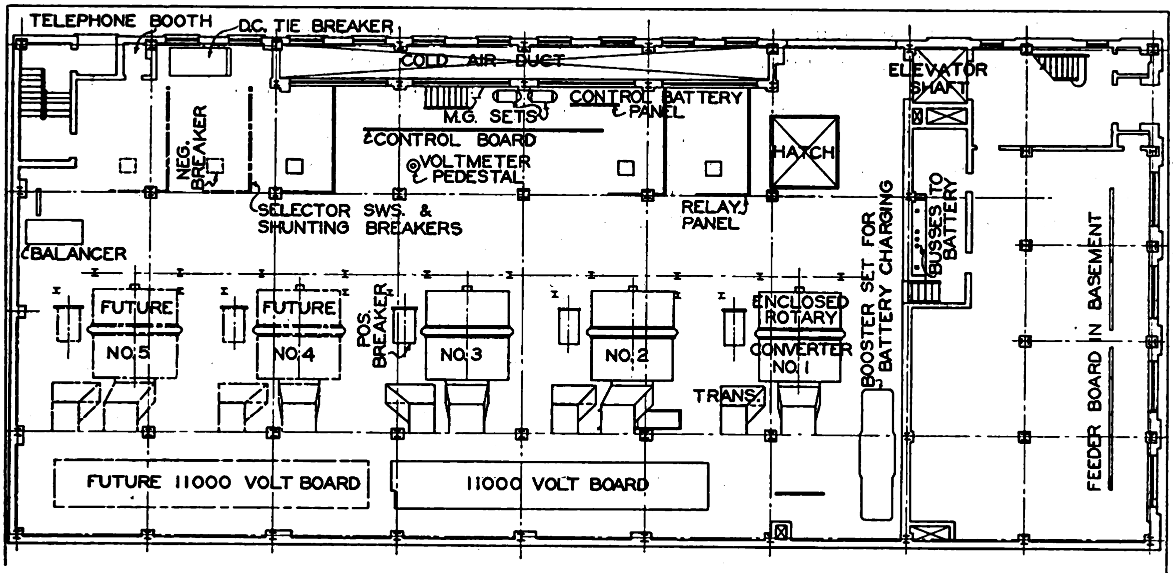

TELEPHONE BOOTH
D.C. TIE BREAKER
COLD AIR DUCT
ELEVATOR SHAFT
NEG. BREAKER
M.G. SETS
CONTROL BATTERY
CONTROL PANEL
CONTROL BOARD
VOLTMETER PEDESTAL
HATCH
SELECTOR SWS. & SHUNTING BREAKERS
RELAY PANEL
BOOSTER SET FOR BATTERY CHARGING
BUSSES TO BATTERY
BALANCER
FUTURE
NO.5
FUTURE
NO.4
POS. BREAKER
NO.3
NO.2
ENCLOSED ROTARY CONVERTER NO.1
TRANS.
FEEDER BOARD IN BASEMENT
FUTURE 11000 VOLT BOARD
11000 VOLT BOARD

FIG. 18—PLAN VIEW, BOLIVAR SUBSTATION.

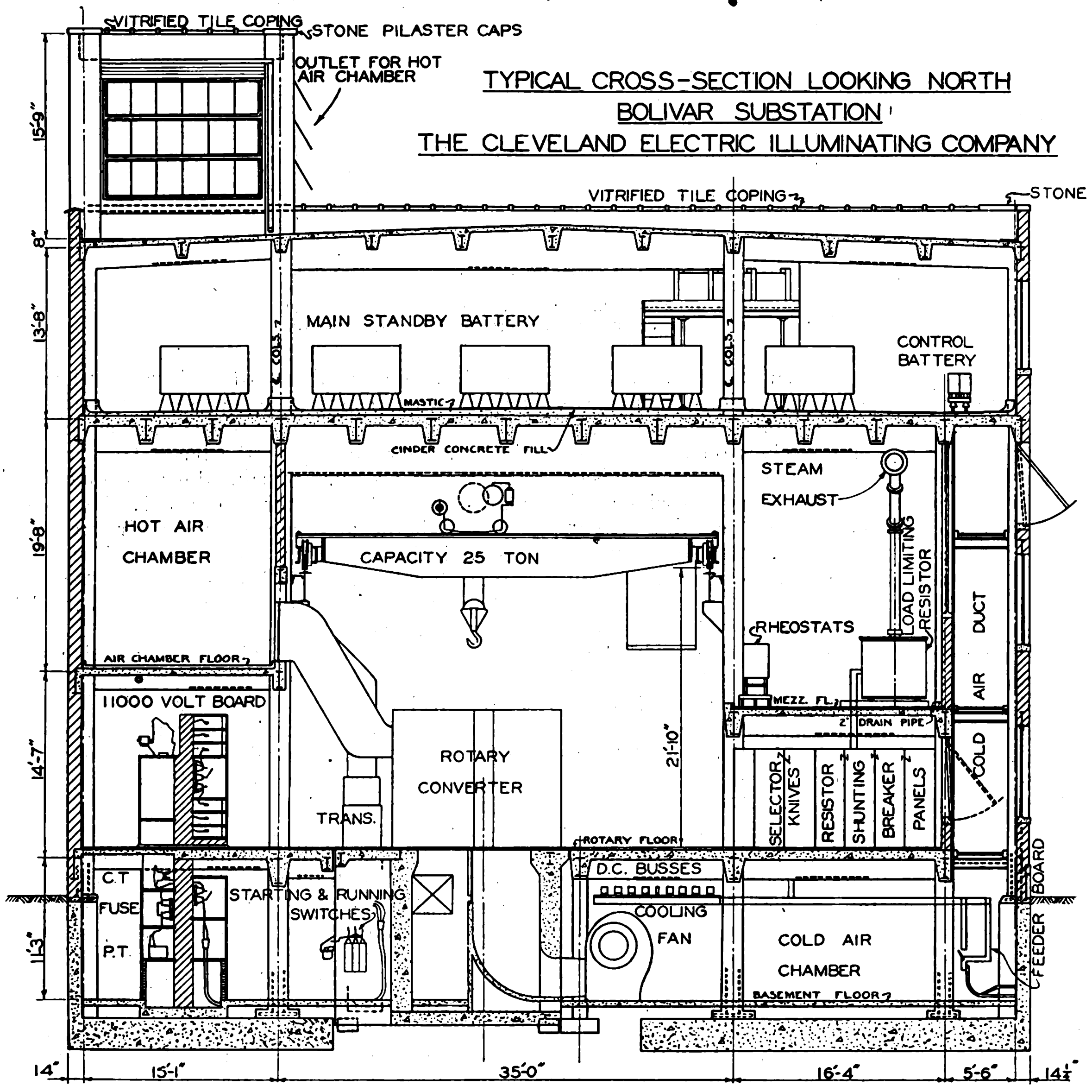

VITRIFIED TILE COPING
STONE PILASTER CAPS
OUTLET FOR HOT AIR CHAMBER
TYPICAL CROSS-SECTION LOOKING NORTH
BOLIVAR SUBSTATION
THE CLEVELAND ELECTRIC ILLUMINATING COMPANY
VITRIFIED TILE COPING
STONE
15'-9"
8"
13'-8"
19'-8"
14'-7"
11'-3"
MAIN STANDBY BATTERY
CONTROL BATTERY
MASTIC
CINDER CONCRETE FILL
HOT AIR CHAMBER
CAPACITY 25 TON
STEAM EXHAUST
LOAD LIMITING RESISTOR
RHEOSTATS
DUCT
AIR
COLD
AIR CHAMBER FLOOR
11000 VOLT BOARD
MEZZ. FL.
2" DRAIN PIPE
21'-10"
ROTARY CONVERTER
TRANS.
SELECTOR KNIVES
RESISTOR
SHUNTING
BREAKER
PANELS
ROTARY FLOOR
C.T.
FUSE
P.T.
STARTING & RUNNING SWITCHES
D.C. BUSSES
COOLING FAN
COLD AIR CHAMBER
BASEMENT FLOOR
FEEDER BOARD
14"
15'-1"
35'-0"
16'-4"
5'-6"
14½"

FIG. 19—SECTION, BOLIVAR SUBSTATION.

Commonwealth Edison Company, Chicago, Ill.—Burnham Bldg. Substation

This substation is located in space leased in the sub-basement of an office building. It receives 12,000-volt, 60-cycle, 3-phase energy from the company's generating stations over three-conductor underground cables, two G. E. 13,000-ampere, 225/275-volt synchronous booster converters are used to convert this energy to direct current for use on the Edison 3-wire system, and for direct feeders to surrounding buildings. The substation also contains a 10,500 ampere-hr. battery, 1-hour rate, which floats on the system.

The high-tension bus structure is of the horizontal isolated-phase type. Oil circuit breakers are interlocked electrically and mechanically. Relays in 12,000-volt tie lines to other substations are the balanced differential type with a non-directional induction type relay on one end. Relays on the a-c. side of converters are inverse-time overload. Provision is made for the installation of a fault-bus which kills any section of the bus should there be a flow of current to ground over any of the normally grounded parts of breakers, disconnecting switches, and instrument and main transformers.

The synchronous converters are of the booster type. The main transformers are air-blast cooled and are mounted on the converter bases, being what is termed the consolidated type. Air is taken from an opening in the sidewalk through air filters. Blowers force the air into a duct under the floor which opens into each synchronous converter and has openings also into the substation space. The transformers have separate blowers because they require higher air pressure. The heated air from converters and transformers is exhausted through a duct on the ceiling which terminates in the alley. The synchronous converters are normally started on the high-tension side by means of two electrically and mechanically interlocked non-automatic oil circuit breakers using the star-delta method. Direct-current starting equipment is also provided.

The direct-current energy goes through remote controlled air-circuit breakers, mounted separately, and then to the armature knife switches on the feeder switchboard.

The d-c. circuit breakers are equipped with what is termed "service restoring equipment," which consists of a load-limiting resistor and an auxiliary air circuit breaker connected in parallel with the main positive air circuit breaker. In cases of a-c. system disturbances which cause momentary dips in the 12,000-volt pressure, the converter will invert. When this happens, a d-c. reverse current relay functions to open the main positive air circuit breaker, thereby inserting the load-limiting resistance and auxiliary air circuit breaker in the positive lead and at the same time opening the neutral circuit breaker. This limits the inverted load to the commutating ability of the converter. If the 12,000-volt pressure is restored within the limits of a thermal relay on the load-limiting resistor, the reverse current relay functions to close the main positive breaker, connecting the converter directly to the bus. If, however, the 12,000-volt pressure remains down beyond the thermal limit of the resistor, a thermal relay functions, opening the negative and auxiliary air circuit breakers and the converter a-c. main and running oil circuit breakers. This leaves the equipment ready to be restarted in the usual manner when the 12,000-volt voltage is restored to normal.

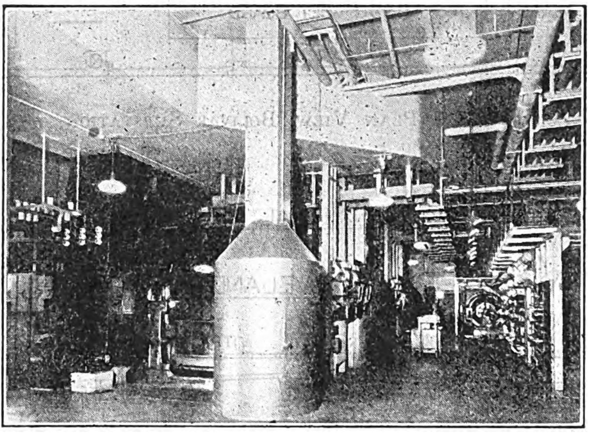


FIG. 20—INTERIOR VIEW SHOWING CONSOLIDATED TYPE SYNCHRONOUS CONVERTER, BURNHAM BLDG. SUBSTATION.

This feeder switchboard has the positive switches on one side and the negative on the other. Switchboard steel is insulated from ground. The feeders are run from this switchboard to the duct outlets on racks which keep each cable separate, and additional protection is provided by fire-proofing each cable with hemp rope and a mixture of sand, cement and fireclay.

The control switchboard has all the necessary control for the high-tension bus, the converters, the booster which is used for charging the battery, and the battery end-cell switch control. A separate operating battery is provided with a carbon pile rheostat for charging from the d-c. bus.

The machinery entrance is through the sidewalk, removable slabs being provided over the shaft through which the machinery is lowered to the substation floor.

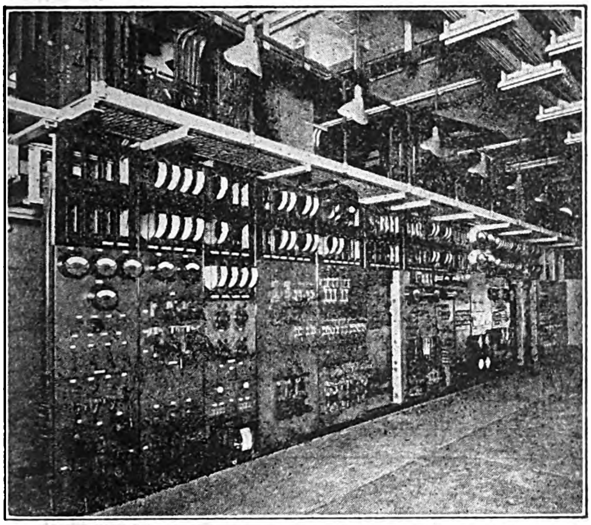


FIG. 21—Switchboard, Burnham Bldg. Substation.

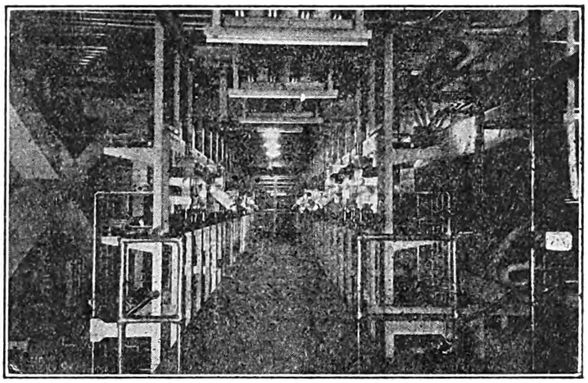


FIG. 22—Interior, Burnham Bldg. Substation.

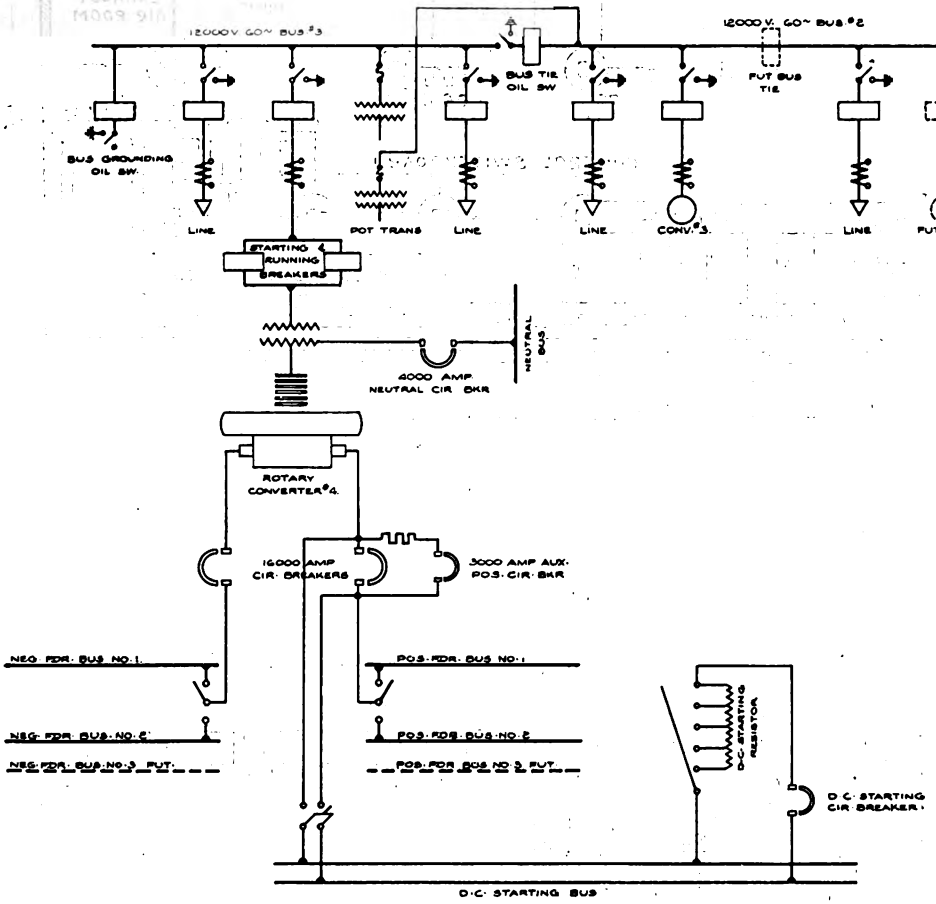

12000V 60~ BUS #3
12000 V. 60~ BUS #2
BUS TIE OIL SW
FUT BUS TIE
BUS GROUNDING OIL SW
LINE
POT TRANS
LINE
LINE
CONV #3
LINE
FUT CONV
LINE
FUT CONV
STARTING & RUNNING BREAKERS
4000 AMP NEUTRAL CIR BKR
NEUTRAL BUS
ROTARY CONVERTER #4
16000 AMP CIR BREAKERS
3000 AMP AUX POS CIR BKR
NEG FDR BUS NO 1
NEG FDR BUS NO 2
NEG FDR BUS NO 3 FUT
POS FDR BUS NO 1
POS FDR BUS NO 2
POS FDR BUS NO 3 FUT
D-C STARTING RESISTOR
D-C STARTING CIR BREAKER
D-C STARTING BUS

FIG. 23—Single Line Diagram, Burnham Bldg. Substation.

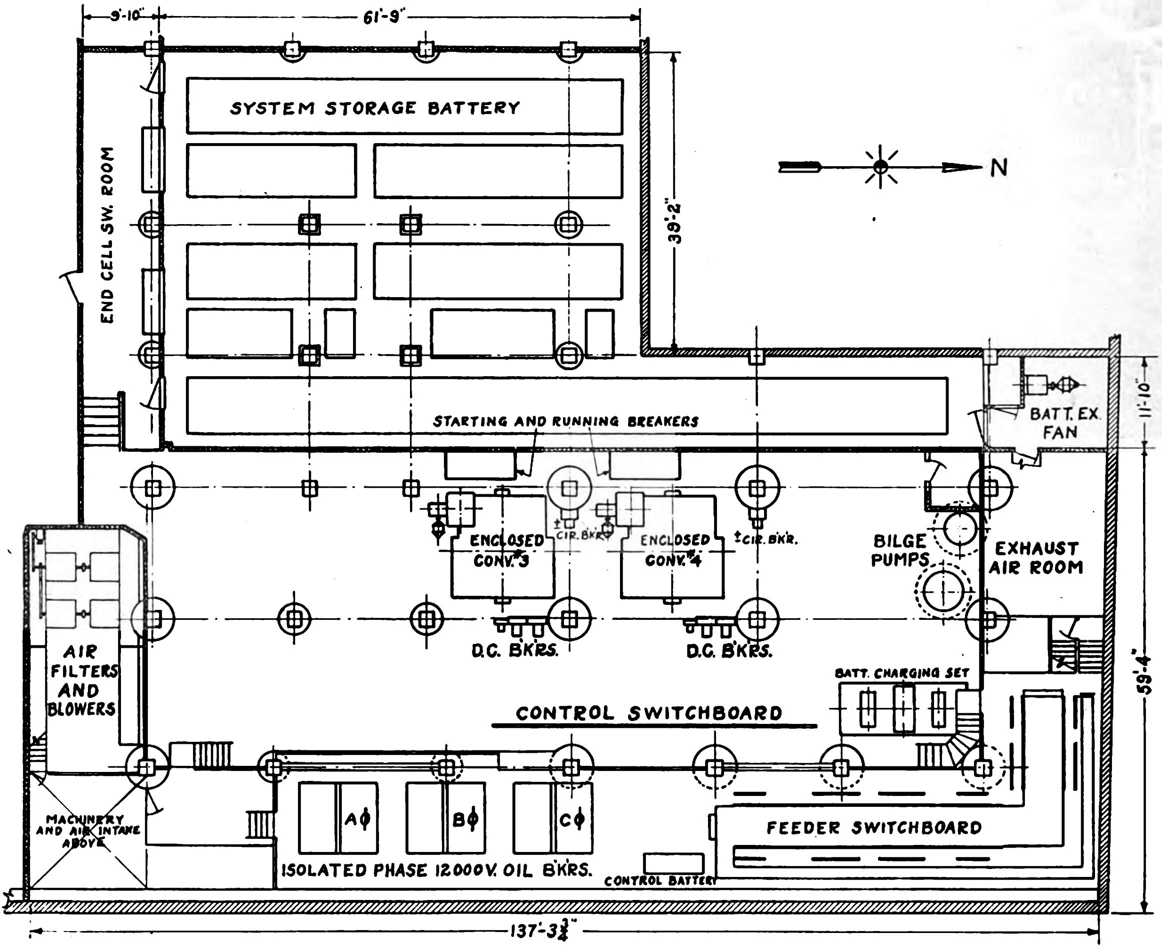

9'-10"
61'-9"
SYSTEM STORAGE BATTERY
N
39'-2"
END CELL SW. ROOM
STARTING AND RUNNING BREAKERS
BATT. EX. FAN
11'-10"
ENCLOSED CONV. #3
CIR. BKR.
ENCLOSED CONV. #4
CIR. BKR.
BILGE PUMPS
EXHAUST AIR ROOM
AIR FILTERS AND BLOWERS
D.C. BKRS.
D.C. BKRS.
BATT. CHARGING SET
CONTROL SWITCHBOARD
59'-4"
MACHINERY AND AIR INTAKE ABOVE
AΦ
BΦ
CΦ
FEEDER SWITCHBOARD
ISOLATED PHASE 12000V. OIL BKRS.
CONTROL BATTERY
137'-3¼"

FIG. 24—General Plan. Burnham Bldg. Substation.

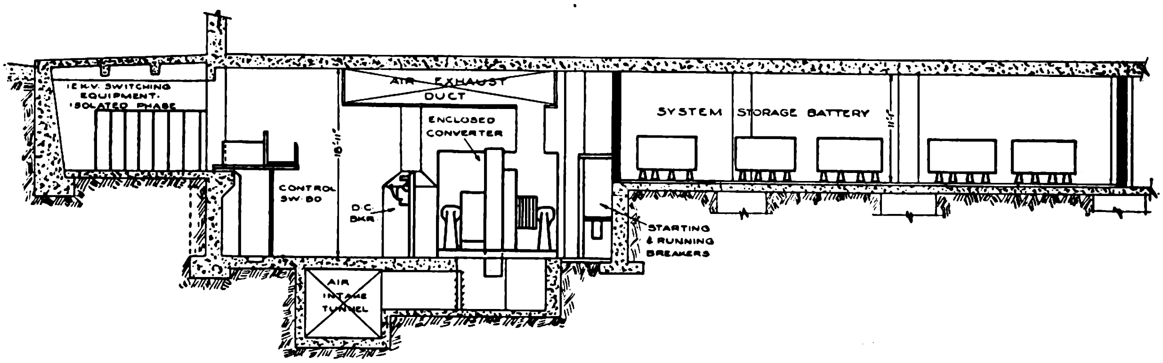

12 K.V. SWITCHING EQUIPMENT. ISOLATED PHASE
AIR EXHAUST DUCT
ENCLOSED CONVERTER
18'-11"
CONTROL SW. BD
D.C. BKR
SYSTEM STORAGE BATTERY
11'-5"
STARTING & RUNNING BREAKERS
AIR INTAKE TUNNEL

FIG. 25—Section, Burnham Bldg. Substation.

The Detroit Edison Company, Detroit, Mich.—Charlotte Substation

This substation is one of the newest Edison System substations now in operation on the Detroit Edison Company's system. The present installation consists of three differentially wound, 2400-kw., motor-generator sets, with a 600-kw., 3-unit balancer. Provision is made for the installation of two 4800-kw., 3-unit machines, making an ultimate station capacity of 16,800 kw. Each machine is fed directly by a 4800-volt tie line, with provision for jumpering to a spare line in case of the failure of one of the lines in use.

Main and auxiliary d-c. buses are provided, with double-throw knife switches to connect machines and feeders to either bus. In the feeder rooms, positive and negative buses are on opposite sides of the room. Provision is made for the future installation of feeder circuit breakers in place of the double-throw knife switches now in use. Ammeters are installed on both positive and negative feeders.

Use of a 3-unit balancer set provides some reserve converting capacity as well as balancing service. The balancer is fed through its own tie line and can be jumpered to the spare line in the same way as the motor-generators.

Cooling air is washed and blown through the machines and discharged into the machine room, whence it is removed through gratings in the ceiling by exhaust fans. The air can be recirculated if it is deemed advisable. Machines are partially enclosed. The air outlet on the motors is at the top; and on the generators the air passes over the commutator as it leaves the machine.

The differential winding on the machines acts to limit the load so that there is no other overload protection necessary on the d-c. end of the units.

The substation is of fireproof construction throughout, with the feeder rooms isolated from the remainder of the bus room in the basement. Hand Pyrene fire extinguishers are provided for use in case of insulation fires in the machines, etc.

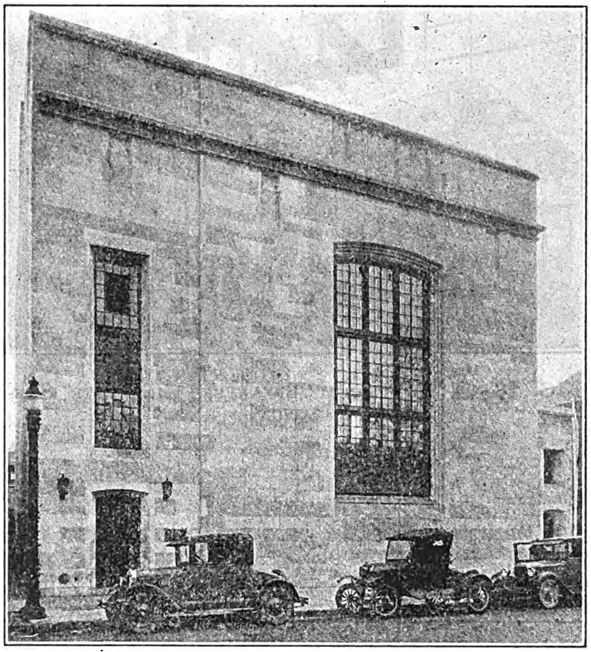


FIG. 26—EXTERIOR, CHARLOTTE SUBSTATION.

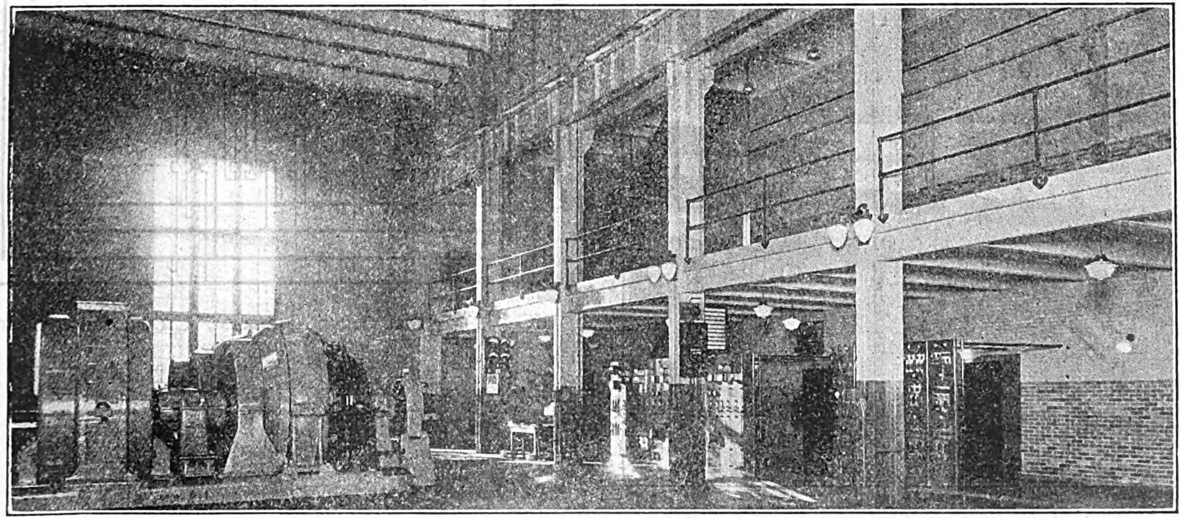


FIG. 27—GENERAL VIEW MACHINE FLOOR, CHARLOTTE SUBSTATION.

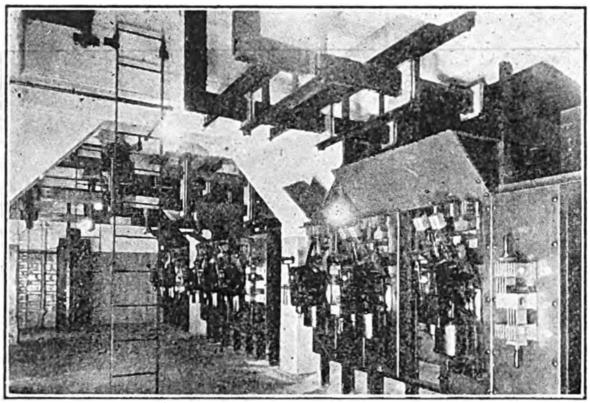


FIG. 28—D. C. CIRCUIT BREAKERS, CHARLOTTE SUBSTATION.

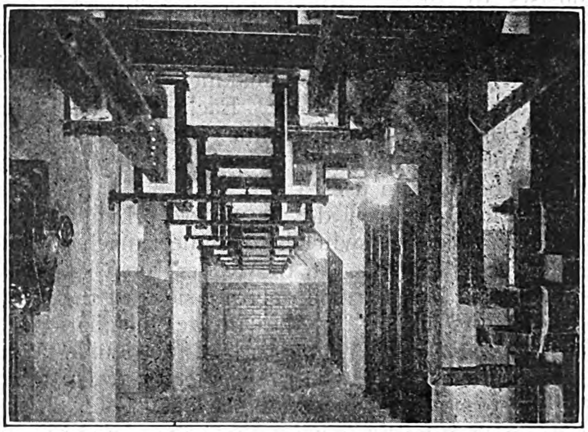


FIG. 29—D. C. BUS WORK, CHARLOTTE SUBSTATION.

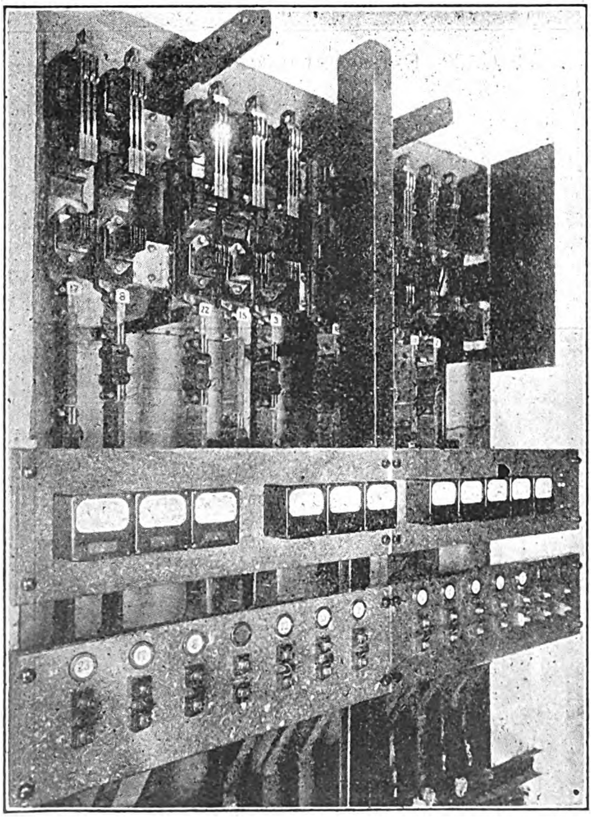


FIG. 30—D. C. FEEDERS, METERS AND SWITCHES, CHARLOTTE SUBSTATION.

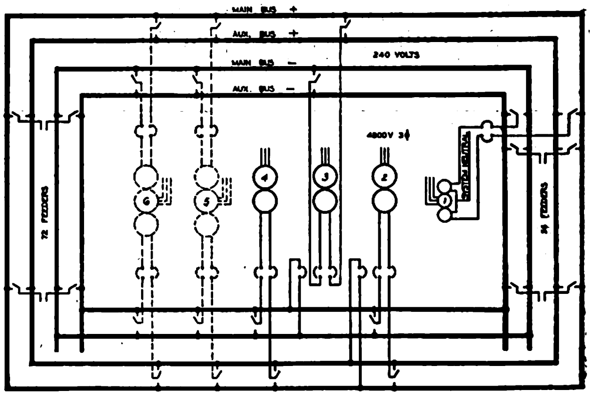

MAIN BUS +
AUX. BUS +
240 VOLTS
MAIN BUS –
AUX. BUS –
4800V 3ϕ
72 FEEDERS
6
5
4
3
2
1
FEEDERS

FIG. 31—SINGLE LINE DIAGRAM, CHARLOTTE SUBSTATION.

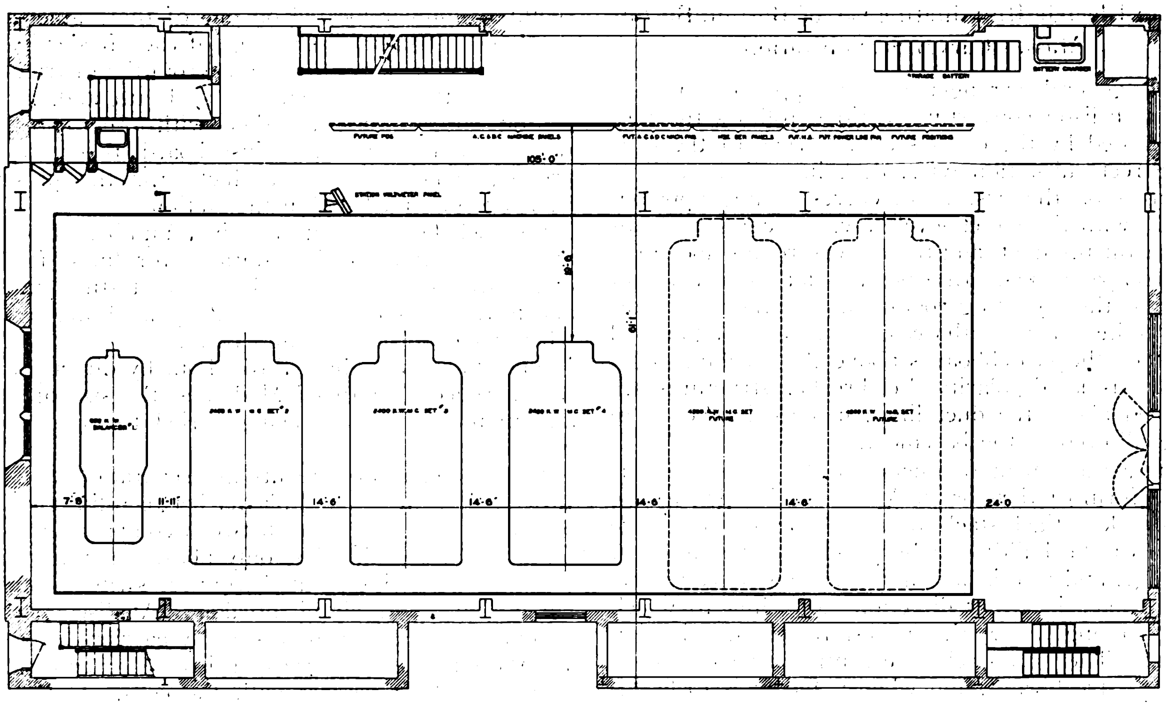

STORAGE BATTERY
BATTERY CHARGER
FUTURE POSITIONS
105'-0"
STATION VOLTMETER PANEL
61'-1"
600 K.W. BALANCER #1
2400 K.W. M.G. SET #2
2400 K.W. M.G. SET #3
2400 K.W. M.G. SET #4
4800 K.W. M.G. SET FUTURE
4800 K.W. M.G. SET FUTURE
7'-8"
11'-11"
14'-6"
14'-6"
14'-6"
14'-6"
24'-0"

FIG. 32—PLAN, CHARLOTTE SUBSTATION.

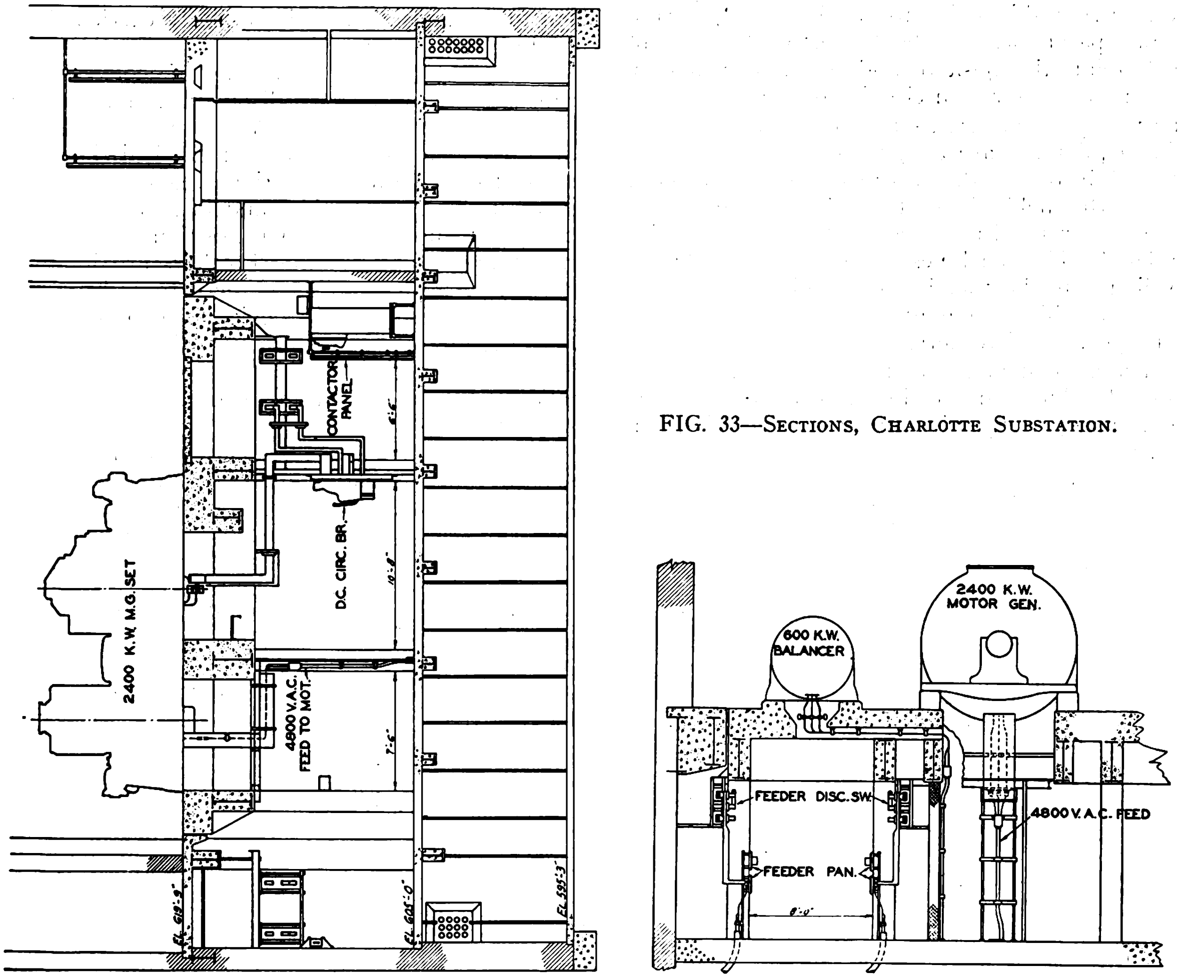

2400 K.W. M.G. SET
CONTACTOR PANEL
6'-6"
D.C. CIRC. BR.
10'-8"
4800 V.A.C. FEED TO MOT.
7'-6"
EL. 619'-9"
EL. 605'-0"
EL. 595'-3"
600 K.W. BALANCER
2400 K.W. MOTOR GEN.
FEEDER DISC. SW.
FEEDER PAN.
4800 V.A.C. FEED
8'-0"

FIG. 33—SECTIONS, CHARLOTTE SUBSTATION.

Edison Electric Illuminating Co. of Boston, Boston, Mass.—Carver St. Substation

The general arrangement of apparatus in the Boston Edison converting stations follows the idea represented by the cross sectional view of the Carver Street substation, viz.: duct lines in basement; machines on the first floor, corresponding approximately with the street level; a-c. switching and bus compartments next, and the battery rooms above the a-c. compartments. In case the lot area will not allow of the operating room being on the first floor, as is quite generally the case, there is an additional floor for the switchboards above the machine room and the isolated-polarity d-c. breaker structures are installed above the duct lines, increased head room being allowed in the basement.

The arrangement of ducts for the d-c. feeders is in the form of tiers or stacks, each of which is two ducts wide. Each stack of ducts is carried the entire length of the building, when each end has a street frontage, and in this way a feeder may leave its circuit breaker in either direction, according to which street routing will work out best for the distribution system. The duct stacks are continuous from street vault to street vault, and when a feeder is to be installed, the stack is broken into at the duct to be occupied, just below the breaker assigned to the new feeder. From this point to the bus the polarities are kept separate, leaving the "D sector" leaded cable by a Y-joint, the positive and negative cables are each carried to their own circuit breakers.

The rotary converter, its transformer and the a-c. starting equipment are all grouped on the machine floor, and below in the basement are the machine breakers, the field rheostats and the transformer blowers, all grouped near the machine to which they are related. The machines are cut into the bus so as to distribute their loads with a minimum of copper, each machine being grouped with its approximate proportion of feeders.

Both a-c. main and transfer buses and the high and low d-c. buses are sectionalized at intervals and the a-c. buses are ringed. Copper runs of high density current are consistently short; the battery runs, considered more or less emergency when called upon to carry full density, are the exception.

An auxiliary power bus is carried near the d-c. switchboard, and sometimes on entirely separate panels, for supplying station light and power and the converter field energy. The sources of supply for this bus are carefully chosen, with a view to minimum interruption. All pilot and indicating lamps are supplied from the auxiliary power board but from a separate bus fed from the control battery.

On the benchboard is a pressure wheel, whereby a rotating arm connects to the voltmeter whatever d-c. feeder is desired by revolving the pointer to the required number located on one of the segments of the wheel. To read the voltage of each feeder in this manner a pilot wire is brought from the distribution center of the feeder within its sheath and, at the station end, carried together with other pressure wires to a pressure wire fuse board, thence to the pressure wheel. Separate ducts for the pressure leads are provided within the station.

On each floor, and usually in a number of places, are located fault testing stations for lines, feeders or apparatus. Phasing and polarity testing stations and testing potential for laboratory work are located wherever conditions require them.

The station is lighted throughout by direct illumination reflected with RLM domes, the size of units and mounting heights being varied to give proper intensities.

In the a-c. compartments are separation walls of expanded metal lath and plaster between line and line or line and machine, and between compartments are 6-in. concrete walls. The only phase separation outside of air spacing is at disconnect switches, fuses, bus and in the oil circuit breaker. At disconnecting switches and fuses, asbestos ebony barriers are used, and the bus itself is carried in isolated concrete construction. Transversely with the cells, at intervals of every half dozen groups, are fire walls of 4 or 6-in. concrete; the bus is carried through this in porcelain tubes, and all cable is similarly carried through the longitudinal walls.

Both a-c. and d-c. starting of converters are utilized at many Boston Edison substations, although a-c. is becoming standard. The star-delta starting is quicker and more satisfactory; brush lifting control is interlocked with the starting breaker to insure the up position when starting, and interlocked with d-c. breakers to insure the down position when converting. Starting and running breakers are interlocked and timed by a time-delay relay to insure smooth starting. An additional device is employed where both a-c. and d-c. starting are available on one machine to allow d-c. starting and closing of running breaker without the routine of operating the starting breaker first.

Generally, all converting stations operate on 13,-800-volt lines radiating direct from the generating station, the lines being equipped at both ends with overload relays. Lines looped through substations have overload protection on leaving and reverse energy protection on incoming ends.

Fire protection is thoroughly covered by systematic mounting of fire extinguishers on distinctively painted metal backgrounds, sand pails with fiber scoops, and a very thorough isolation of portions of the equipment. The stairways are entirely inclosed in brick walls, all doors swing out of apparatus rooms, and there are exits to the street and roof at both the front and the rear of the substation.

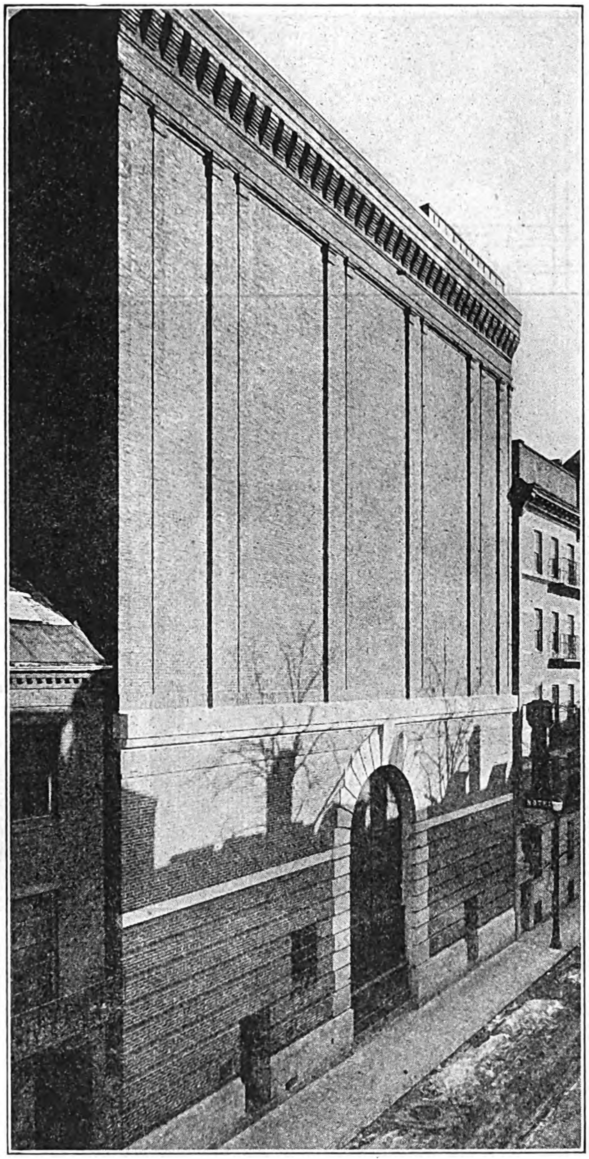


FIG. 34—EXTERIOR, CARVER ST. SUBSTATION.

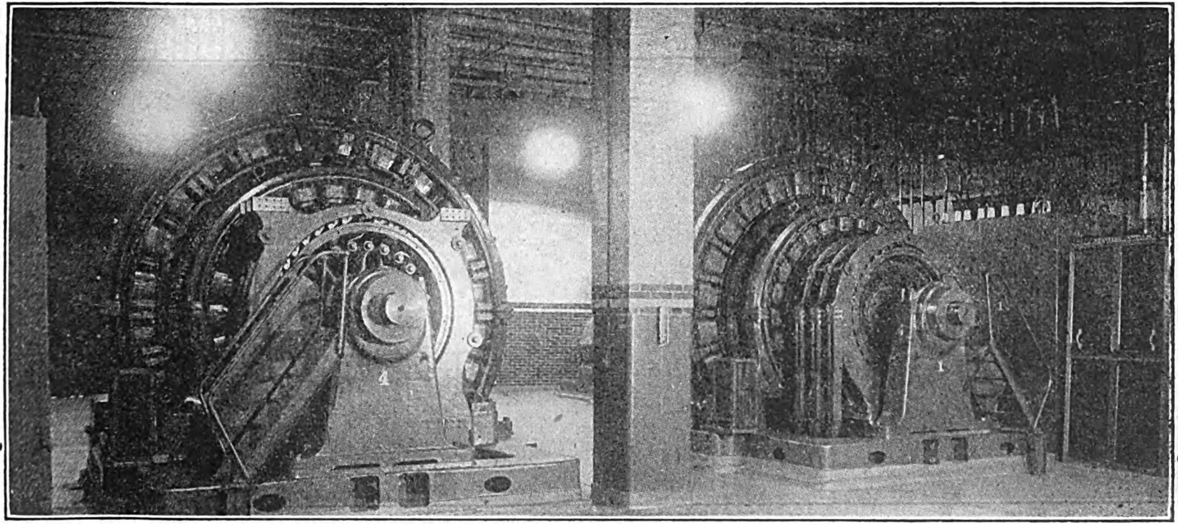


FIG. 35—MACHINE ROOM, CARVER ST. SUBSTATION.

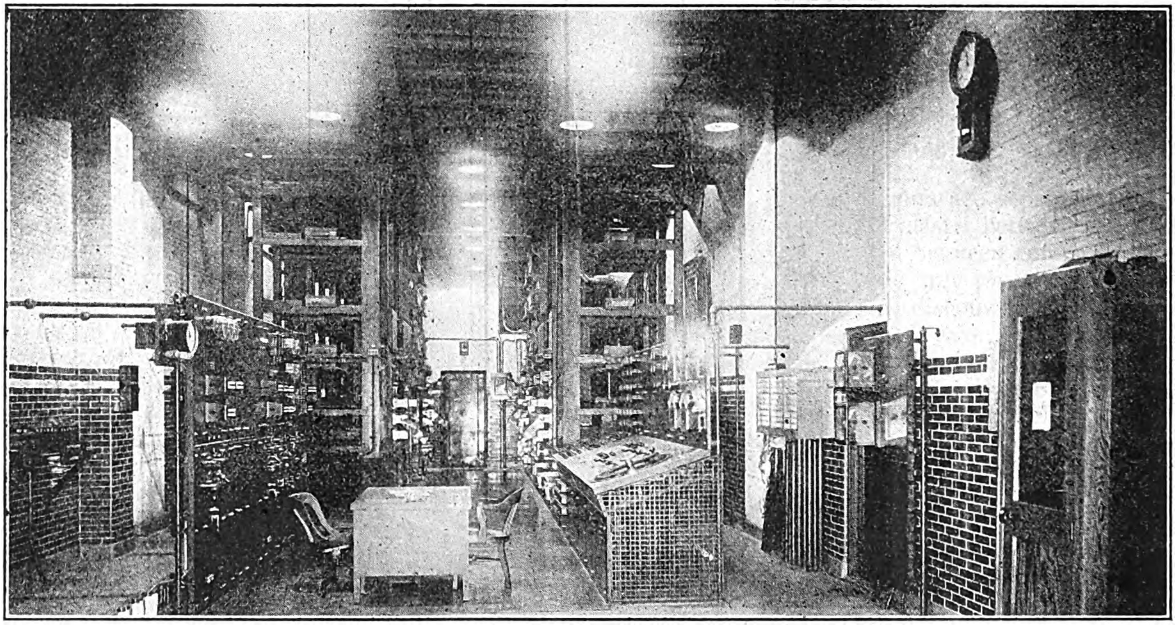


FIG. 36—OPERATING ROOM, CARVER ST. SUBSTATION.

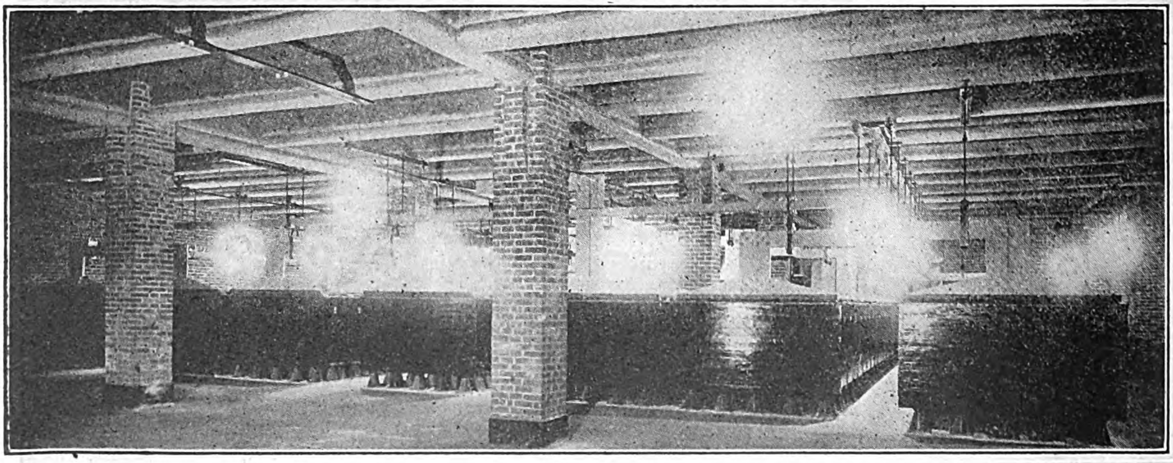


FIG. 37—BATTERY NO. 1, CARVER ST. SUBSTATION.

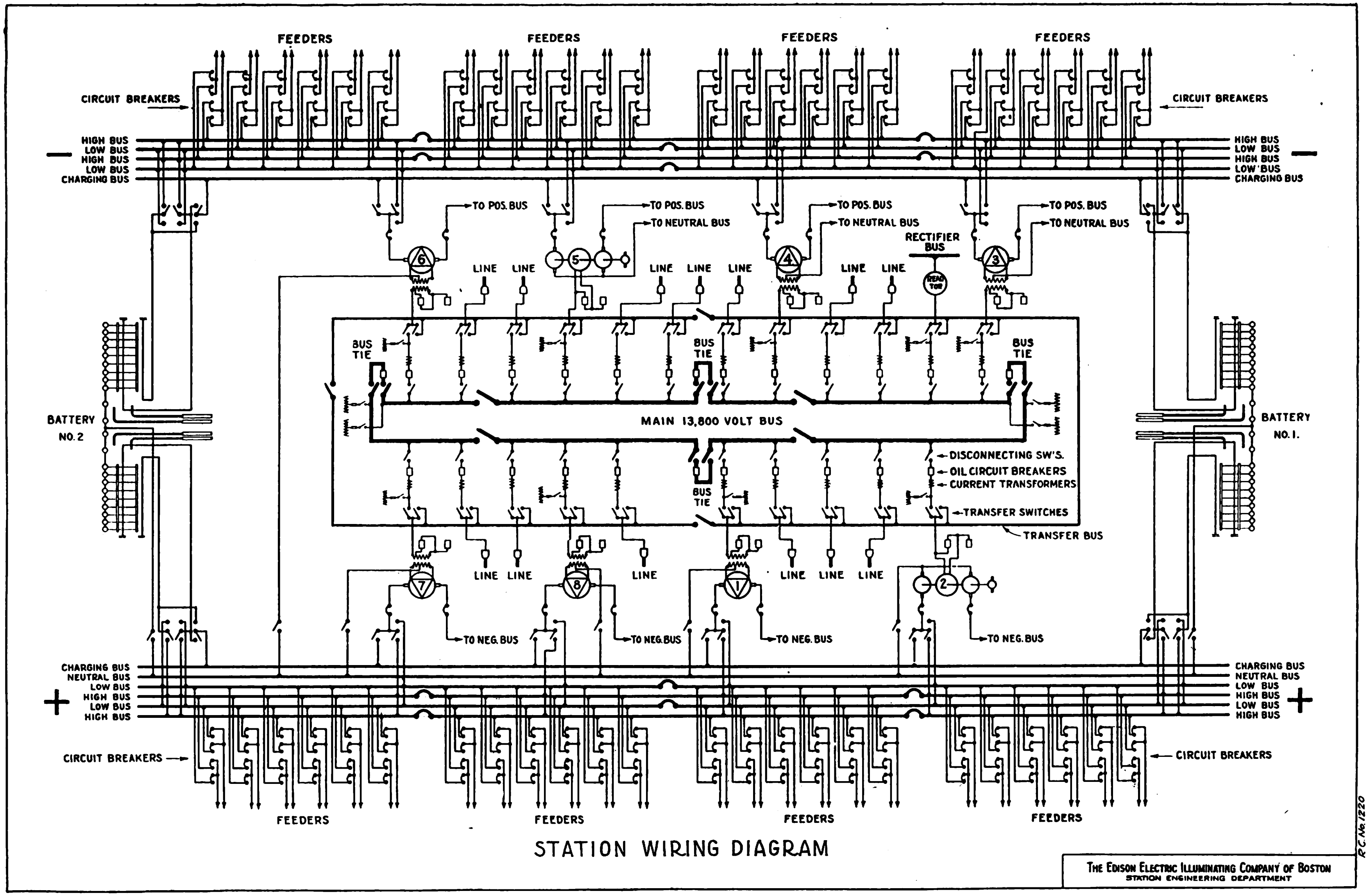

FEEDERS
FEEDERS
FEEDERS
FEEDERS
CIRCUIT BREAKERS
CIRCUIT BREAKERS
HIGH BUS
LOW BUS
HIGH BUS
LOW BUS
CHARGING BUS
—
TO POS. BUS
TO POS. BUS
TO NEUTRAL BUS
TO POS. BUS
TO NEUTRAL BUS
TO POS. BUS
TO NEUTRAL BUS
RECTIFIER BUS
6
5
4
3
LINE
LINE
LINE
LINE
LINE
LINE
LINE
BUS TIE
BUS TIE
BUS TIE
BUS TIE
MAIN 13,800 VOLT BUS
BATTERY NO. 2
BATTERY NO. 1.
DISCONNECTING SW'S.
OIL CIRCUIT BREAKERS
CURRENT TRANSFORMERS
TRANSFER SWITCHES
TRANSFER BUS
LINE
LINE
LINE
LINE
LINE
LINE
7
8
1
2
TO NEG. BUS
TO NEG. BUS
TO NEG. BUS
TO NEG. BUS
CHARGING BUS
NEUTRAL BUS
LOW BUS
HIGH BUS
LOW BUS
HIGH BUS
+
CIRCUIT BREAKERS
CIRCUIT BREAKERS
FEEDERS
FEEDERS
FEEDERS
FEEDERS
STATION WIRING DIAGRAM
THE EDISON ELECTRIC ILLUMINATING COMPANY OF BOSTON
STATION ENGINEERING DEPARTMENT
R.C. No. 1220

FIG. 38—Single Line Diagram, Carver St. Substation.

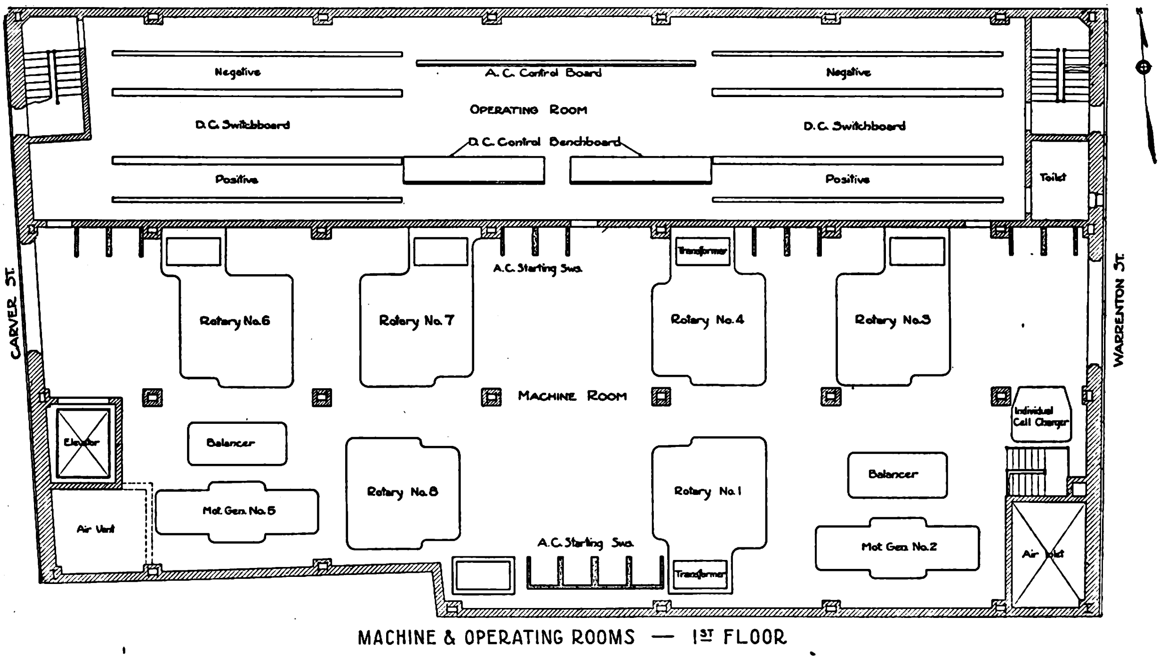

Negative
A. C. Control Board
Negative
Operating Room
D. C. Switchboard
D. C. Switchboard
D. C. Control Benchboard
Positive
Positive
Toilet
Carver St.
Warrenton St.
Transformer
A. C. Starting Sws.
Rotary No. 6
Rotary No. 7
Rotary No. 4
Rotary No. 3
Machine Room
Individual Cell Charger
Elevator
Balancer
Balancer
Rotary No. 8
Rotary No. 1
Air Vent
Mot. Gen. No. 5
A. C. Starting Sws.
Transformer
Mot. Gen. No. 2
Air Vent
MACHINE & OPERATING ROOMS — 1ST FLOOR

FIG. 39—PLAN, FIRST FLOOR, CARVER ST. SUBSTATION.

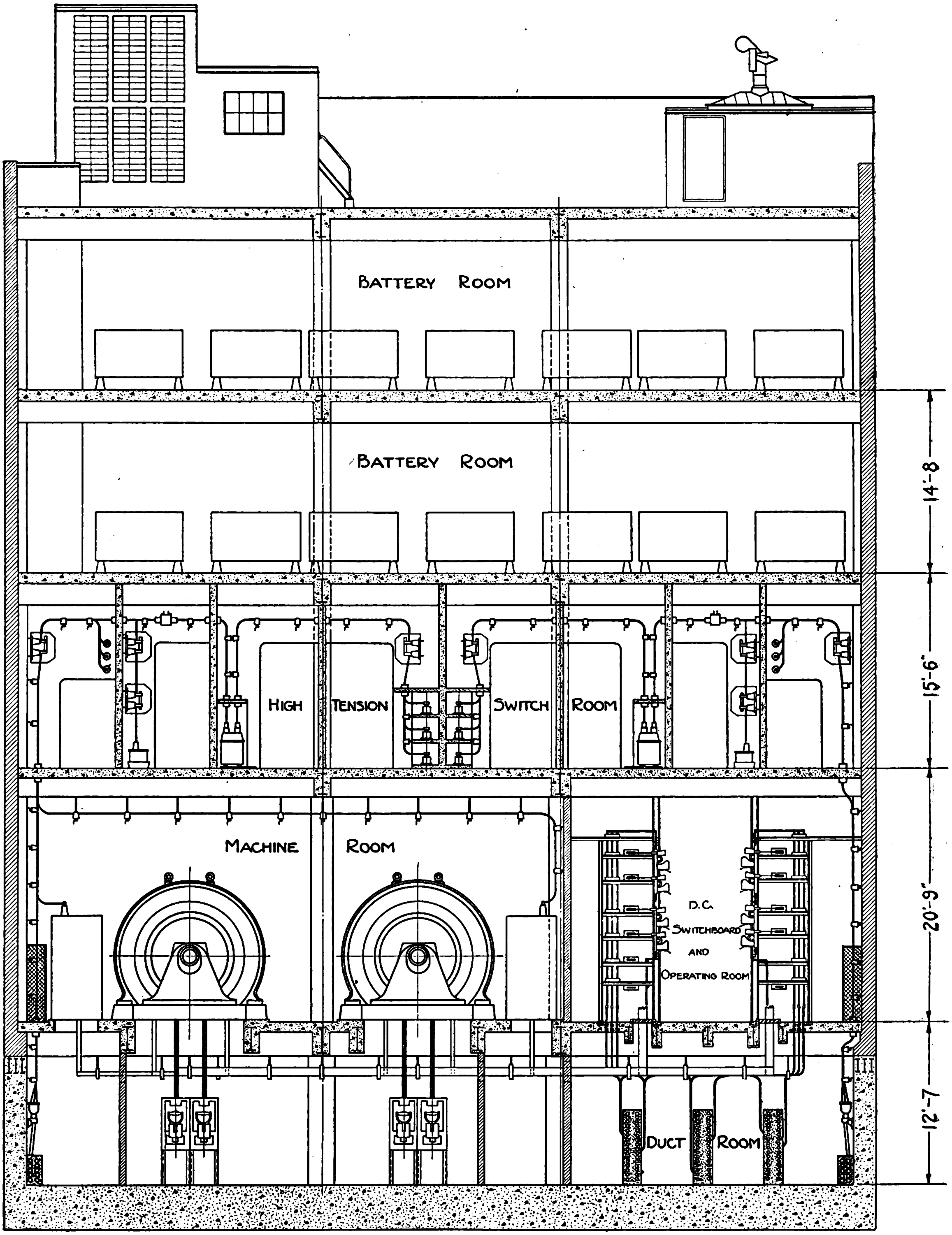

BATTERY ROOM
BATTERY ROOM
HIGH TENSION SWITCH ROOM
MACHINE ROOM
D.C. SWITCHBOARD AND OPERATING ROOM
DUCT ROOM
14'-8"
15'-6"
20'-9"
12'-7"
CROSS SECTION — CARVER ST. STATION

FIG. 40—SECTION, CARVER ST. SUBSTATION.

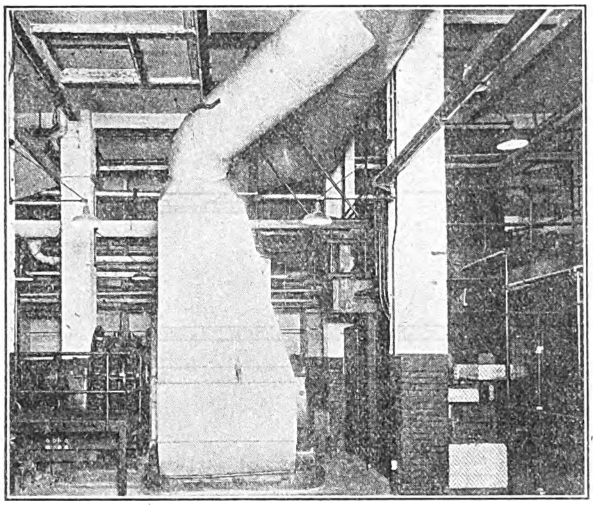


FIG. 41—3900-Kw. Synchronous Converter Installation—Stephenson Bldg. Substation.

The Milwaukee Electric Railway & Light Co., Milwaukee, Wis.—Stephenson Building Substation

This substation is located in the basement of one of the downtown office buildings and serves a portion of the 125/250-volt d-c. Edison system. The station has space for an ultimate capacity of four rotary converters, but only two are installed at present, one 2775-kw., manually operated machine, and one 3900-kw., semi-automatic converter with water-cooled load-limiting resistor. The latter machine is shown on accompanying drawings and photographs.

The 4200-kv-a. transformer is air cooled, and the rotary converter is kept cool by means of a sheet iron inclosure leading to a stack running to the roof of the building, which carries off the hot air from the machine before it can recirculate about the room. Cool air is supplied to the machine and transformer through openings in the sidewalk.

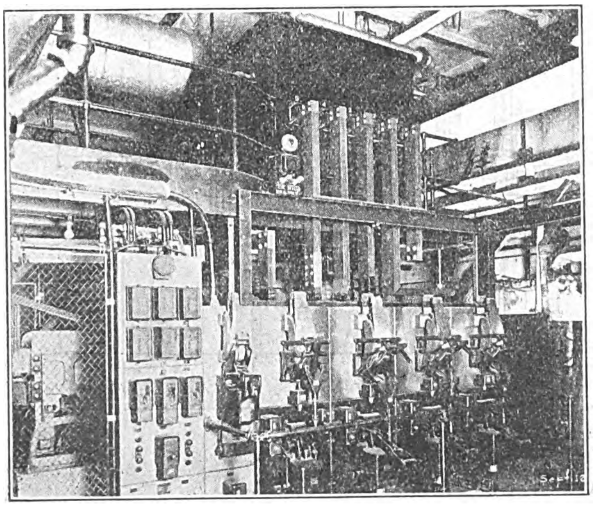


FIG. 42—Load Limiting Resistor Installation, Stephenson Bldg. Substation.

Water-cooled resistors are installed in the negative lead and limit the load on the machine to 150 per cent of its capacity. This resistance is cut in and out of the circuit automatically by means of circuit breakers.

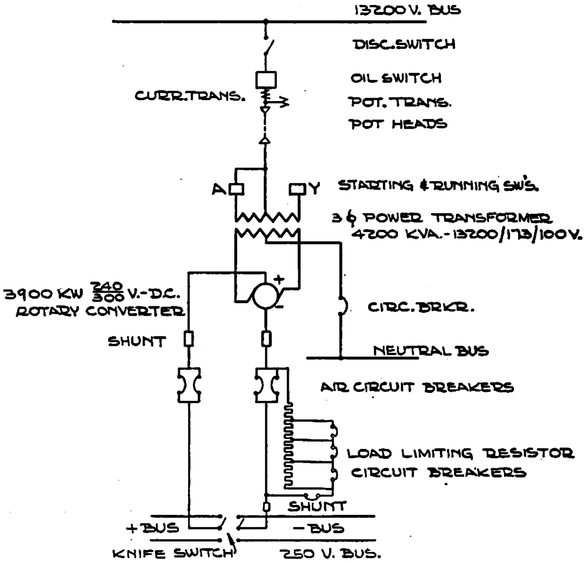

13200 V. BUS
DISC. SWITCH
OIL SWITCH
CURR. TRANS.
POT. TRANS.
POT HEADS
A
Y
STARTING & RUNNING SW'S.
3 ϕ POWER TRANSFORMER
4200 KVA.-13200/173/100 V.
3900 KW 240/300 V.-D.C.
ROTARY CONVERTER
+
CIRC. BRKR.
SHUNT
NEUTRAL BUS
AIR CIRCUIT BREAKERS
LOAD LIMITING RESISTOR
CIRCUIT BREAKERS
SHUNT
+BUS
-BUS
KNIFE SWITCH
250 V. BUS.

FIG. 43—Single Line Diagram, Stephenson Bldg. Substation.

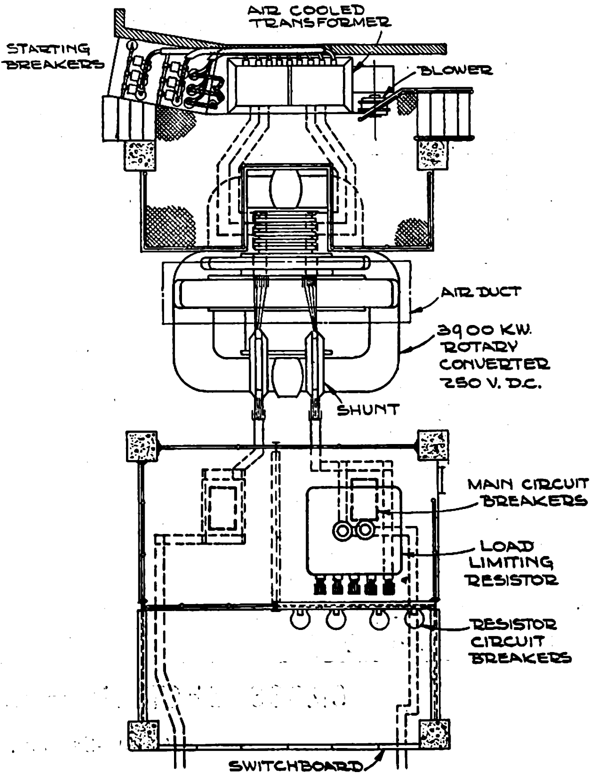

AIR COOLED TRANSFORMER
STARTING BREAKERS
BLOWER
AIR DUCT
3900 KW. ROTARY CONVERTER 250 V. D.C.
SHUNT
MAIN CIRCUIT BREAKERS
LOAD LIMITING RESISTOR
RESISTOR CIRCUIT BREAKERS
SWITCHBOARD

FIG. 44—Plan, Stephenson Bldg. Substation.

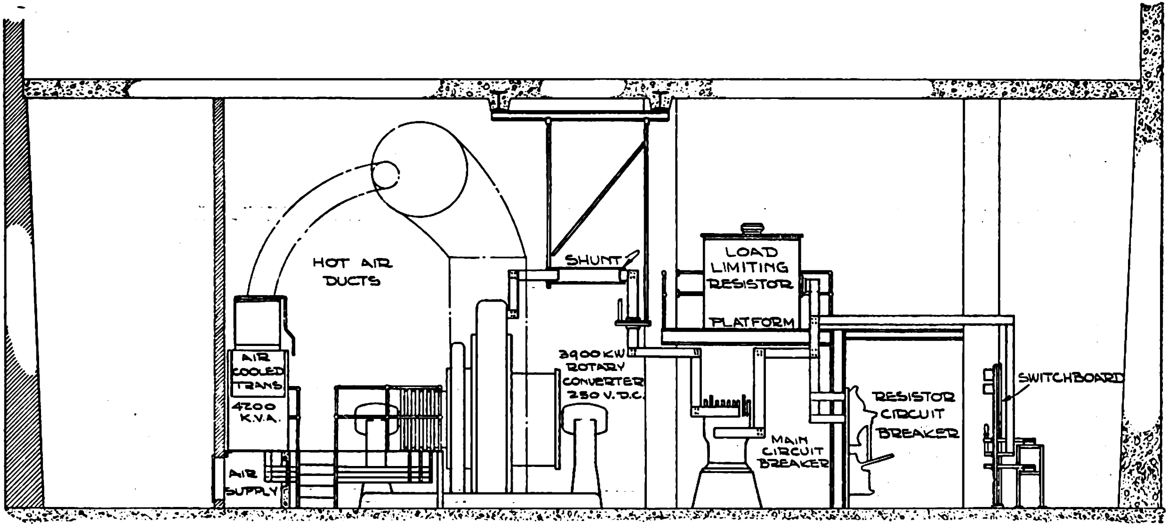

HOT AIR DUCTS
SHUNT
LOAD LIMITING RESISTOR
PLATFORM
AIR COOLED TRANS
4200 K.V.A.
AIR SUPPLY
3900 KW ROTARY CONVERTER 250 V.D.C.
MAIN CIRCUIT BREAKER
RESISTOR CIRCUIT BREAKER
SWITCHBOARD

FIG. 45—Section, Stephenson Bldg. Substation.

New Orleans Public Service, Inc., New Orleans, La.—Dryades Substation

This substation, located in the commercial district, receives its power from the main generating station through six 6600-volt underground feeders. This power is delivered to the following loads:

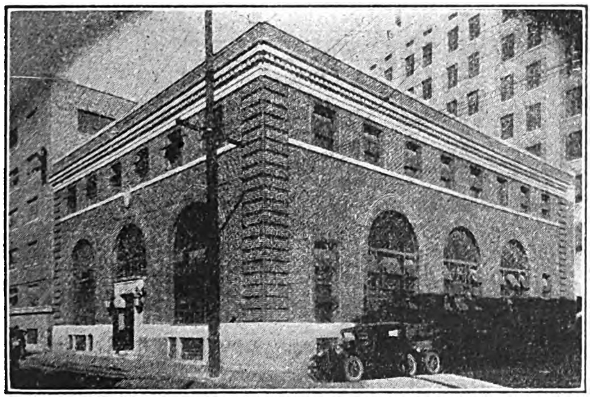


FIG. 46—Exterior, Dryades Substation.

(a) Edison 220-volt d-c. system.
(b) 600-volt railway system.
(c) 4000-volt commercial feeders.
(d) Mercury-arc rectifiers and Whiteway circuits for street lighting.

The conversion apparatus for the Edison load consists of two motor-generator sets supplied directly from the 6600-volt bus and one 6-phase rotary converter connected through transformers to the 6600-volt bus. These machines feed into the Edison 220-volt, 3-wire system through thirty-five d-c. feeders.

Two 6-phase rotary converters connected through transformers to the 6600-volt bus feed through seventeen feeders into the 600-volt, d-c. railway system.

From the 6600-volt bus two banks of transformers supply a 4000-volt bus, from which power is delivered to 4000-volt feeders for local distribution, and three Whiteway transformers and circuits for street lighting.

Power is supplied to twelve street lighting circuits from mercury-arc rectifiers connected to the 6600-volt bus.

All Edison feeders are entirely underground. All feeders are brought into the station underground.

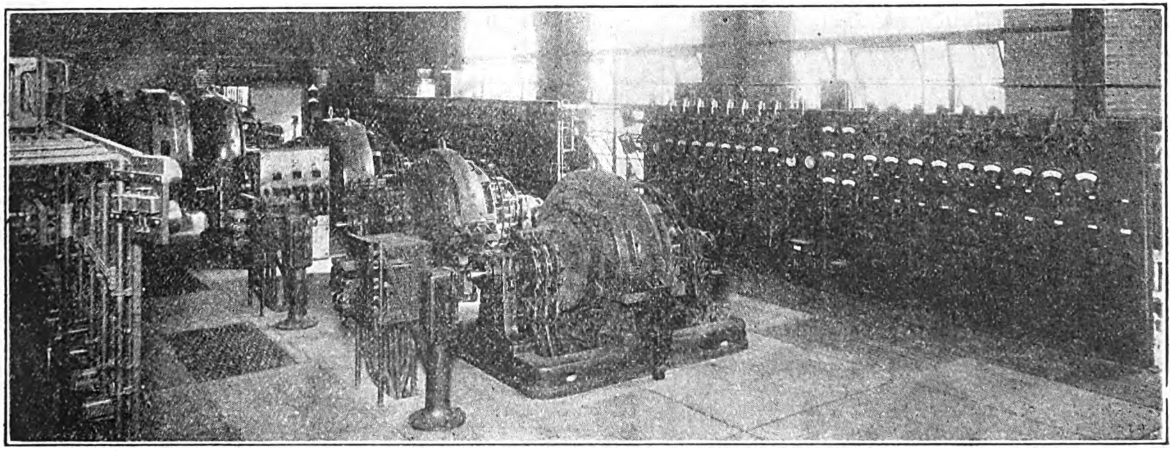
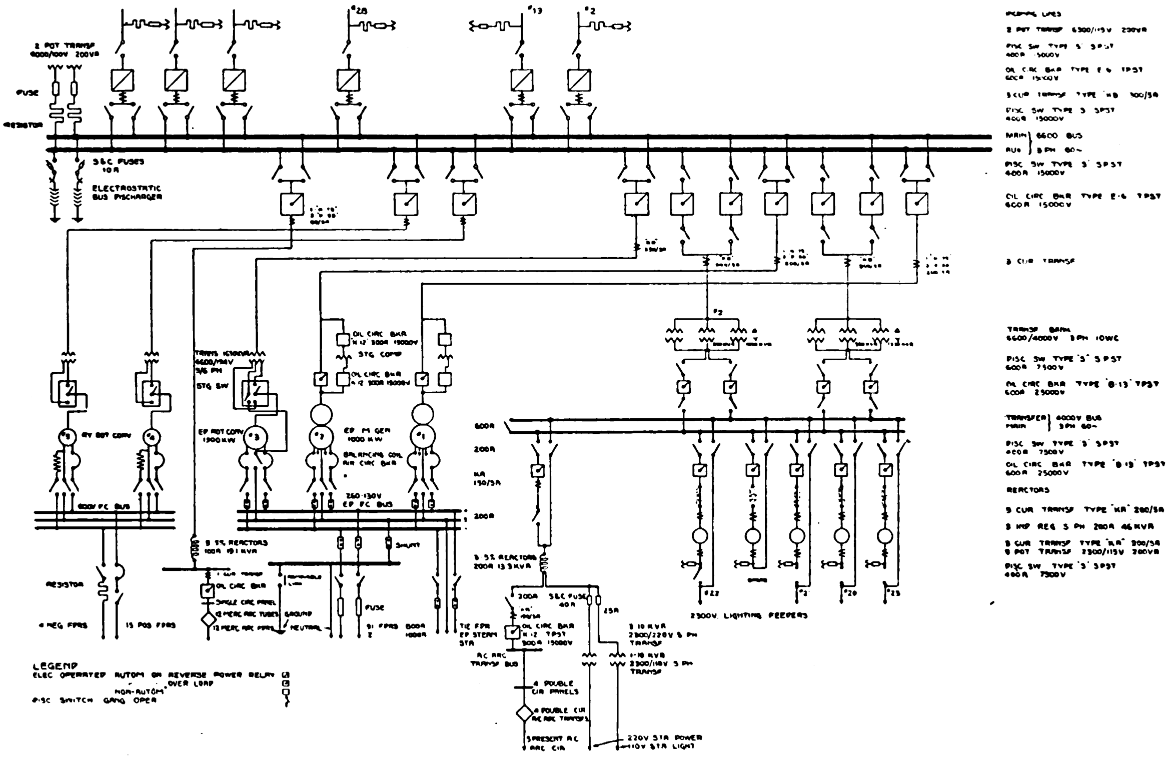
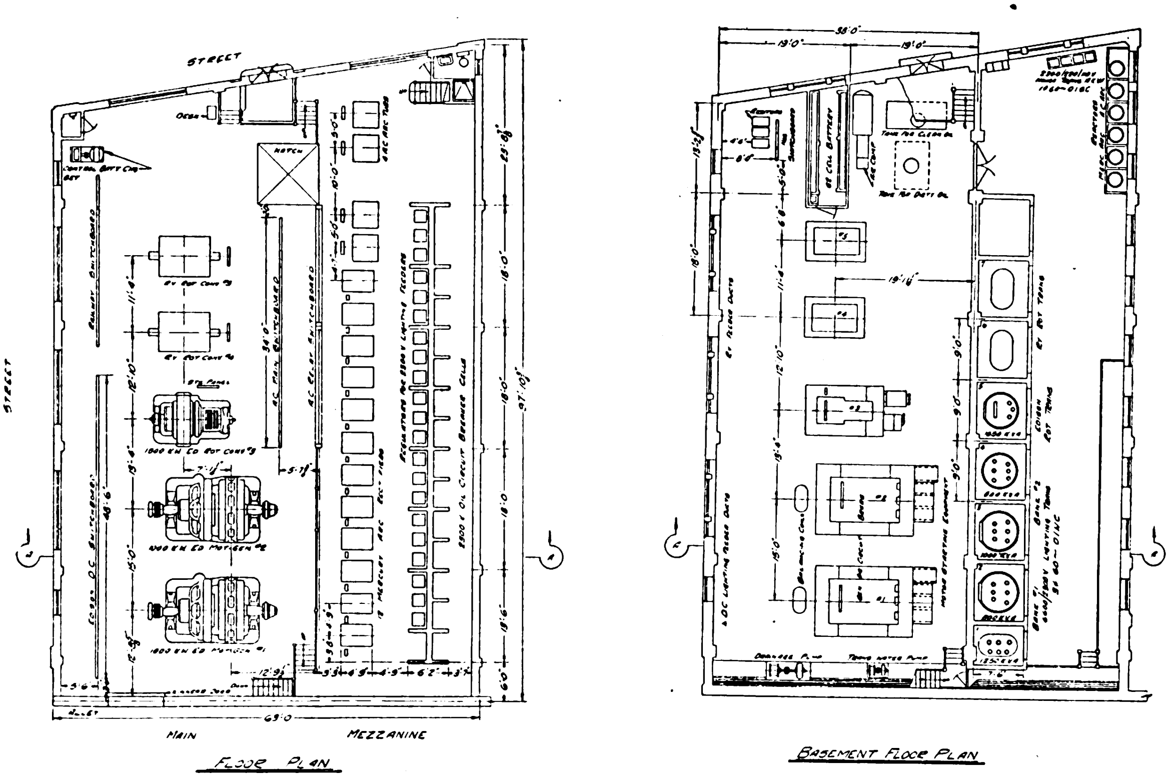


FIG. 47—Railway and Edison Machines and Switchboard, Dryades Substation.



INCOMING LINES
2 POT TRANSF 6300/115V 200VA
DISC SW TYPE 'S' SPST
400A 15000V
OIL CIRC BKR TYPE E-6 TPST
600A 15000V
3 CUR TRANSF TYPE HB 300/5A
DISC SW TYPE S SPST
400A 15000V
MAIN 6600 BUS
AUX 3 PH 60~
DISC SW TYPE 'S' SPST
400A 15000V
OIL CIRC BKR TYPE E-6 TPST
600A 15000V
3 CUR TRANSF
TRANSF BANK
6600/4000V 3 PH 10WC
DISC SW TYPE 'S' SPST
600A 7500V
OIL CIRC BKR TYPE 'B-13' TPST
600A 25000V
TRANSFER 4000V BUS
MAIN 3 PH 60~
DISC SW TYPE 'S' SPST
400A 7500V
OIL CIRC BKR TYPE 'B-13' TPST
600A 25000V
REACTORS
3 CUR TRANSF TYPE 'KR' 200/5A
3 IND REG 3 PH 200A 46 KVA
3 CUR TRANSF TYPE 'KR' 200/5A
3 POT TRANSF 2300/115V 200VA
DISC SW TYPE 'S' SPST
400A 7500V
2 POT TRANSF
6600/100V 200VA
FUSE
RESISTOR
S&C FUSES
10A
ELECTROSTATIC
BUS DISCHARGER
RY ROT CONV
EP ROT CONV
1500 KW
EP M GEN
1000 KW
BALANCING COIL
AIR CIRC BKR
600V RC BUS
250-130V
EP DC BUS
3 5% REACTORS
100A 19.1 KVA
3 5% REACTORS
200A 13.3 KVA
SHUNT
RESISTOR
FUSE
4 NEG FDRS
15 POS FDRS
OIL CIRC BKR
SINGLE CIRC PANEL
12 MERC ARC TUBES
12 MERC ARC FDRS
GROUND
NEUTRAL
TIE FDR
EP STERN STA
AC ARC TRANSF BUS
4 DOUBLE CIR PANELS
4 DOUBLE CIR AC ARC TRANSFS
5 PRESENT AC ARC CIR
200A S&C FUSE 40A
3-10 KVA
2300/220V 3 PH
TRANSF
1-10 KVA
2300/110V 3 PH
TRANSF
220V STA POWER
110V STA LIGHT
2300V LIGHTING FEEDERS
600A
200A
150/5A
LEGEND
ELEC OPERATED AUTOM OR REVERSE POWER RELAY
OVER LOAD
NON-AUTOM
DISC SWITCH GANG OPER

FIG. 48—SINGLE LINE DIAGRAM, DRYADES SUBSTATION.



STREET
STREET
HATCH
RY ROT CONV #3
RY ROT CONV #4
1500 KW EP ROT CONV #3
1000 KW EP MOTGEN #2
1000 KW EP MOTGEN #1
RAILWAY SWITCHBOARD
EDISON D.C. SWITCHBOARD
AC MAIN SWITCHBOARD
AC RELAY SWITCHBOARD
REGULATORS FOR 2300 V LIGHTING FEEDERS
12 MERCURY ARC RECTIFIERS
2300 V OIL CIRCUIT BREAKER CELLS
69'0"
97'10½"
MAIN
MEZZANINE
FLOOR PLAN
38'0"
19'0"
19'0"
RY FEEDER DUCTS
DC LIGHTING FEEDER DUCTS
CELL BATTERY
AIR COMP
RY ROT TRANS
EDISON ROT TRANS
BANK #2
2300 V LIGHTING TRANS
DRAINAGE PUMP
BASEMENT FLOOR PLAN

FIG. 49—PLANS, DRYADES SUBSTATION.

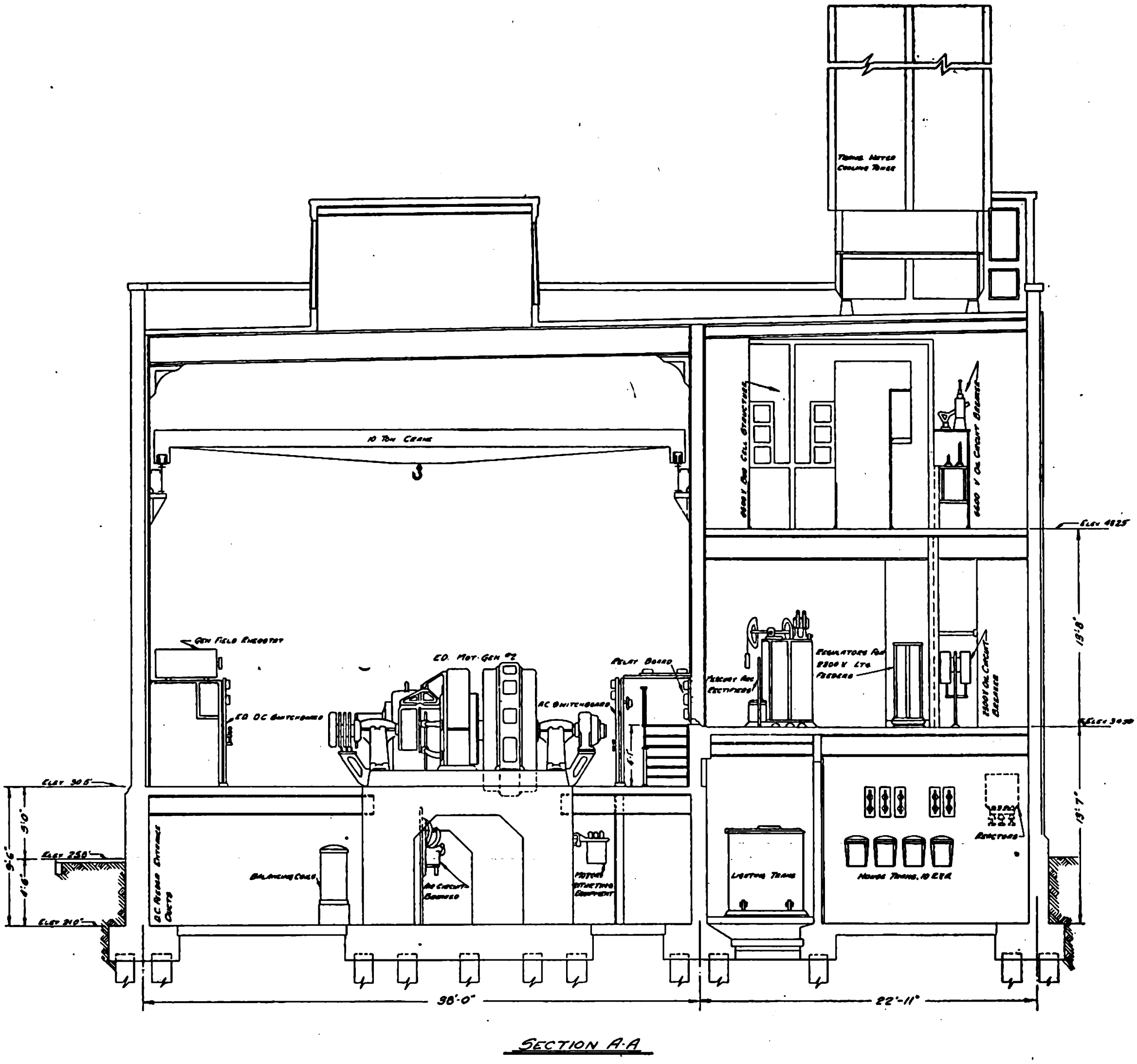

Cooling Tower
10 Ton Crane
Gen Field Rheostat
E.D. Mot-Gen #2
Relay Board
E.D. DC Switchboard
AC Switchboard
6'-1"
D.C. Feeder Entrance Ducts
Balancing Coils
AC Circuit Breaker
Motor Starting Equipment
6600 V Bus Cell Structures
6600 V Oil Circuit Breakers
Elev 48.25
Mercury Arc Rectifiers
Regulators for 2300 V Ltg Feeders
2300 V Oil Circuit Breakers
Elev 34.50
13'-8"
13'-7"
Lighting Trans
House Trans. 10 K.V.A.
Reactors
Elev 30.5'
Elev 25.0'
Elev 21.0'
9'-6"
5'-0"
4'-6"
38'-0"
22'-11"
SECTION A-A

FIG. 50—SECTION, DRYADES SUBSTATION.

The New York Edison Company, New York, N. Y. —East 32nd Street Substation

This substation typifies the construction and layout necessary in a substation built on small city lots, and yet giving ample street frontage for outlet of feeders and ducts.

The substation is built on three 25-ft. lots in the form of a "T," and has frontage on three streets. Each section of the "T" will ultimately be equipped with two 4200-kw. converters, the output of the converters leaving the station through feeders in the same section in which the converters are installed. The control room is located at the midpoint of the "T" and is remote from the rest of the apparatus.

Successful means were employed throughout the erection of the substation for the elimination of vibration and noise. Cork insulation was used between the substation and adjacent buildings. The rotary converter foundations are entirely separate from the main building, and the converters and transformers are inclosed in sheet steel housings. The air intake

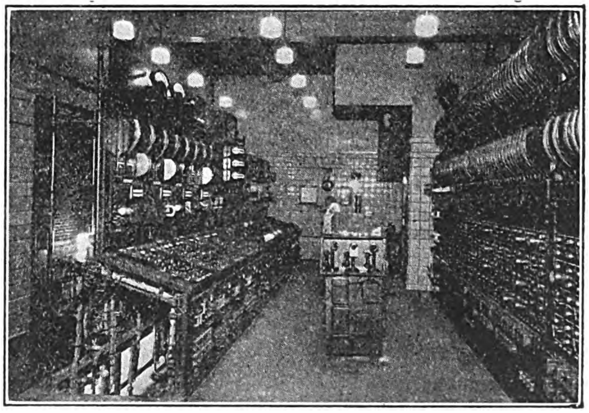


FIG. 51—BENCHBOARD AND D. C. FEEDER CONTROL BOARD, EAST 32ND ST. SUBSTATION.

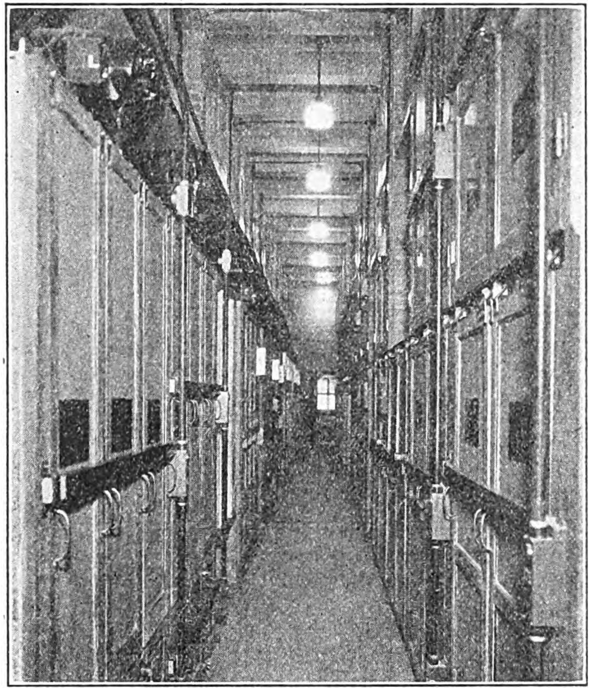


FIG. 52—HIGH VOLTAGE GALLERY SHOWING COMPARTMENT INTERLOCKS, EAST 32ND ST. SUBSTATION.

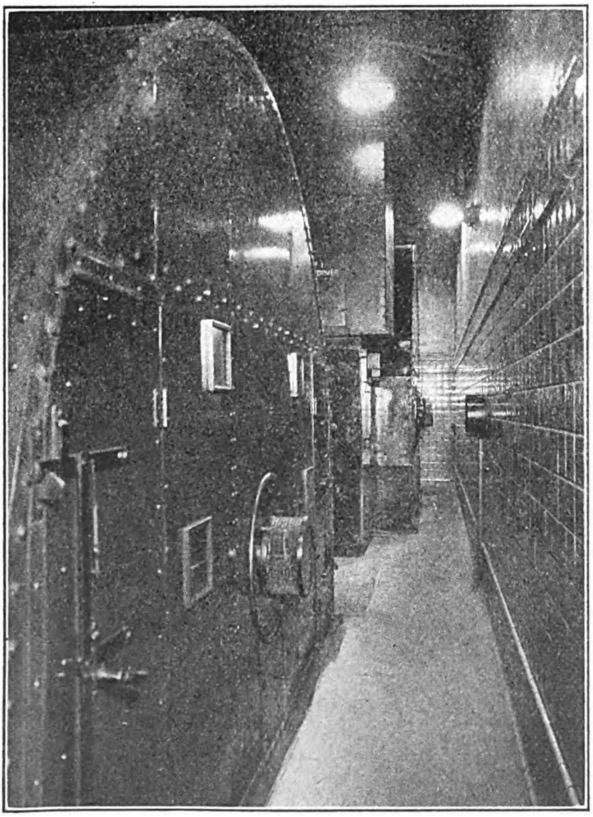


FIG. 53—SYNCHRONOUS CONVERTER FLOOR—EAST 32ND ST. SUBSTATION.

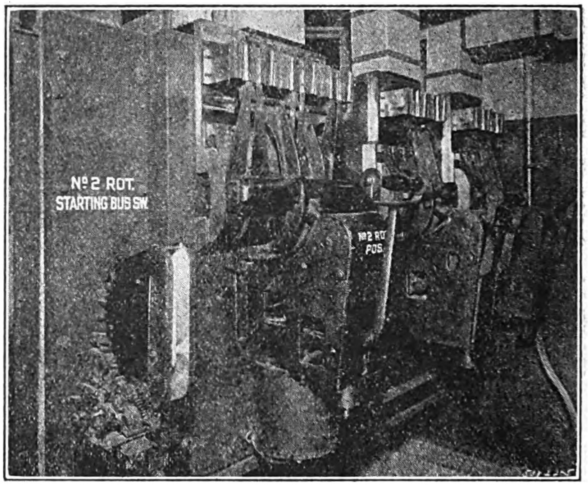


FIG. 54—CONVERTER CIRCUIT BREAKERS AND BUSES UNDER CONVERTER PIT, EAST 32ND ST. SUBSTATION.

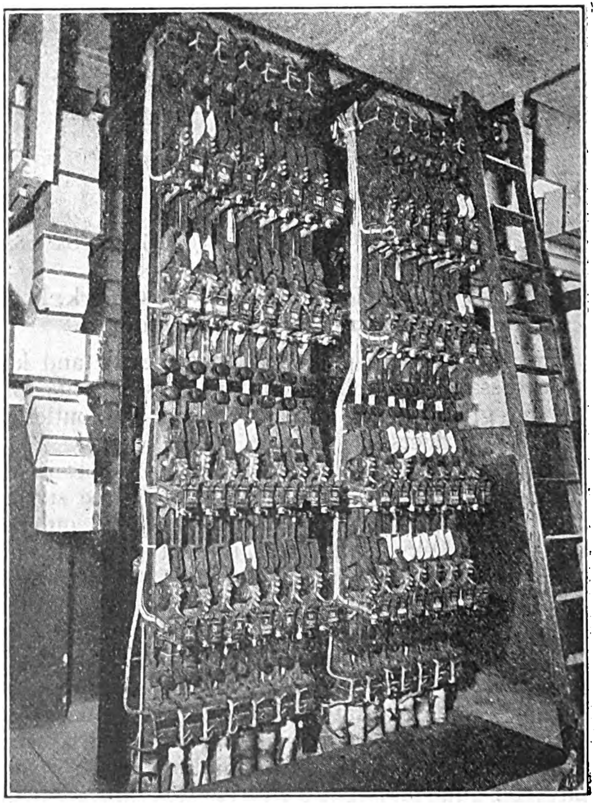


FIG. 55—REMOTE CONTROL D. C. FEEDER CIRCUIT BREAKERS IN BASEMENT, EAST 32ND ST. SUBSTATION.

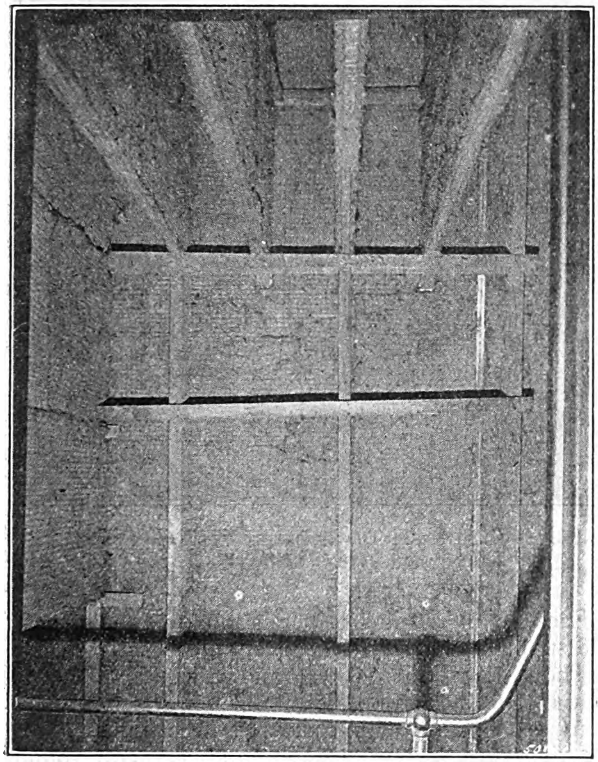


FIG. 56—METHOD USED FOR PADDING AND SOUND-PROOFING AIR DUCTS, EAST 32ND ST. SUBSTATION.

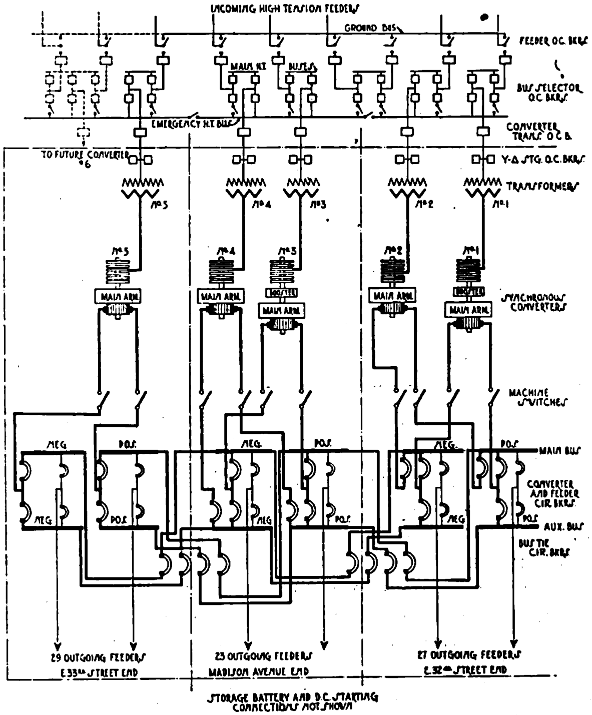

INCOMING HIGH TENSION FEEDERS
GROUND BUS
FEEDER O.C. BKRS.
MAIN H.T. BUSES
BUS SELECTOR O.C. BKRS.
EMERGENCY H.T. BUS
CONVERTER TRANS. O.C.B.
TO FUTURE CONVERTER #6
Y-Δ STG. O.C. BKRS.
TRANSFORMERS
No 5
No 4
No 3
No 2
No 1
MAIN ARM.
BOOSTER
SYNCHRONOUS CONVERTERS
MACHINE SWITCHES
NEG.
POS.
MAIN BUS
CONVERTER AND FEEDER CIR. BKRS.
AUX. BUS
BUS TIE CIR. BKRS.
29 OUTGOING FEEDERS
E. 33rd STREET END
23 OUTGOING FEEDERS
MADISON AVENUE END
27 OUTGOING FEEDERS
E. 32nd STREET END
STORAGE BATTERY AND D.C. STARTING CONNECTIONS NOT SHOWN

FIG. 57—SINGLE LINE DIAGRAM, EAST 32ND ST. SUBSTATION.

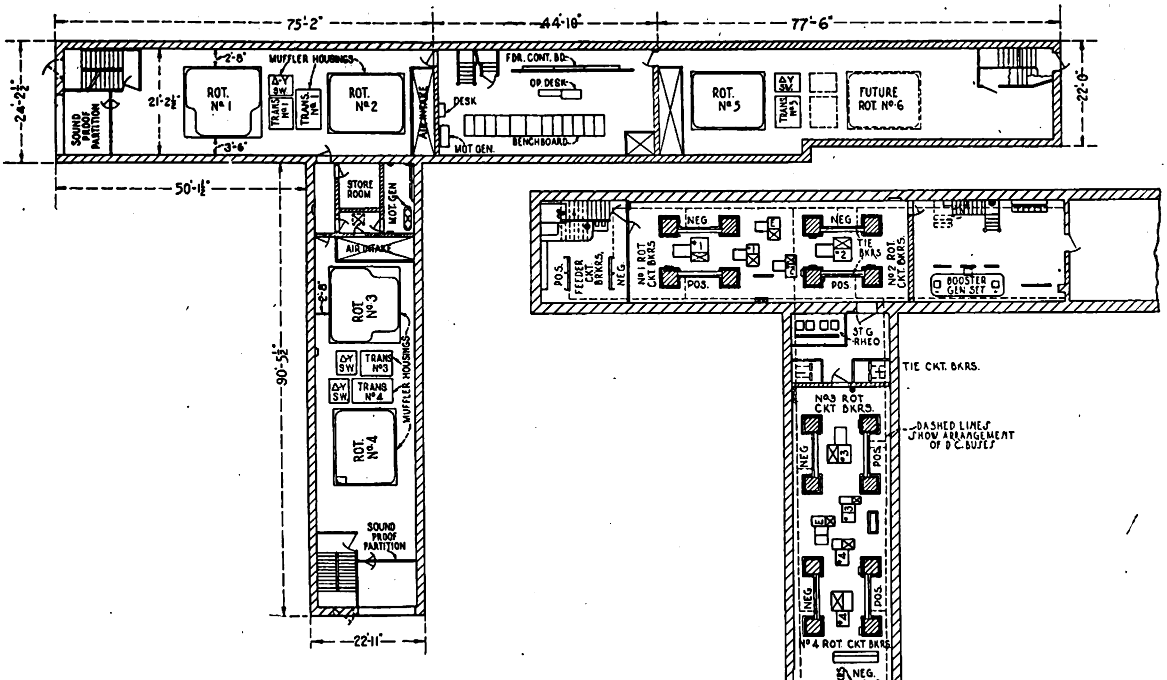

75'-2"
44'-10"
77'-6"
24'-2½"
22'-0"
21'-2½"
2'-8"
3'-6"
50'-1½"
90'-5½"
22'-11"
2'-8"
SOUND PROOF PARTITION
MUFFLER HOUSINGS
ROT. No 1
Δ-Y SW.
TRANS. No 1
ROT. No 2
AIR INTAKE
DESK
MOT. GEN.
FDR. CONT. BD.
OP. DESK
BENCHBOARD
ROT. No 5
ΔY SW.
TRANS. No 5
FUTURE ROT. No 6
STORE ROOM
MOT. GEN.
ROT. No 3
ΔY SW
TRANS No 3
TRANS No 4
ROT. No 4
POS.
FEEDER CKT. BKRS.
NEG.
No 1 ROT. CKT. BKRS.
No 2 ROT. CKT. BKRS.
TIE BKRS.
BOOSTER GEN. SET
STG RHEO
TIE CKT. BKRS.
No 3 ROT CKT BKRS.
DASHED LINES SHOW ARRANGEMENT OF D.C. BUSES
No 4 ROT. CKT BKRS.
FDR. CKT. BKRS.

FIG. 58—PLAN VIEWS, EAST 32ND ST. SUBSTATION.

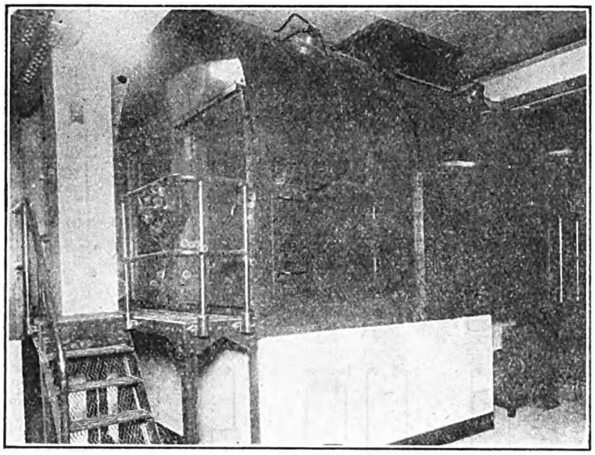


FIG. 59—2100-Kw. Synchronous Converter, Madison Ave. Substation.

and outlet ducts are padded, and a special system of padded louvres is effectively used in the fresh air inlet.

The incoming high-tension feeders and the converter transformers have only overload relay protection. The direct-current end of the machines has overspeed protection but no overload or reverse-power relays.

The electrically operated d-c. feeder circuit breakers are located near the street entrance of the feeders, thereby eliminating all station runs for both feeders and converters. They are arranged to protect from cable faults only. This is accomplished by connecting their trip coils through a control wire in the feeder cable to the trip coils of the junction box breakers. A cable fault thereby simultaneously opens the feeder at both ends, and notifies the operator through an annunciator system and horn.

The New York Edison Co., New York, N. Y.—Madison Avenue Substation

This substation is installed in the basement of a large office building in a midtown business district. Due to a very low ceiling, special equipment, consisting of a large capacity sidewalk lift and a special cradle was necessary for handling the substation apparatus.

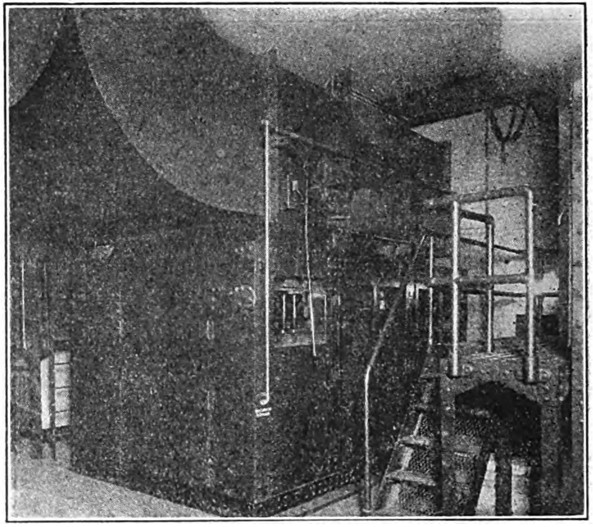


FIG. 60—4750-Kv-a. Transformer Installation, Madison Ave. Substation.

Each air blast transformer is mounted on its side, and supplies two 2100-kw. converters.

The elimination of noise and vibration being essential, the substation floor and converter foundations are padded with cork and the inlet air duct, entering into a courtyard, is equipped with soundproofing louvres. All air from the rotary converter housings and transformers discharges into a hung ceiling which exhausts into a chimney running to the top of the building.

The transformer secondaries consist of two 6-phase diametrical windings, one for each rotary converter. Only three synchronizing breakers located beneath the transformers are required for each rotary converter as the midpoint of the transformer windings is not connected. A fourth breaker is installed to ground the machine through a low resistance when it is desired to work on the converter when the transformer is excited.

The high tension and d-c. feeder equipments are the same as for East Thirty-second Street Substation except that the d-c. feeder circuit breakers are mounted above knife switches in the switchboard room.

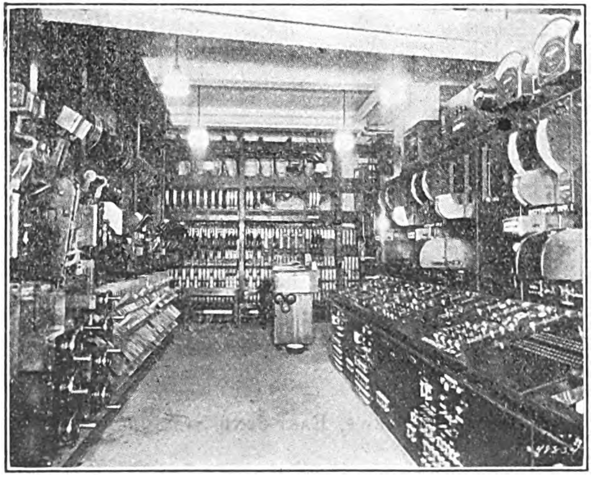


FIG. 61—Switchboard, Madison Ave. Substation.

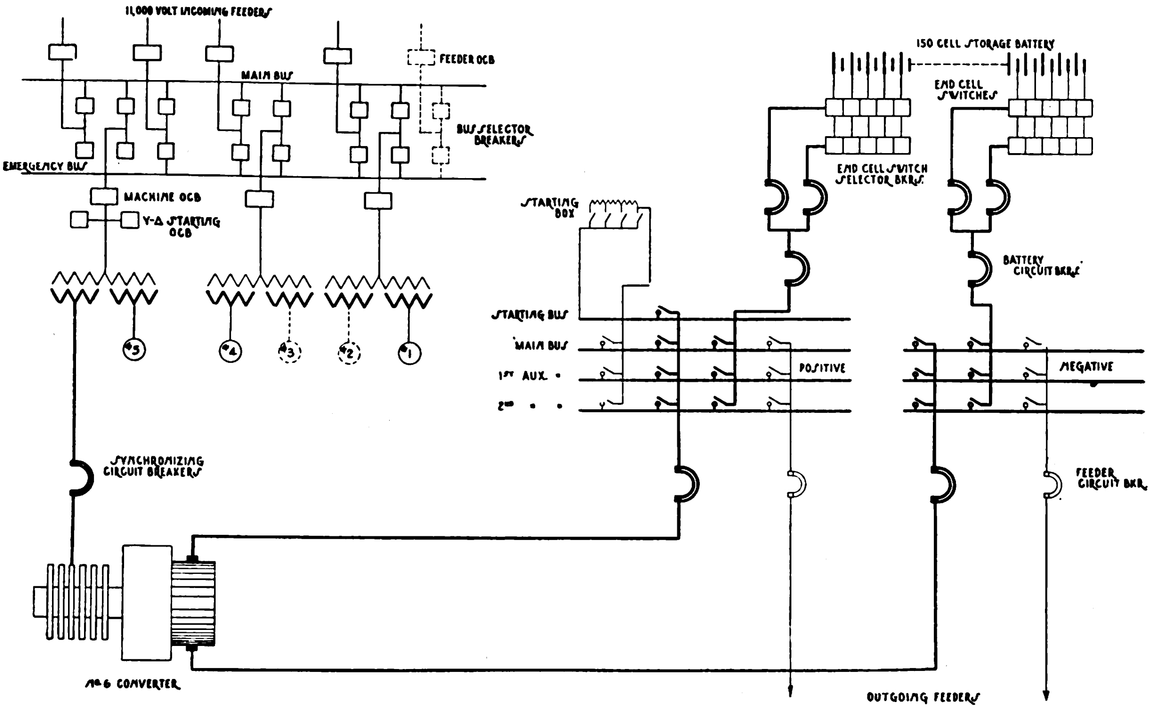

11,000 VOLT INCOMING FEEDERS
FEEDER OCB
MAIN BUS
BUS SELECTOR BREAKERS
EMERGENCY BUS
MACHINE OCB
Y-Δ STARTING OCB
5
4
3
2
1
SYNCHRONIZING CIRCUIT BREAKERS
No 6 CONVERTER
150 CELL STORAGE BATTERY
END CELL SWITCHES
END CELL SWITCH SELECTOR BKRS.
BATTERY CIRCUIT BKRS.
STARTING BOX
STARTING BUS
MAIN BUS
1ST AUX.
2ND
POSITIVE
NEGATIVE
FEEDER CIRCUIT BKR.
OUTGOING FEEDERS

FIG. 62—SINGLE LINE DIAGRAM, MADISON AVE. SUBSTATION.

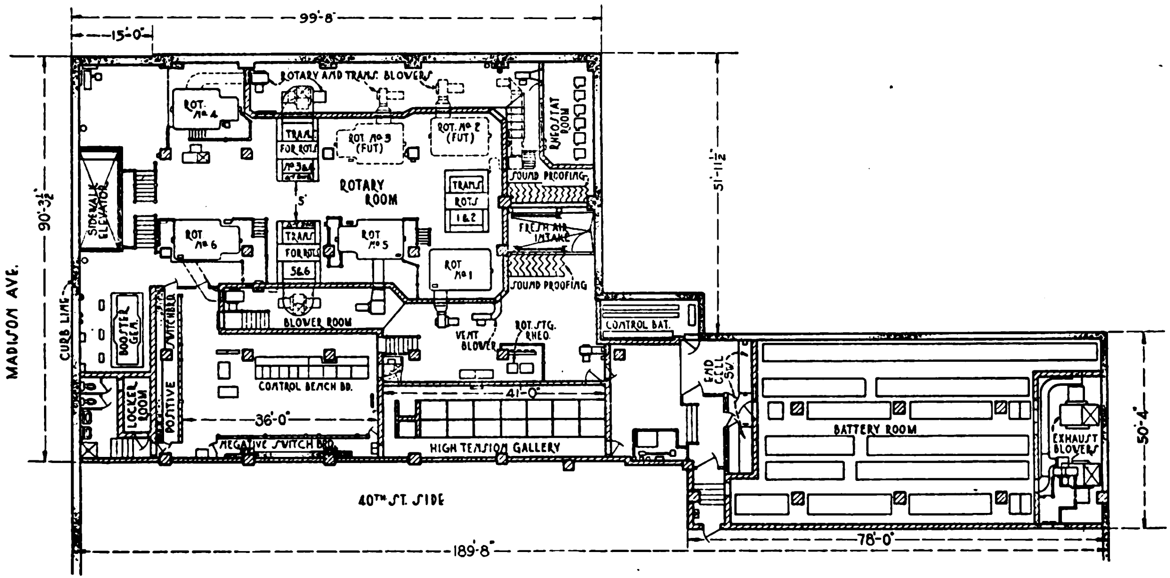

99'-8"
15'-0"
90'-3½"
51'-11½"
50'-4"
189'-8"
78'-0"
41'-0"
36'-0"
5'
MADISON AVE.
CURB LINE
40TH ST. SIDE
ROTARY AND TRANS. BLOWERS
ROT. No 4
TRANS FOR ROTS No 3&4
ROT. No 3 (FUT)
ROT. No 2 (FUT)
RHEOSTAT ROOM
SOUND PROOFING
ROTARY ROOM
TRANS ROTS 1&2
SIDEWALK ELEVATOR
ROT No 6
TRANS FOR ROTS 5&6
ROT No 5
FRESH AIR INTAKE
ROT No 1
SOUND PROOFING
BOOSTER GEN.
SWITCHBD.
BLOWER ROOM
VENT BLOWER
ROT. STG. RHEO.
CONTROL BAT.
CONTROL BENCH BD.
LOCKER ROOM
POSITIVE
NEGATIVE SWITCH BD.
HIGH TENSION GALLERY
END CELL SW.
BATTERY ROOM
EXHAUST BLOWERS

FIG. 63—PLAN, MADISON AVE. SUBSTATION.

The Northern States Power Company, Minneapolis, Minn.—Sixth Street Substation

This substation operates in parallel with another substation of similar design, and a 1200-kw. automatic substation. These three substations serve a d-c. network in the loop district of Minneapolis. The following description deals with Sixth Street Substation:

Standby Battery

This substation is equipped with a 150-cell Exide battery of 8184 ampere-hr. capacity at the 8-hr. discharge rate or 14,652 amperes for 10 minutes. This battery is floated across the d-c. bus at all times. Two batteries of the same size are floated on the d-c. bus at another substation. Remote controlled, electrically operated end-cell switches are provided. This battery is charged from the d-c. bus by means of a booster motor-generator set. Suitable cables and switches are provided to make it possible to connect a booster generator to any cell or group of cells for special charging. Special charging can be carried on while the battery is tied to the d-c. bus.

D-C. Buses

Two separate 3-wire, 250-volt d-c. buses are provided, and the d-c. switching equipment is so arranged that any feeder or generator can be connected to either or both of the d-c. buses. One of these buses, called the "high" bus, is operated at about 8 volts higher than the other bus, which is called the "low" bus. Those feeders supplying the more remote parts of the d-c. network are connected to the "high" bus and the shorter feeders are connected to the "low" bus. This double bus system permits practically uniform voltage in all parts of the network and divides the load among the various feeders to better advantage.

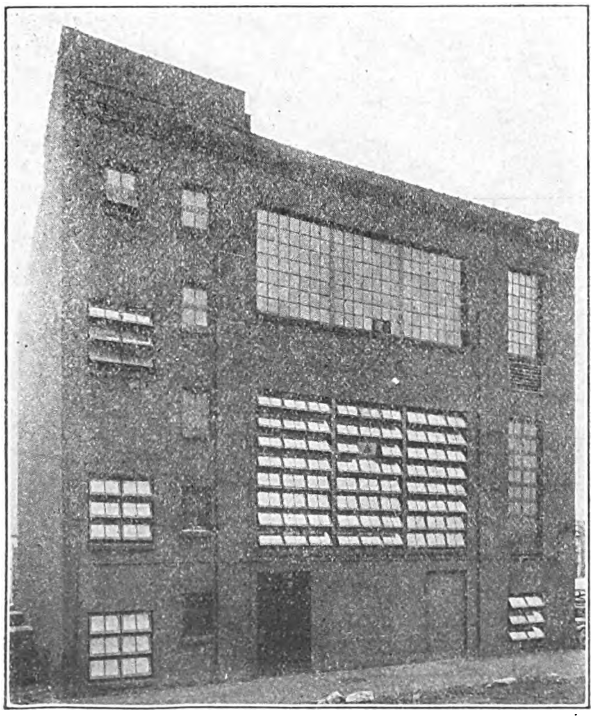


FIG. 64—EXTERIOR, SIXTH ST. SUBSTATION.

Sectionalization of D-C. Network

The d-c. network is segregated into three independent zones for the purpose of giving greater flexibility in picking up the d-c. load in case of an interruption. Each substation serves feeders of all three zones, and the substation d-c. buses serve as the only ties between these zones. These zones are known as the black zone, the blue zone and the white zone. The handle of every feeder switch in each substation is enamelled black, light blue or white, to denote which zone that feeder serves. In case of an interruption the zones are separated by means of feeder switches. All feeder switches for one zone are closed in on one of the buses which is temporarily left dead. This bus is then tied to a second bus which is live. The feeders are then all transferred to the second bus, after which the buses are separated, leaving the first bus dead and available for picking up another zone. The above-described procedure is repeated until all three zones have been picked up.

Control Bus

All oil circuit breakers, all main generator d-c. breakers, and all field rheostats for the motor-generator sets are electrically operated. The 125-volt, d-c. supply for these controls and for the indicating lights is supplied by a 60-cell control battery which is constantly floated on a small battery-charging motor-generator set. Normally the motor-generator carries the control load, and the battery remains fully charged. Between the generator and the control battery is an automatic circuit breaker which will trip on the occurrence of reverse current, overload or under-voltage. The motor is protected for overload and under-voltage. In case of interruption affecting the motor-generator set, the battery serves the controls. The battery is protected by a heavy fuse and the various controls are supplied through a number of fused branch circuits. Pilot lights are connected to each branch circuit to indicate the condition of the fuses. The control bus is operated ungrounded and is equipped with ground detector lamps.

Starting of Machine

In normal operation the motor-generator sets are started from the d-c. end by means of step switches and resistors. During the starting period the field of the d-c. machine is supplied from the main d-c. bus. After the synchronous motor has been synchronized in on the a-c. bus, the field of the d-c. generator is transferred to self-excitation.

The motor-generator sets are provided with compensators for emergency a-c. starting in case of the d-c. bus being dead.

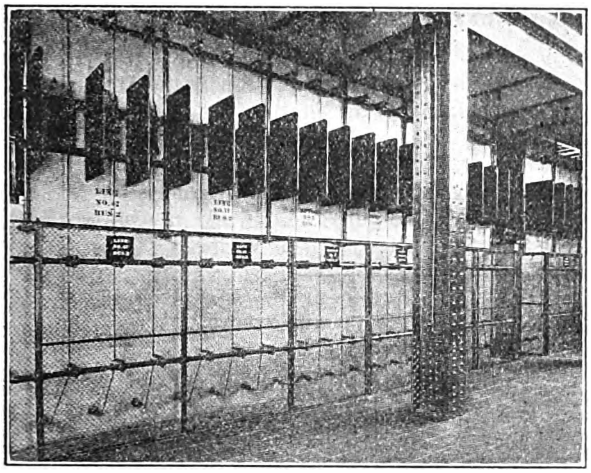


FIG. 65—13.2-Kv. Disconnecting Switches Between Oil Circuit Breakers and Bus, Sixth St. Substation.

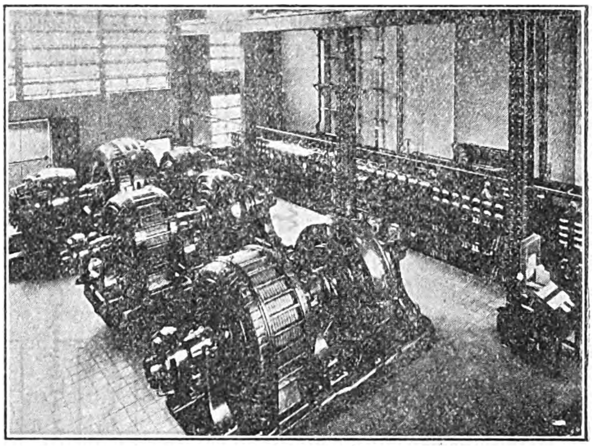


FIG. 66—Machine Room, Sixth St. Substation.

Relays and Protection

Each pair of incoming feeders has balanced protection. With this protection scheme a line will trip out only when there is an unbalance in current between the individual lines of a pair. Then the more heavily loaded line will trip, leaving the other line of the pair in service with straight overload protection.

The synchronous motors are provided with straight overload protection only.

The d-c. generator circuit breakers trip only on the occurrence of a reverse current.

Fire Protection

Fire-extinguishing devices, including Pyrene guns, Phister one-gallon extinguishers, sand pails, and soda and acid extinguishers are located at various points about the substation so that the nearest one is never more than a few feet away. Near each soda and acid extinguisher is a large red sign which cautions against using the extinguisher on live apparatus.

Safety

Wherever high-voltage conductors are not sufficiently protected by the concrete cell structures, wire netting barriers are provided.

A removable wooden bar is placed in front of each set of three cell doors on the FH-203 oil circuit breakers to prevent the mistake of opening a cell of a switch adjacent to a switch which is to be inspected. In addition, the concrete cell wall between each switch and the adjacent switch is painted red so as to clearly mark the limits of each set of three cells.

Interlocks

An electrical interlock is provided which trips the neutral breaker if either the positive or negative breaker is opened. Interlocks are provided to close the neutral breaker when the positive breaker is closed, and to prevent the positive breaker from closing when the negative breaker is open. The interlocking scheme also prevents closing the positive high bus breaker if only the negative low bus breaker has been closed and closing the positive low bus breaker if only the negative high bus breaker has been closed.

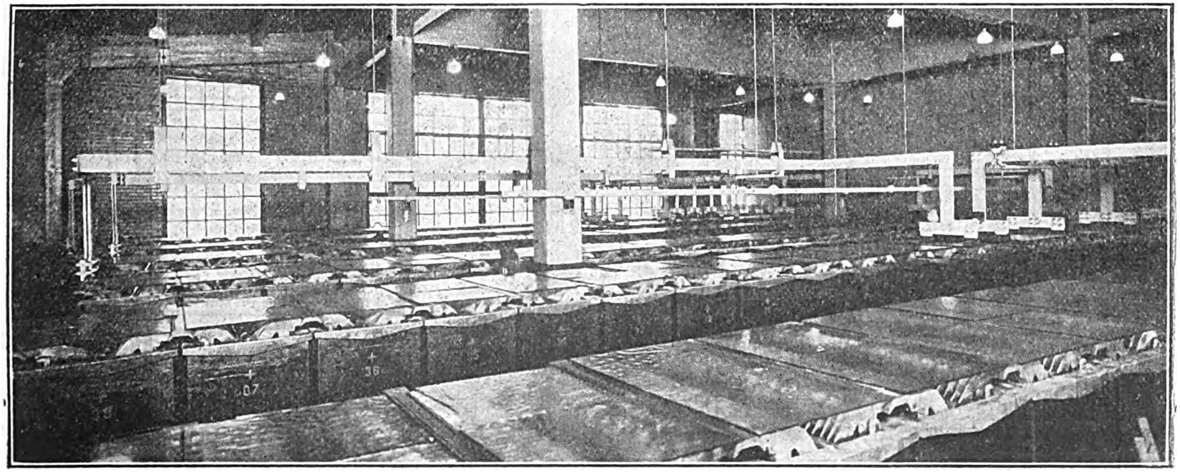


FIG. 67—Battery Room, Sixth St. Substation.

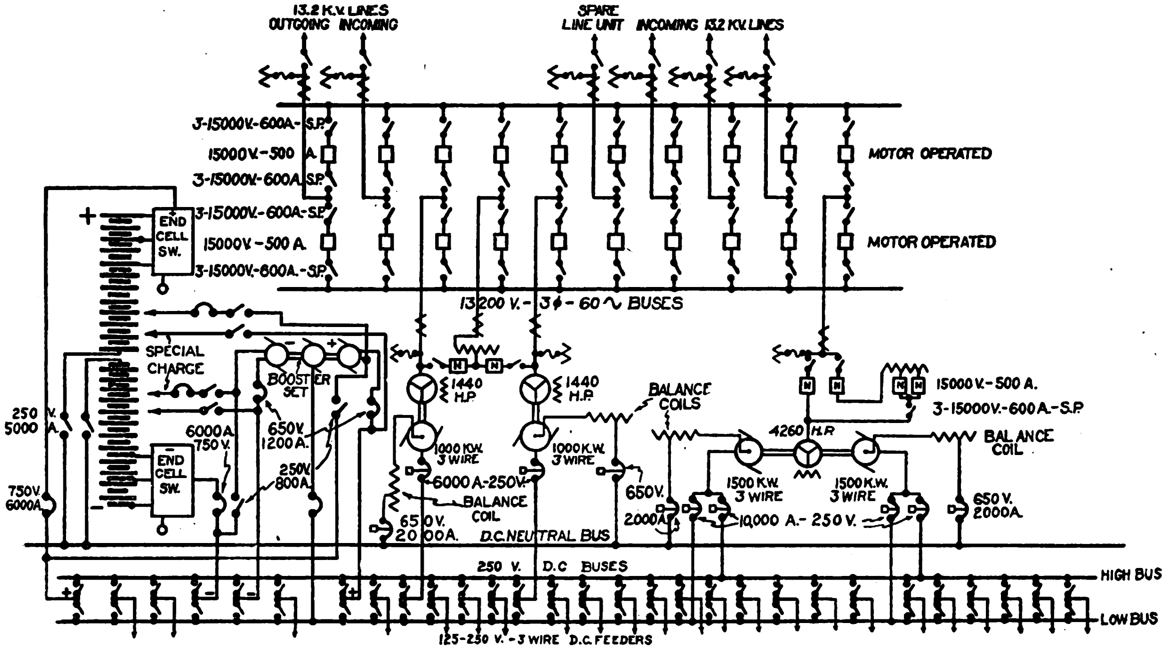

13.2 K.V. LINES
OUTGOING
INCOMING
SPARE LINE UNIT
INCOMING
13.2 K.V. LINES
3-15000V.-600A.-S.P.
15000V.-500 A.
3-15000V.-600A.-S.P.
3-15000V.-600A.-S.P.
15000V.-500 A.
3-15000V.-600A.-S.P.
MOTOR OPERATED
MOTOR OPERATED
13200 V.-3φ-60∿ BUSES
END CELL SW.
END CELL SW.
SPECIAL CHARGE
BOOSTER SET
250 V. 5000 A.
6000A. 750V.
650V. 1200A.
250V. 800A.
750V. 6000A.
1440 H.P.
1440 H.P.
1000 K.W. 3 WIRE
1000 K.W. 3 WIRE
6000 A-250V.
BALANCE COIL
650V. 2000A.
BALANCE COILS
650V. 2000A.
4260 H.P.
1500 K.W. 3 WIRE
1500 K.W. 3 WIRE
10,000 A.- 250 V.
BALANCE COIL
650 V. 2000A.
15000 V.-500 A.
3-15000V.-600A.-S.P.
D.C. NEUTRAL BUS
250 V. D.C BUSES
HIGH BUS
LOW BUS
125-250 V.-3 WIRE D.C. FEEDERS

FIG. 68—Single Line Diagram, Sixth St. Substation.

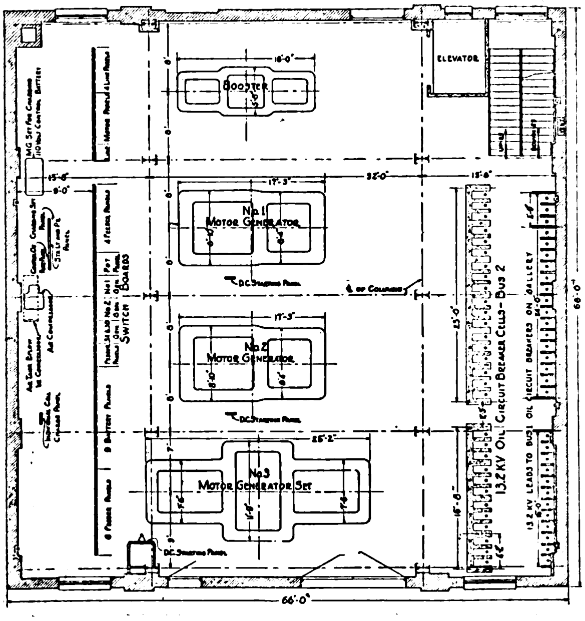

ELEVATOR
BOOSTER
No 1 Motor Generator
No 2 Motor Generator
No 3 Motor Generator Set
D.C. Starting Panel
SWITCH BOARD
13.2 KV Oil Circuit Breaker Cells - Bus 2
13.2 KV Leads to Bus 1 Oil Circuit Breakers on Gallery
66'-0"
66'-0"

FIG. 69—Main Floor Plan, Sixth St. Substation.

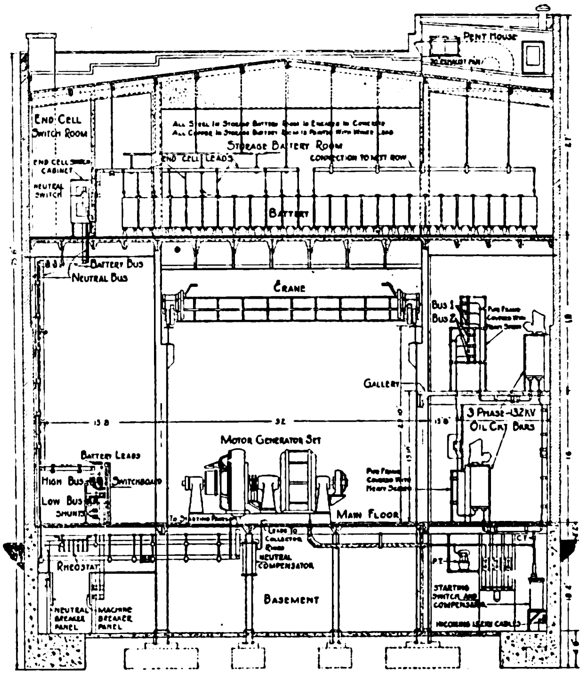

Pent House
End Cell Switch Room
Storage Battery Room
Battery
Battery Bus
Neutral Bus
Crane
Bus 1
Bus 2
Gallery
3 Phase-13.2 KV Oil Ckt Bkrs
Motor Generator Set
Battery Leads
High Bus
Low Bus
Switchboard
Main Floor
Rheostat
Neutral Compensator
Basement
Neutral Breaker Panel
Machine Breaker Panel
Starting Switch and Compensator

FIG. 70—Section, Sixth St. Substation.

Union Gas and Electric Company, Cincinnati, Ohio—Baker Alley Substation

The general practice in Cincinnati is to locate large manually operated substations at approximate load centers with small automatic substations spaced between. This practice is followed out in both the a-c. and the d-c. systems. Of the substations supplying the Edison system, the Baker Alley Substation is the best example of modern design for the large manually operated substations. The Jackson Street Substation is also a very good example of a small automatic d-c. substation.

Baker Alley

This substation of the Union Gas & Electric Company is located in the downtown section of Cincinnati. The building is constructed of red wire-cut brick and contains five floors, a basement and a sub-basement. This substation building contains no windows except those in the monitor above the fifth floor. This feature reduces the fire hazard to the substation from adjoining buildings and prevents undesirable noises from the rotating equipment. The equipment in the building is located as follows:

Sub-basement

150-cell, 9300-ampere-hr. stand-by storage battery.
60-cell, 120-ampere-hr. control battery.

Basement

D-c. buses, breakers and feeders. Control and ventilating equipment for rotating machinery and end cell switches for the Edison storage battery. Also starting and running breakers for rotary converters and motor-generator sets.

First Floor

Two 3700-kw. rotary converters with their two 4000-kv-a., 13,200/192-volt transformer banks.
Two 1500-kw. motor-generator sets. 13,200-volt a-c. 250-volts d-c.
Two 6000-kv-a., 13,200/4325-volt transformer banks.
These transformers supply a-c. distribution.
Eight 72-kw. constant-current transformers for street lighting.
One 30-ton crane for handling equipment.

Second Floor

Control room consisting of 27 control panels and 8 relay panels.
Motor-generator sets for charging control battery.

Third Floor

4325-volt apparatus room containing positions for 8 regulated feeders and 2 non-regulated feeders.

Fourth Floor

13,200-volt bus and breaker room equipped for 13 circuits all having dual switching. The main bus is separated into two parts. Reactor structures have been built to equip all 13,200-volt positions with current-limiting reactors.

Fifth Floor

Two intake air fans.
Intake air filter (dry type).
Four exhaust fans.

Ventilation

The first floor is constructed so that the space occupied by the rotating equipment, which is slightly more than one-half the width of the building, is three floors high.

The second floor is a mezzanine to the machine room with a glass partition on the side overlooking the machines. This is the control room for the station.

The ventilating system of this substation is one of the unique features in the design. All the air for ventilation is taken in at the roof through dry air filters, and after going down through the building is discharged again at the roof.

The air is admitted through the roof monitor to an intake chamber located on the fifth floor. It then passes through the air filters, which comprise one-half of the walls of the intake chamber, into a second chamber. From this chamber it is drawn through two 50-h.p. induced draft fans to an air well on each end of the building. The air wells extend from the fifth floor to the first basement level, where the forced draft fans are located. These air wells are also used as stairways, and iron grating stairs are used throughout to get greater area. The circulation of the air down these two wells is aided by two 30-h.p. forced draft fans located in the basement which force air through the rotary converters and thence through ducts along the wall to the exhaust room located on the fifth floor. Both rotary converters are totally inclosed. Two 20-h.p. forced draft fans ventilate the rotary converter transformers which discharge the air directly into the machine room. The power transformer banks are cooled by means of two 30-h.p. forced draft fans also located in the basement. The air is forced through these banks and thence through ducts to the roof.

Ventilation for the machine room is furnished by two 25-h.p. exhaust fans located on the fifth floor with intake openings in the ceiling of the machine room. Auxiliary openings in the ducts for these fans are located in the fourth floor switch room, the discharge being taken through the fifth floor roof to the outside.

Ventilation of the second floor control room and the third floor regulator room is accomplished by means of louvres into the north and south air wells.

The battery room in the basement requires special ventilation due to the acid fumes from the battery. Two 15-h.p. exhaust fans located on the fifth floor draw the exhausted air from the battery room through acid eliminators located at the intake of the ducts. Fresh air is drawn into the battery room through special ducts directly from the fifth floor. These exhaust fans discharge directly through the roof.

The ventilating system when in full operation moves approximately 125,000 cu. ft. of air per minute throughout the station.

Feeders

The present number of feeders consists of four incoming and one outgoing 13,200-volt a-c., four outgoing (three regulated and one non-regulated), 4325-volt a-c., and 28 outgoing 250-volt d-c. feeders. The ultimate capacity of this substation is four incoming and three outgoing, 13,200-volt a-c., ten outgoing (eight regulated and two non-regulated), 4325-volt a-c. and 60 outgoing 250-volt d-c. feeders. All these feeders leave or enter the substation underground. The substation is also laid out to supply eight 70-kw., 6.6-ampere constant-current street lighting circuits.

Relay Equipment

Incoming Lines—Balanced directional.

Outgoing Lines a-c.—Overload.

Rotary converters and motor-generator sets.

A-c. overload and ground.

Bearing temperature.

Overspeed.

Flash relay (frame of machines connected to ground through a relay).

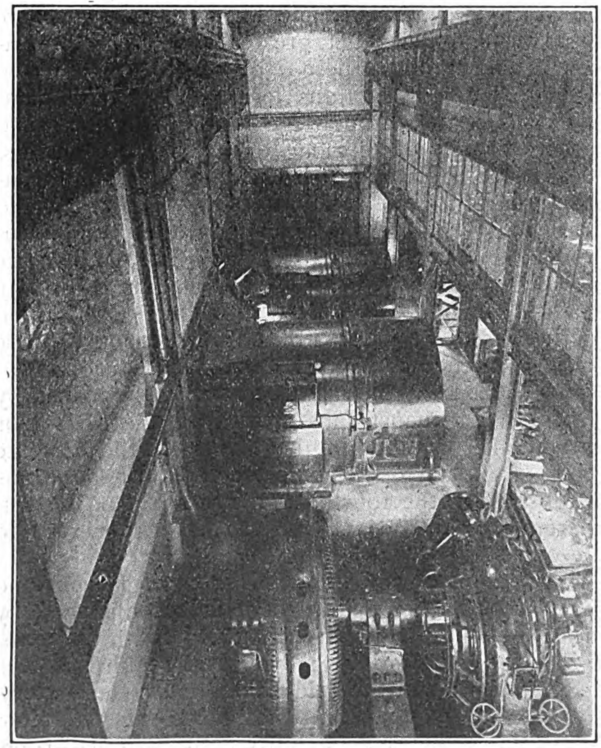


FIG. 71—MACHINE ROOM, BAKER ALLEY SUBSTATION.

D-c. Feeders

Breakdown or burnout on d-c. cables energizes a pilot wire which in turn energizes a tripping coil on the feeder breaker.

Rotary Converter and Motor-Generator Control

These machines have a system of control which might be termed "semi-automatic." To start a machine, the operator closes the main line a-c. switch and the starting sequence from then on is automatic up to the last d-c. breaker to parallel the machine with the d-c. system. The operator closes this d-c. breaker.

The rotary converters in Baker Alley Substation have a special feature on the d-c. end which was developed in Cincinnati and which has given an excellent account of itself.

The a-c. supply system to Baker Alley Substation is subjected to severe voltage drops that take place when short circuits or other disturbances occur on other parts of the system. The rotary converters operate on the station bus on which stand-by batteries float. When there is a depression in voltage the rotary converters tend to reverse and clear themselves from the d-c. bus. After the disturbance the machine must then be paralleled with the d-c. bus by the operator. This requires from one to two minutes, depending on conditions.

The special features developed here consist of tying the machine to the d-c. buses by single-pole breakers; one of the breakers connects the machine direct and the other short-circuits a resistance. When an a-c. disturbance takes place, the breaker short-circuiting the resistance opens on reverse current. This leaves the machine connected to the d-c. system through the resistance. Upon recovery of the a-c. voltage, the breaker again closes automatically across the resistance and normal operation is resumed. The resistance is protected by thermal relays.

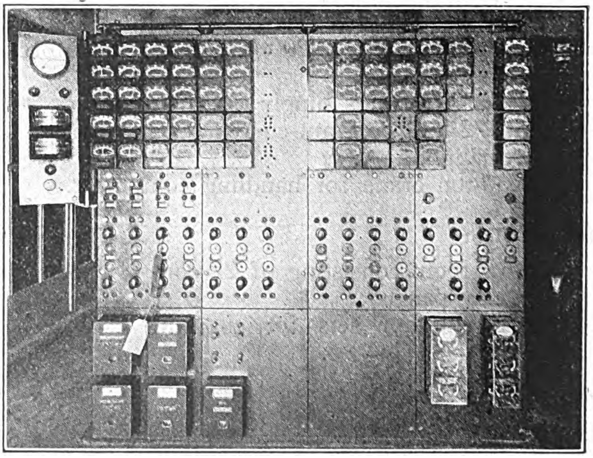


FIG. 72—13.2-KV. SWITCHBOARD, BAKER ALLEY SUBSTATION.

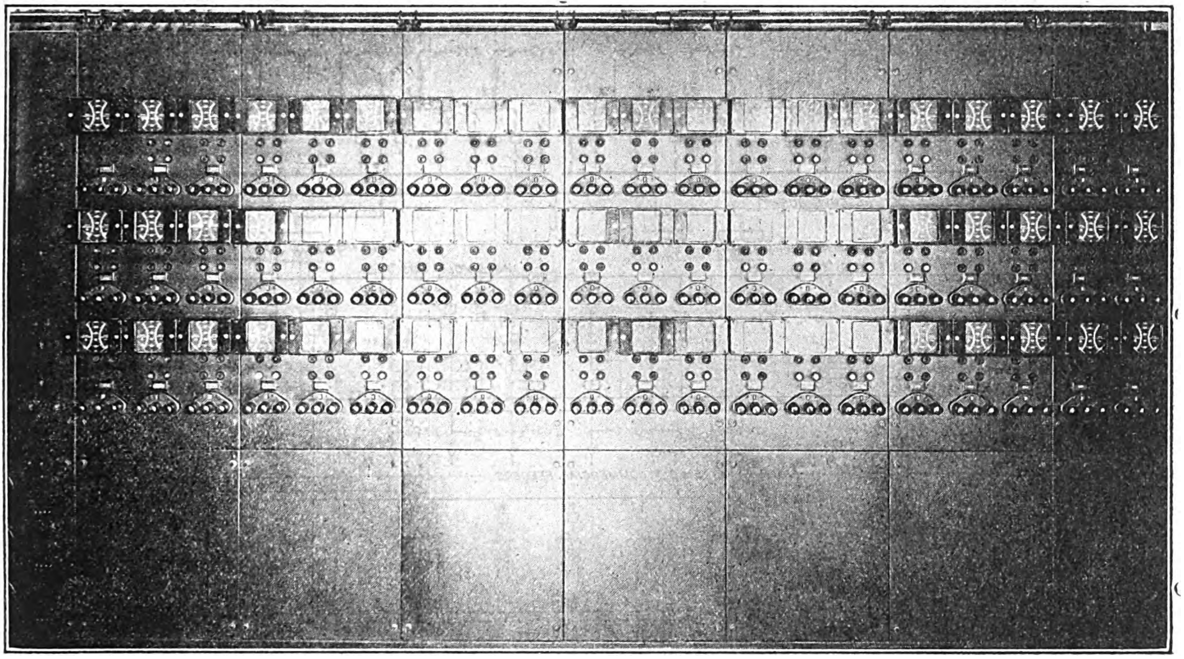


FIG. 73—D. C. SWITCHBOARD, BAKER ALLEY SUBSTATION.

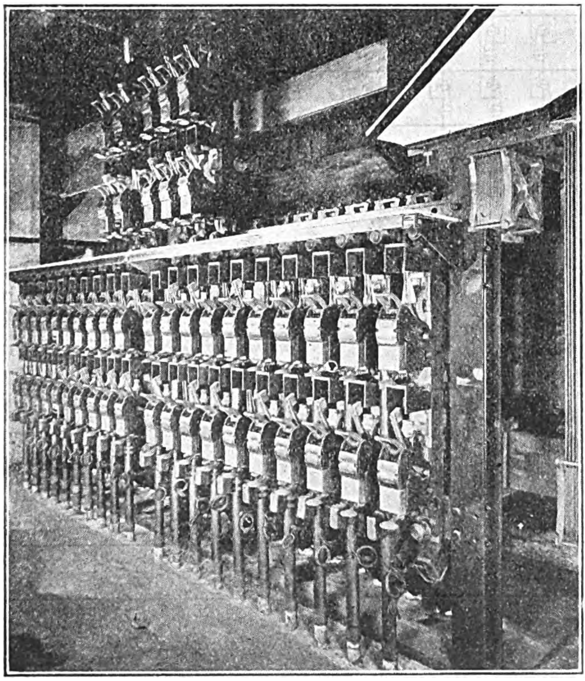


FIG. 74—D. C. FEEDER BREAKERS, BAKER ALLEY SUBSTATION.

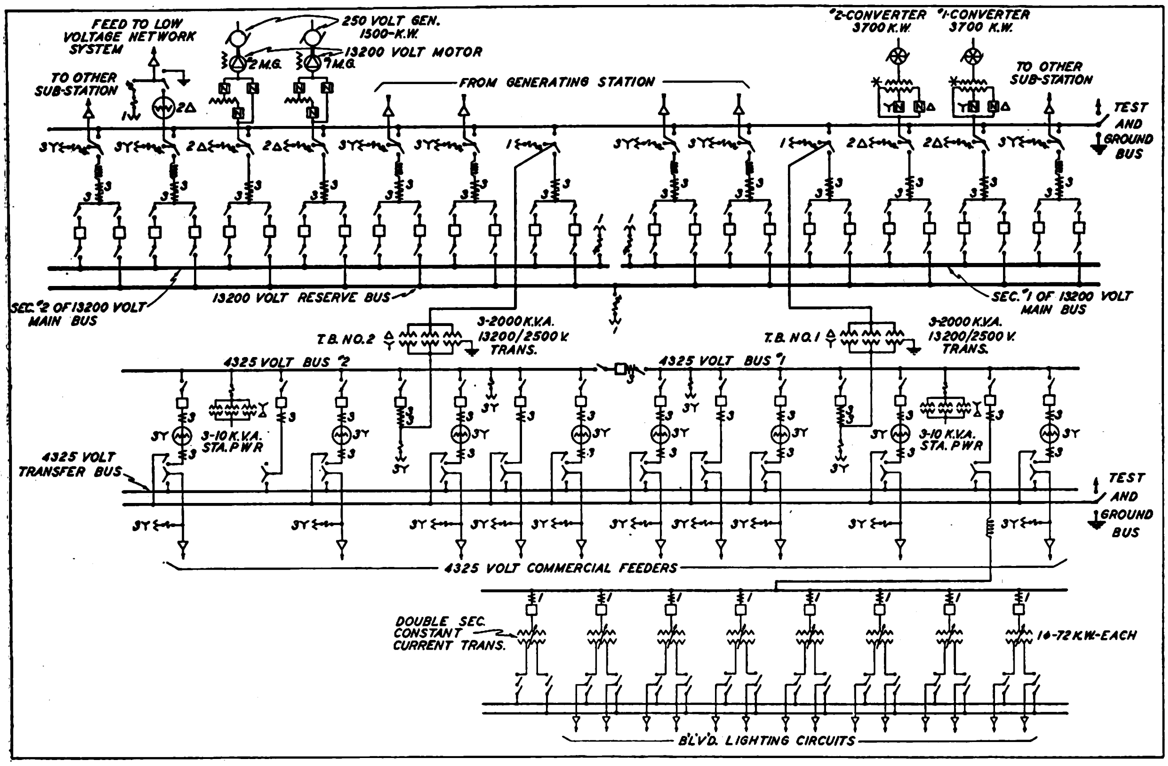

FEED TO LOW VOLTAGE NETWORK SYSTEM
TO OTHER SUB-STATION
250 VOLT GEN. 1500-K.W.
13200 VOLT MOTOR
2 M.G.
1 M.G.
2Δ
FROM GENERATING STATION
*2-CONVERTER 3700 K.W.
*1-CONVERTER 3700 K.W.
TO OTHER SUB-STATION
TEST AND GROUND BUS
3Y
2Δ
1
3
SEC. *2 OF 13200 VOLT MAIN BUS
13200 VOLT RESERVE BUS
SEC. *1 OF 13200 VOLT MAIN BUS
T.B. NO. 2
3-2000 K.V.A. 13200/2500 V. TRANS.
T.B. NO. 1
3-2000 K.V.A. 13200/2500 V. TRANS.
4325 VOLT BUS *2
4325 VOLT BUS *1
3-10 K.V.A. STA. PWR
3-10 K.V.A. STA. PWR
4325 VOLT TRANSFER BUS
TEST AND GROUND BUS
4325 VOLT COMMERCIAL FEEDERS
DOUBLE SEC. CONSTANT CURRENT TRANS.
14-72 K.W.-EACH
BLV'D. LIGHTING CIRCUITS

FIG. 75—SINGLE LINE DIAGRAM, A. C. CONNECTIONS, BAKER ALLEY SUBSTATION.

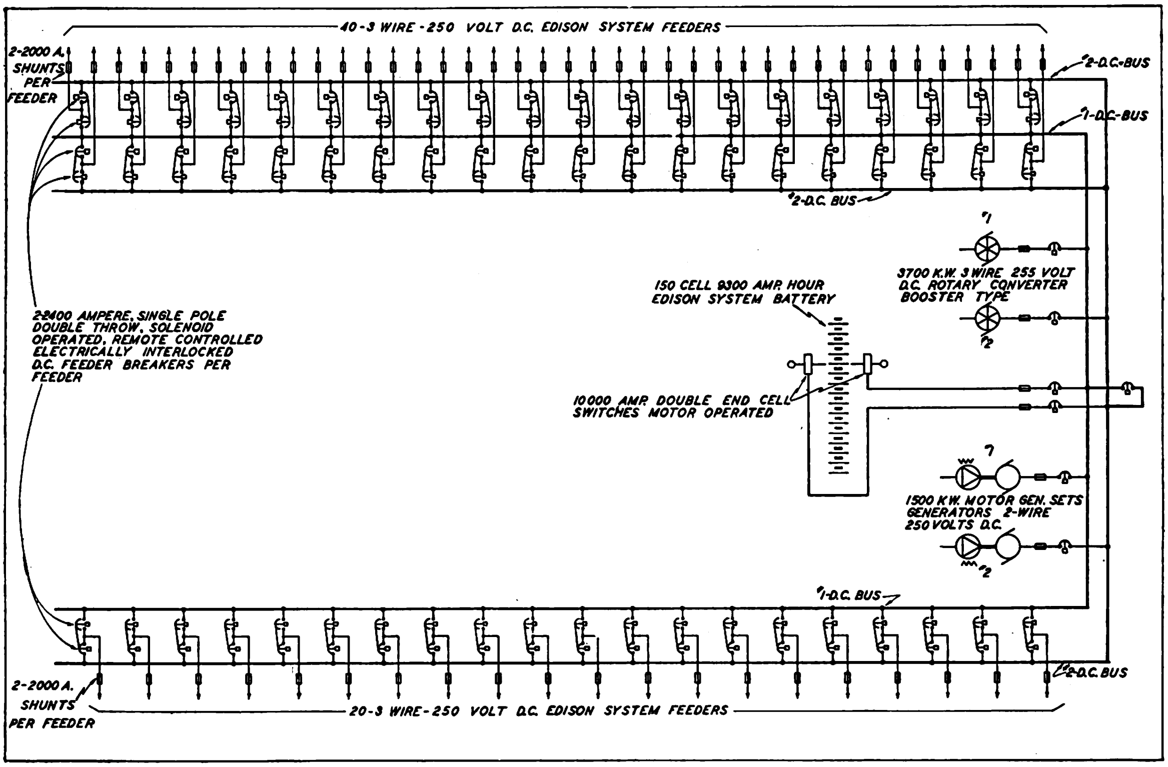

40-3 WIRE-250 VOLT D.C. EDISON SYSTEM FEEDERS
2-2000 A. SHUNTS PER FEEDER
*2-D.C.-BUS
*1-D.C.-BUS
*2-D.C. BUS
*1
3700 K.W. 3 WIRE 255 VOLT D.C. ROTARY CONVERTER BOOSTER TYPE
*2
150 CELL 9300 AMP. HOUR EDISON SYSTEM BATTERY
2-2400 AMPERE, SINGLE POLE DOUBLE THROW, SOLENOID OPERATED, REMOTE CONTROLLED ELECTRICALLY INTERLOCKED D.C. FEEDER BREAKERS PER FEEDER
10000 AMP. DOUBLE END CELL SWITCHES MOTOR OPERATED
1500 K.W. MOTOR GEN. SETS GENERATORS 2-WIRE 250 VOLTS D.C.
*1-D.C. BUS
*2-D.C. BUS
2-2000 A. SHUNTS PER FEEDER
20-3 WIRE-250 VOLT D.C. EDISON SYSTEM FEEDERS

FIG. 76—SINGLE LINE DIAGRAM, D. C. CONNECTIONS, BAKER ALLEY SUBSTATION.

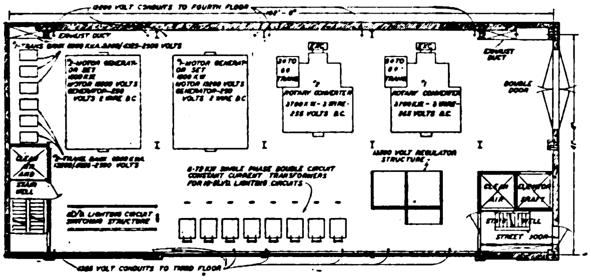

13200 VOLT CONDUITS TO FOURTH FLOOR
103'-0"
EXHAUST DUCT
TRANS BANK
MOTOR GENERATOR SET
MOTOR 13200 VOLTS
GENERATOR—250 VOLTS 2 WIRE D.C.
ROTARY CONVERTER
DOUBLE DOOR
13200 VOLT REGULATOR STRUCTURE
CONSTANT CURRENT TRANSFORMERS
LIGHTING CIRCUIT SWITCHING STRUCTURE
CLEAN AIR
STAIR WELL
ELEVATOR SHAFT
STREET DOOR
4325 VOLT CONDUITS TO THIRD FLOOR

FIG. 77—Plan, Machine Room, Baker Alley Substation.

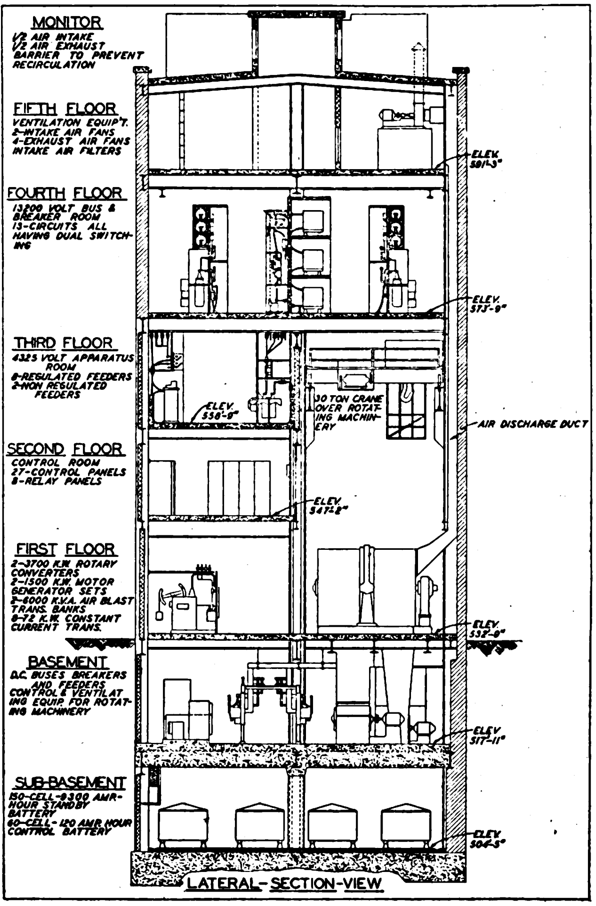

MONITOR
1/2 AIR INTAKE
1/2 AIR EXHAUST
BARRIER TO PREVENT RECIRCULATION
FIFTH FLOOR
VENTILATION EQUIP'T.
2-INTAKE AIR FANS
4-EXHAUST AIR FANS
INTAKE AIR FILTERS
FOURTH FLOOR
13200 VOLT BUS & BREAKER ROOM
13-CIRCUITS ALL HAVING DUAL SWITCHING
THIRD FLOOR
4325 VOLT APPARATUS ROOM
8-REGULATED FEEDERS
2-NON REGULATED FEEDERS
SECOND FLOOR
CONTROL ROOM
27-CONTROL PANELS
8-RELAY PANELS
FIRST FLOOR
2-3700 K.W. ROTARY CONVERTERS
2-1500 K.W. MOTOR GENERATOR SETS
2-6000 K.V.A. AIR BLAST TRANS. BANKS
8-72 K.W. CONSTANT CURRENT TRANS.
BASEMENT
D.C. BUSES BREAKERS AND FEEDERS
CONTROL & VENTILATING EQUIP. FOR ROTATING MACHINERY
SUB-BASEMENT
150-CELL-9300 AMP-HOUR STANDBY BATTERY
60-CELL-120 AMP HOUR CONTROL BATTERY
ELEV. 591'-3"
ELEV. 573'-9"
ELEV. 558'-9"
30 TON CRANE OVER ROTATING MACHINERY
AIR DISCHARGE DUCT
ELEV. 547'-2"
ELEV. 532'-9"
ELEV. 517'-11"
ELEV. 504'-5"
LATERAL-SECTION-VIEW

FIG. 78—Section, Baker Alley Substation.

TABLE I

TABULATION OF DATA

EDISON SUBSTATIONS

For Key to Abbreviations, See Accompanying List

HIGH TENSION

	Feeders							Oil Circuit Breakers		
Substations	Voltage	Frequency	Location	Pres. No.	Ultimate No.	Pres. Size	Ultimate Size	Mfr. & Type	Rated Volts	Operation
AUTOMATIC										
Kansas City Power & Lt.Co. Substation "T"	13,200	60	U.G.	3	3	400 MCM	400 MCM	GE-EB	15,000	Elec.
Union Gas & Elec. Co. Jackson St. Substation	13,200	60	U.G.	2	2	400 MCM	400 MCM	W-O-1 Tr.	15,000	Elec.
NON-AUTOMATIC										
Cleveland Elec. Ill. Co. Bolivar Substation	11,000	60	U.G.	5 In 2 Out	10 In 4 Out	4/0	4/0	GE-HB03	15,000	Elec.
Commonwealth Edison Co. Burnham Bldg. Substation	12,000	60	U.G.	5	7	500 MCM	500 MCM	Con-F11 isolated ph.	15,000	Elec.
Detroit Edison Co. Charlotte Substation	4,800	60	U.G.	5	9	1-200 MCM 4-450 MCM	1-200 MCM 8-450 MCM	None	-	-
Edison El.Ill.Co.of Boston Carver St. Substation	13,800	60	U.G.	3	23	350 MCM	500 MCM	Cond.-F-11-A	15,000	Elec.
Milwaukee El.Ry.& Lt.Co. Stephenson Bldg. Substation	13,800	60	U.G.	3	4	4/0	4/0	W-B-16	15,000	Elec.
New Orleans Public Serv.Inc. Dryades Substation	6,600	60	U.G.	6	6	4-4/0 2-300 MCM	4-4/0 2-300 MCM	W-B-16	20,000	Elec.
New York Edison Co. East 32nd St. Substation	11,400	25	U.G.	3 Direct 2 Tie	6 Direct 2 Tie	350 MCM	350 MCM	GE-FH 103 auto GE-K 12 non-auto	15,000	Elec.
New York Edison Co. Madison Ave. Substation	11,400	25	U.G.	3 Direct 1 Tie	3 Direct 2 Tie	350 MCM	350 MCM	GE-FH 103 auto GE-K 12 non-auto	15,000	Elec.
Northern States Pr. Co. 6th St. Substation	13,200	60	U.G.	4 In 1 Out	4 In 1 Out	4-4/0 1-350 MCM	4-4/0 1-350 MCM	GE-FH 203	15,000	Elec.
Union Gas & Elec. Co. Baker Alley Substation	13,200	60	U.G.	4 In 1 Out	4 In 3 Out	400 MCM	400 MCM	GE-FK-220-16-A	15,000	Elec.

HIGH TENSION

	Air Break Switches			Disconnecting Switches				Potential Transformers			Current Transf.			Lightning Arresters	
Substations	Mfr. & Type	Rated Volts	Rated Amps.	Mfr.	Rated Volts	Rated Amps.	Operation	Mfr. & Type	Ratio	No. per Circuit	Mfr. & Type	Ratio	No. per Circuit	Location	Mfr. & Type
AUTOMATIC															
Kansas City Power & Lt.Co. Substation "T"	None	-	-	GE	15,000	300	Hook Stick	GE-EM 13	120/1	1	GE-K 48	100/5	3	None	-
Union Gas & Elec. Co. Jackson St. Substation	None	-	-	GE	15,000	600	Hook Stick	GE-EM 13	120/1	3	GE-K 48	400/5	3	None	-
NON-AUTOMATIC															
Cleveland Elec.Ill.Co. Bolivar Substation	None	-	-	GE	15,000	300	Hook Stick	GE-K113	100/1	3 Rot. 2 Fdr.	GE-K58	300/5	3	None	-
Commonwealth Edison Co. Burnham Bldg. Substation	None	-	-	Con	15,000	600	Hook Stick	GE-K113	100/1	3 per bus	GE-K48 GE-KC58	600/5 350/5	3	None	-
Detroit Edison Co. Charlotte Substation	None	-	-	None	-	-	-	None	-	-	None	-	-	None	-
Edison El.Ill.Co.of Boston Carver St. Substation	None	-	-	T.& M.	15,000	300 600	Hook Stick	GE-EM13 GE-K113	120/1	3 Relays 2 Mach.	GE-Y456 GE-K48	400/5 250/5	3	None	-
Milwaukee El.Ry.& Lt.Co. Stephenson Bldg. Substation	None	-	-	E.E.E.	15,000	300	Gang Hook Stick	GE-EM-13	120/1	2	GE	300/5	3	None	-
New Orleans Public Serv.Inc. Dryades Substation	None	-	-	GE	15,000	400	Gang	W-Dry	60/1 80/1	2	W-KA	200/5	3	None	-
New York Edison Co. East 32nd St. Substation	None	-	-	E.D.& M.	15,000	800	Hook Stick	GE-K12	100/1	1 Fdr. 2 Trans.	GE-K46	400/5 Fdr. 500/5 Trans.	3	None	-
New York Edison Co. Madison Ave. Substation	None	-	-	None	-	-	-	GE-K12	100/1	1 Fdr. 2 Trans.	GE-K48	500/5	3	None	-
Northern States Power Co. 6th St. Substation	None	-	-	D.S. GE	15,000	600	Hook Stick	GE-EM14 GE-P-CQ	120/1	2	GE-K48	300/5	3	None	-
Union Gas & Elec. Co. Baker Alley Substation	None	-	-	Champion	15,000	600	Hook Stick & Gang	Packard PD	120/1	2	Sang. 0-25	400/5	3	None	-

1. Voltage rating of taps 10900-10630-10360-10090-9820/206 volts.
2. Voltage rating of taps 11400-11150-10000-10630-10360/206 for booster control converters.
   Voltage rating of taps 11950-11300-11000-10900-10500-10100/206 for field control converters.
3. Normal full load rating based on 35 deg. cent. rise in windings and 50 deg. cent. rise on commutator. No continuous rating on nameplate.

LIST OF ABBREVIATIONS

ABB	—American Brown Boveri Co.
Al.	—Aluminum
And.	—Albert &J.M. Anderson Mfg. Co.
ARCBCo.	—Automatic Reclosing Circuit Breaker Co.
Bullock	—T. H. Bullock Mfg. Co.
Champion	—Champion Switch Co.
Cond.	—Condit Electric Mfg. Corp.
Comp.	—Compensator
Cutter	—Cutter Electrical & Mfg. Co.
DS	—Delta Star Electric Co.
ED&M	—Electrical Devices & Machine Co.
EEE	—Electrical Engineers Equipment Co.
El.	—Electrolytic
Elpeco	—Electric Power Equipment Corp.
ESB	—Electric Storage Battery Co.
GD&F	—General Devices & Fittings Corp.
G&D	—Garton & Daniel
GE	—General Electric Co.
ID	—Indoor
MCM	—Thousand circular mils
ME&M Co.	—Mutual Electric & Machine Co.
MG	—Motor Generator
OD	—Outdoor
OH	—Overhead
Packard	—Packard Electric Co.
Pringle	—Pringle Electrical Mfg. Co.
Rect.	—Mercury arc rectifier
R&IE	—Railway & Industrial Eng. Co.
RV	—Reduced Voltage
Sang.	—Sangamo Electric Co.
Sup.	—Supervisory
Syn. C.	—Synchronous converter
T&M	—Thoner & Martens
Trumb.	—Trumbull Electric Mfg. Co.
UG	—Underground
W.	—Westinghouse Elec. & Mfg. Co.
Walker	—Walker Electric Co.

TABLE I—(Continued)

TRANSFORMERS

Substations	Location	Mfr.	Bank or 3Ø KVA Rating Continuous	Bank or 3Ø KVA Rating 2 Hour	Single or 3 Phase Units	Cooling	Primary Phase Voltage	Primary Connections	Secondary Connections	Voltage Rating of Taps	Full or Reduced Capacity	External Tap Changer	Transf. de-energized when conv. equipt. is idle	Method of Starting
AUTOMATIC														
Kansas City Power & Lt. Co. Substation "T"	I.D.	GE	1650	100%	3	OISC	13800	Delta	Dia.	4-2½%	F.C.	Yes	Yes	Y-Delta
Union Gas & Elec. Co. Jackson St. Substation	None	-	-	-	-	-	-	-	-	-	-	-	-	Reactor
NON-AUTOMATIC														
Cleveland Elec. Ill. Co. Bolivar Substation	I.D.	GE	4000	100%	3	Air Blast	11400	Delta	6 ph.	10990	F.C.	No	Yes	Y-Delta on HV Tap
Commonwealth Edison Co. Burnham Bldg. Substation	I.D.	GE	3850	100%	3	Air Blast	12000	Delta	6 ph. Dia.	4-2½%	F.C.	No	Yes	Y-Delta
Detroit Edison Co. Charlotte Substation	None	-	-	-	-	-	-	-	-	-	-	-	-	Comp.
Edison El. Ill. Co. of Boston Carver St. Substation	Unit with mch. I.D.	W	3860	100%	3	Air Blast	14300	Delta	Star Dia.	13945-13590 13285-12880	F.C.	No	Yes	Y-Delta on HV Tap
Milwaukee El. Ry. & Lt. Co. Stephenson Bldg. Substation	I.D.	GE	4200	100%	3	Air Blast	13800	Delta	6 ph. Dia.	5-2½%	F.C.	No	Yes	Y-Delta on HV Tap
New Orleans Public Serv. Inc. Dryades Substation	I.D.	W	1650	100%	3	Water	6600	Delta	Double Delta	5-2½%	F.C.	No	Yes	Comp. for MG HV Tap for Syn. C.
New York Edison Co. East 52nd St. Substation	I.D.	1-W 4-GE	4750	150%	3	Air Blast	11400	Delta	6 ph. Star	See Note 1	F.C.	One Trans.	Yes	Y-Delta or D.C.
New York Edison Co. Madison Ave. Substation	I.D.	W	4750	150%	3	Air Blast	11400	Delta	6 ph. double. sec.	See Note 2	F.C.	No	Yes	Y-Delta or D.C.
Northern States Power Co. 6th St. Substation	None	-	-	-	-	-	-	-	-	-	-	-	-	Knife type step D.C.
Union Gas & Elec. Co. Baker Alley Substation	I.D.	GE	4000	100%	3	Air Blast	13200	Delta	6 ph. Dia.	4-2½%	F.C.	No	Yes	Y-Delta

CONVERSION APPARATUS

Substations	No. & Class	Mfg.	RPM	Continuous Rating KW	2 Hour Rating	Normal D.C. Volts	Operating D.C. Volts Max.	Operating D.C. Volts Min.	Wound	Excited	Foundations Integral With Sta. Floor	Special Sound-Proofing	Special Ventilation	Provision for Handling Conv. Parts
AUTOMATIC														
Kansas City Power & Lt. Co. Substation "T"	2 Syn C	GE	600	1500	100%	245	260	240	Shunt	Self	No	No	Yes	None
Union Gas & Elec. Co. Jackson St. Substation	1 Syn MG	GE	600	1875	100%	250	280	230	Shunt	Exc. on Shaft	No	Yes	Yes	None
NON-AUTOMATIC														
Cleveland Elec. Ill. Co. Bolivar Substation	3 Syn C	GE	300	3710	100%	250	265	210	Shunt Booster	Self	No	Yes	Yes	Crane
Commonwealth Edison Co. Burnham Bldg. Substation	2 Syn C	GE	300	2425/3575	100%	250	275	225	Booster	Self	Yes	Yes	Yes	None
Detroit Edison Co. Charlotte Substation	3 Syn MG	GE	450	2400	100%	300	278	248	Dif. Comp.	Self & Sep.	No	Yes	Yes	Crane
Edison El. Ill. Co. of Boston Carver St. Substation	2 Syn MG 6 Syn C	W W	720 300	375-375 3120	100% 100%	120-120 240	195-195 270	105-105 210	Booster	Sep. Sep.	Yes Yes	No No	No	None
Milwaukee El. Ry. & Lt. Co. Stephenson Bldg. Substation	2 Syn C	GE	300	2775 3900	100% 100%	250	300	240	Shunt	Self	Yes	No	Yes	None
New Orleans Public Serv. Inc. Dryades Substation	1 Syn C 2 Syn MG	W GE	600 514	1500 1000	100% 100%	242 at center of system	265	245	Comp.	Self	Yes	No	No	Crane
New York Edison Co. East 52nd St. Substation	5 Syn C	1 W 4 GE	167	4200 See Note 3	150%	275	310	240	Shunt	Sep. Main Bus	No	Yes	Yes	None
New York Edison Co. Madison Ave. Substation	5 Syn C	W	300	2100 See Note 3	150%	275	310	240	Shunt	Sep.	No	Yes	Yes	Sidewalk Lift & Spec. Cradle
Northern States Power Co. 6th St. Substation	3 Syn MG	2 GE 1 W	514	1000 3000	100% 100%	260	255	230	Inter-pole Shunt	Self or main bus	Yes No	No	No	Crane
Union Gas & Elec. Co. Baker Alley Substation	2 Syn C 2 Syn MG	GE Bul-lock	300 300	3700 1500	100% 100%	255 255	285 280	225 230	Shunt Comp.	Dir. conn. Self or Sep.	Yes Yes	Yes	Yes	Crane

TABLE I—(Continued)

SWITCHBOARD

Substations	Auto or Manual	Source of Control Current	Battery Charging Source	AIR CIRCUIT BREAKERS (MACHINE) High Speed	Mfg. & Type	Rated Volts	Rated Amps.	AIR CIRCUIT BREAKERS (FEEDER) High Speed	Mfg. & Type	Rated Volts	Rated Amps.	KNIFE SWITCH Mfg.	Rated Amps.
AUTOMATIC													
Kansas City Power & Lt.Co. Substation "T"	Auto	Trans.	-	No	GE-CK3	650	6000		None	-	-	GE	2000
Union Gas & Elec. Co. Jackson St. Substation	Auto	Batt	Float on Ed.Sys.	No.	GE-CK	250	10000		None	-	-	GE	1600
NON-AUTOMATIC													
Cleveland Elec.Ill.Co. Bolivar Substation	Semi-Auto	Batt	Trickle DC/DC MG Set	Yes No	GE-CJ GE-CK	250	20000 12000		None	-	-	Leonard El. Co.	6-4000
Commonwealth Edison Co. Burnhom Bldg. Substation	Manual	Batt	DC Bus	No	And. Cutter	300	16000 4000 3000 2000		None	-	-	And.	3-5800 Mch. 2000 fdrs.
Detroit Edison Co. Charlotte Substation	Manual	Batt	MG	No	And.-E	300	10000		None	-	-	And.	10000 mch. 2400 fdrs.
Edison El.Ill.Co.of Boston Carver St. Substation	Manual	Aux. Bus	-	No	And.-E	300	15000	No	And.Fdr.	250	1500	T&M	15000
Milwaukee El.Ry.& Lt.Co. Stephenson Bldg.Substation	Semi-Auto	Ed. System		Yes No	GE-CJ GE-CK	250	20000 10000		None	-	-	Trumb.	3-6000 ea.
New Orleans Public Serv.Inc. Dryades Substation	Manual	Batt	MG	No (RO) No (MG)	W-CA GE-CK3	260 650	10000 6000		None	-	-	W W GE	800 Fdr. 10000 Syn C 6000 MG
New York Edison Co. East 32nd St. Substation	Manual	Batt	Float MG	No	And.-"H"	300	20000	No	GE-SA-2	300	2500	And.	Mch. 20000
New York Edison Co. Madison Ave. Substation	Manual	Batt	Float MG	No	And.-"H"	300	12000	No	GE-SA-3	300	2500	And.	12000 Mch. 1500} Fdrs. 2500}
Northern States Power Co. 6th St. Substation	Manual	Batt	Float MG	No	GE-CTC GE-C Form 3	250	6000 10000		None	-	-	GE DS	1000 Fdrs. 3000 Mch.
Union Gas & Elec. Co. Baker Alley Substation	Semi-Auto	Batt	MG	No	And.-E	250	MG 6000 Syn C 20000	No	And.-E	250	2400	None	

Substations	SWITCHBOARD Auto Re-Closing Features	Swbd. Framed Insulated	Ins.Fl. Mat. Around Mch. & Swbd.	Load Lim. Res. Min.	Load Lim. Res. Amp.	LOW TENSION & D.C. SIDE — OIL CIRCUIT BREAKERS Mfr. & Type	Rated Volts	Rated Amps.	Auto or Non Auto	STARTING SWITCHES Kind	Mfr. & Type	Rated Volts	Rated Amps.
AUTOMATIC													
Kansas City Power & Lt. Co. Substation "T"	None	Yes	Both	Cont.	12000	None	-	-	-	OCB	GE-K12	15000	500
Union Gas & Elec. Co. Jackson St. Substation	None	No	No	None	-	None	-	-	-	OCB	GE-FK 158 A	15000	600
NON-AUTOMATIC													
Cleveland Elec.Ill.Co. Bolivar Substation	None	No	Swbd.	Cont.	16000	None	-	-	-	None	-	-	-
Commonwealth Edison Co. Burnham Bldg. Substation	None	Yes	Both	5 Sec.-for inverted op.	10000	None	-	-	-	OCB	GE-K12	15000	500
Detroit Edison Co. Charlotte Substation	None	No	Swbd.	None	-	None	-	-	-	OCB	GE-K12	15000	500 stg. 300 run.
Edison El.Ill.Co.of Boston Carver St. Substation	None	Yes	Swbd.	None	-	None	-	-	-	None	-	-	-
Milwaukee El.Ry.& Lt.Co. Stephenson Bldg. Substation	None	Yes	Swbd.	5	19000	None	-	-	-	None	-	-	-
New Orleans Public Serv.Inc. Dryades Substation	None	No	Both	None	-	None	-	-	-	(Syn C) Knife (MG) OCB	W-TPDT GE-FK 17	500 15000	4000 300
New York Edison Co. East 32nd St. Substation	None	No	No	None	-	None	-	-	-	Contactors	GE-CR-2800	250	1500
New York Edison Co. Madison Ave. Substation	None	No	No	None	-	None	-	-	-	Contactor	GE-CR-2800	250	600
Northern States Pr. Co. 6th St. Substation	None	No	Tile	None	-	None	-	-	-	Knife Step Sw.	GE W	250	1200 2000
Union Gas & Elec. Co. Baker Alley Substation	None	No	No	MG-None Syn 0-5 sec.	20000	None	-	-	-	OCB	GE-FK-152 B	15000	600

TABLE I—(Continued)

LOW TENSION & D.C. SIDE

	POT. TRANS.		CURRENT TRANS.			D.C. FEEDERS					LIGHTNING ARRESTERS	
Substations	Mfr. & Type	Ratio	Mfr. & Type	Ratio	No. per Circuit	Location	Pres. Number	Ult. Number	Present Size	Ultimate Size	Mfr. & Type	Location
AUTOMATIC												
Kansas City Power & Lt. Co. Substation "T"	None	-	GE-K48	4000/5	3	U.G.	18	15	1,000 MCM 1,500 MCM	1,000 MCM 1,500 MCM	None	-
Union Gas & Elec Co. Jackson St. Substation	None	-	None	-	-	U.G.	12	24	1,500 MCM	1,500 MCM 2,000 MCM	None	-
NON-AUTOMATIC												
Cleveland Elec.Ill.Co. Bolivar Substation	None	-	None	-	-	U.G.	38	50	2,000 MCM	2,000 MCM	None	-
Commonwealth Edison Co. Burnham Bldg. Substation	None	-	None	-	-	U.G.	28	60	1,500 MCM 2,000 MCM	1,500 MCM 2,000 MCM	None	-
Detroit Edison Co. Charlotte Substation	W-VS	40/0	GE-K75	600/5	1	U.G.	51	126	21-750 MCM 10-1000 MCM	750 MCM or 1,000 MCM	None	-
Edison El.Ill.Co.of Boston Carver St. Substation	None	-	None	-	-	U.G.	19	96	1,500 MCM	1,500 MCM	None	-
Milwaukee Ry.& Lt.Co. Stephenson Bldg. Substation	None	-	GE	8000/5	1	U.G.	19	36	2,000 MCM	2,000 MCM	None	-
New Orleans Public Serv.Inc. Dryades Substation	None	-	None	-	-	U.G.	35	35	1,000 MCM	1,000 MCM	None	-
New York Edison Co. East 32nd St. Substation	None	-	None	-	-	U.G.	59	79	1,000 MCM 2,500 MCM	2,500 MCM	None	-
New York Edison Co. Madison Ave. Substation	None	-	None	-	-	U.G.	29	44	1,000 MCM 2,500 MCM	2,500 MCM	None	-
Northern States Power Co. 6th St. Substation	None	-	None	-	-	U.G.	22		2,000 MCM		None	-
Union Gas & Elec. Co. Baker Alley Substation	None	-	None	-	-	U.G.	28	60	1-2500 MCM 22-2000 MCM 4-1500 MCM 1-1000 MCM	2,000 MCM 1,000 MCM	None	-

LOW TENSION & D.C. SIDE

STANDBY STORAGE BATTERIES

Substations	No.	Mfg.	Type	No. of Cells	Rating Amp. Hrs.	Floating
AUTOMATIC						
Kansas City Power & Lt. Co. Substation "T"	None	-	-	-	-	-
Union Gas & Elec. Co. Jackson St. Substation	None	-	-	-	-	-
NON-AUTOMATIC						
Cleveland Elec.Ill.Co. Bolivar Substation	1	ESB	H-137	150	10,000	Yes
Commonwealth Edison Co. Burnham Bldg. Substation	1	ESB	H-141	150	10,500	Yes
Detroit Edison Co. Charlotte Substation	None	-	-	-	-	-
Edison El.Ill.Co.of Boston Carver St. Substation	2	ESB	H-141	130	17,360	Yes
Milwaukee El.Ry.& Lt.Co. Stephenson Bldg. Substation	None	-	-	-	-	-
New Orleans Public Serv.Inc. Dryades Substation	None	-	-	-	-	-
New York Edison Co. East 32nd St. Substation	2	ESB	H-79 H-95	154 165	5,850 7,050	Yes
New York Edison Co. Madison Ave. Substation	1	ESB	H-93	154	6,900	Yes
Northern States Power Co. 6th St. Substation	1	ESB	Exide	150	8,184	Yes
Union Gas & Elec. Co. Baker Alley Substation	1		Lead	150	9,300	Yes

SECTION III

AUTOMATIC RAILWAY SUBSTATIONS

Cleveland Railway Co., Cleveland, Ohio—Standard Automatic Substation

The power conversion system at the present time consists of five manually operated substations having a total installed capacity of 31,500 kw. and ten automatic substations with an aggregate capacity of 24,000 kw. The company is definitely committed to the utilization of the automatic substation to the extent that the present manually operated plants are either to be supplemented by automatically operated plants or the present plants automatized. In view of the fact that the entire system will be automatic in the near future, the data herein submitted are limited to the automatic type of substation.

Principal among the unusual features found in these substations are the following:

1. Method of control of outgoing d-c. feeders.
2. Electro-pneumatic contactors.
3. Sheet steel high-tension bus and cell compartments.
4. Remote supervisory control including remote metering.
5. Utilization of the one size converter.
6. Location of current-limiting resistance.

1. Method of Control of Outgoing d-c. Feeders

All substations are equipped with main and auxiliary d-c. positive buses. The d-c. feeders are normally connected through contactors to the main bus, receiving their power from the converters located in each particular substation. In the event of short circuit on a feeder by reason of grounded trolleys, the feeder is automatically transferred to the auxiliary bus without delay. In this position, it receives energy from the main bus through a current-limiting resistance and from additional feeders fed from other stations which may be transferred by the load-dispatcher to the auxiliary bus. When the short circuit has been removed by the burning-off process, the feeder is automatically connected to the main bus again by being retransferred.

2. Electro-pneumatic Contactors

To insure supply of energy to trolleys and further to enable the load-dispatcher to exercise control of d-c. feeders and the system under all conditions, electrically controlled, pneumatically operated locomotive-type contactors have been utilized for all feeders. This type of contactor has also been used for all heavy-current d-c. circuits of the converters.

3. Sheet Steel High Tension Bus and Cell Compartments

To economize space, facilitate erection and obtain lower initial costs, sheet steel bus compartments, switch compartments, and cell structures have been used throughout.

4. Remote Supervisory Control Including Remote Metering

All automatic substations, while designed to operate fully automatically, have superimposed upon their control a complete system of remote supervisory control for the operation of converters and control of outgoing d-c. feeders. This enables securing the most efficient operation from the converters and insures the very highest degree of continuity of service from the substations.

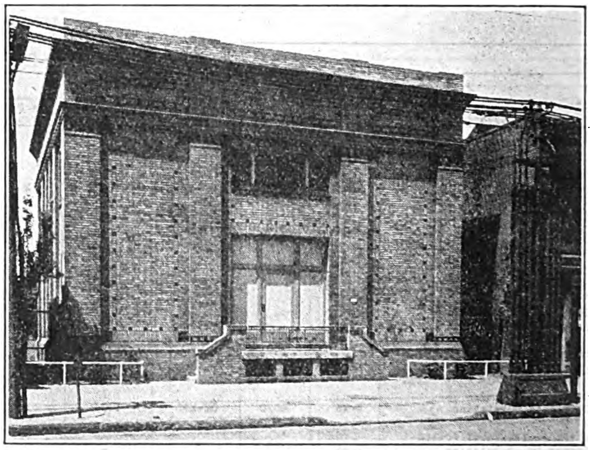


FIG. 79—EXTERIOR, STANDARD TWO-UNIT SUBSTATION, CLEVELAND RAILWAY CO.

The total load of the individual stations in d-c. amperes is indicated in the dispatcher's desk by use of a remote metering system.

5. Utilization of the One Size Rotary Converter

It is interesting to note that all machines on the system, both those in manual and automatic operation, are of one design, type and capacity, namely 1500-kw., 60-cycle.

6. Location of Current Limiting Resistance

Current-limiting resistances for both converter cir-

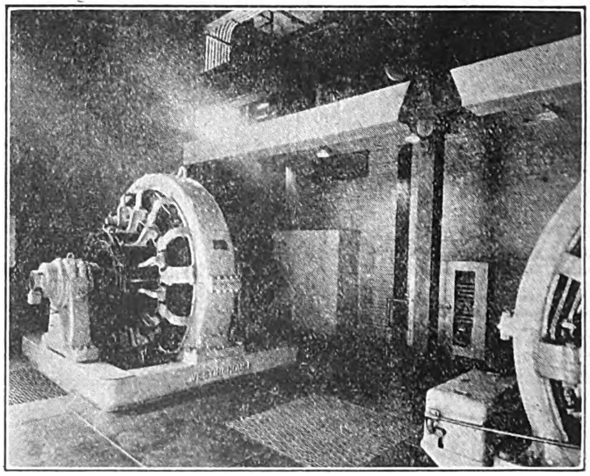


FIG. 80—GENERAL VIEW, MAIN FLOOR, STANDARD TWO-UNIT SUBSTATION, CLEVELAND RAILWAY CO.

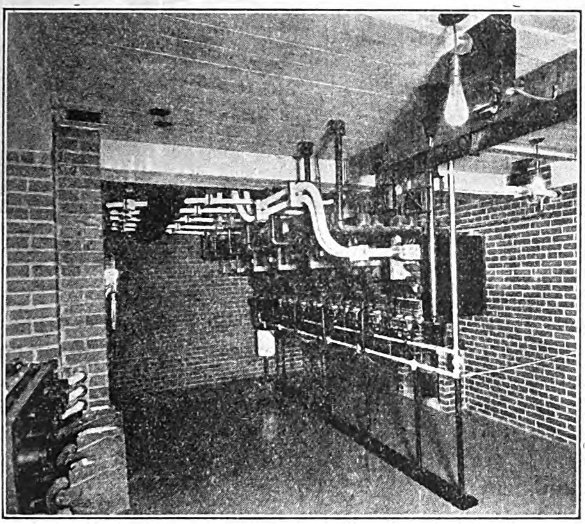


FIG. 81—D. C. Positive Feeder Pneumatically-Operated Contactors, Standard Two-Unit Substation, Cleveland Railway Co.

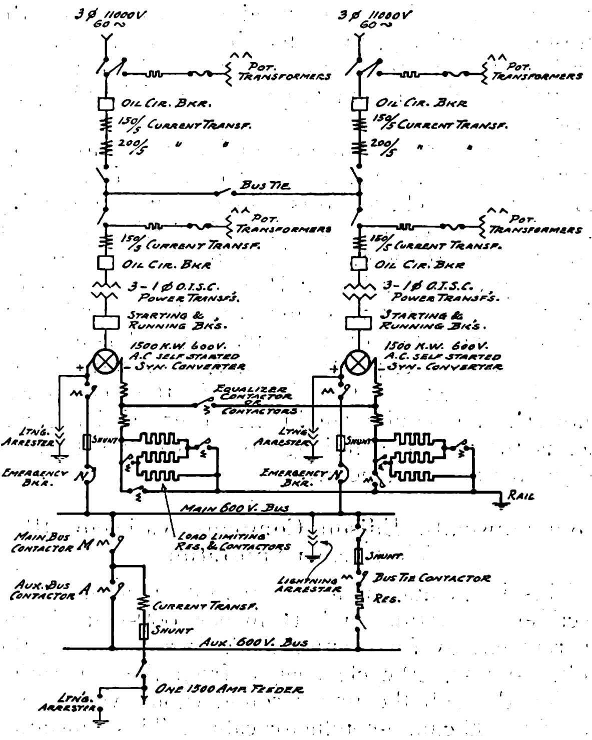

3 ϕ 11000V 60 ~
3 ϕ 11000V 60 ~
Pot. Transformers
Pot. Transformers
Oil Cir. Bkr.
Oil Cir. Bkr
150/5 Current Transf.
150/5 Current Transf.
200/5 " "
200/5 " "
Bus Tie
Pot. Transformers
Pot. Transformers
150/5 Current Transf.
150/5 Current Transf.
Oil Cir. Bkr
Oil Cir. Bkr
3-1 ϕ O.I.S.C. Power Transf's.
3-1 ϕ O.I.S.C. Power Transf's.
Starting & Running Bk's.
Starting & Running Bk's.
1500 K.W. 600V. A.C self started Syn. Converter
1500 K.W. 600V. A.C. self started Syn. Converter
+
-
+
-
M
M
Equalizer Contactor or Contactors
Ltng. Arrester
Ltng. Arrester
Shunt
Shunt
Emergency Bkr.
Emergency Bkr.
N
N
Rail
Main 600 V. Bus
Main Bus Contactor M
Load Limiting Res. & Contactors
Aux. Bus Contactor A
Lightning Arrester
Shunt
Bus Tie Contactor
Res.
Current Transf.
Shunt
Aux. 600 V. Bus
One 1500 Amp. Feeder
Ltng. Arrester

FIG. 82—Single Line Diagram, Standard Two-Unit Substation, Cleveland Railway Co.

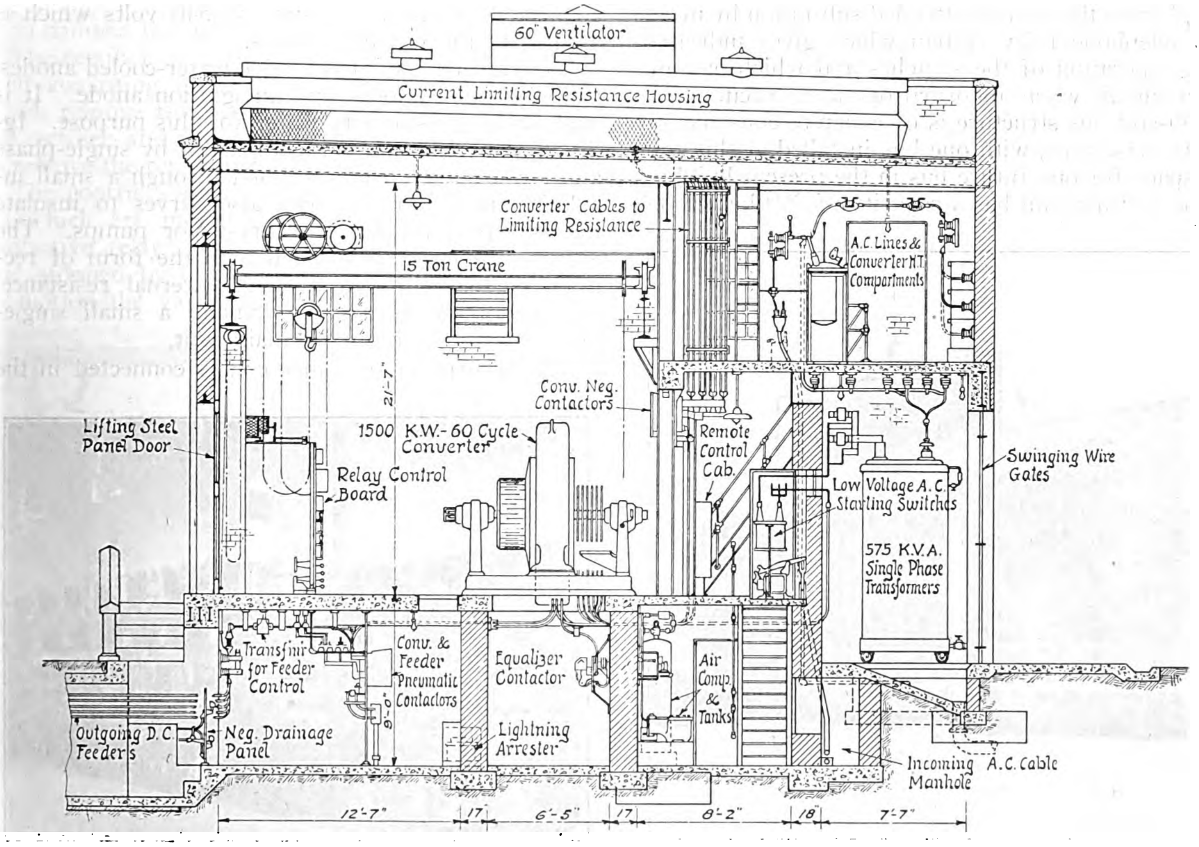

60" Ventilator
Current Limiting Resistance Housing
Converter Cables to Limiting Resistance
15 Ton Crane
A.C. Lines & Converter H.T. Compartments
21'-7"
Conv. Neg. Contactors
1500 K.W.-60 Cycle Converter
Lifting Steel Panel Door
Relay Control Board
Remote Control Cab.
Low Voltage A.C. Starting Switches
575 K.V.A. Single Phase Transformers
Swinging Wire Gates
Transf'mr for Feeder Control
Conv. & Feeder Pneumatic Contactors
Equalizer Contactor
Air Comp. & Tanks
9'-0"
Outgoing D.C. Feeders
Neg. Drainage Panel
Lightning Arrester
Incoming A.C. Cable Manhole
12'-7"
17"
6'-5"
17"
8'-2"
18"
7'-7"

FIG. 83—Section, Standard Two-Unit Substation, Cleveland Railway Co.

cuits and bus ties are located on the roof of the substation building, protected from the elements by steel cabs. In this position there results maximum natural ventilation and reduced size of building interior.

Referring to the accompanying illustrations of equipment, Fig. 80 is a general view of the main floor. In the background is a steel cabinet containing the rotary converter low-voltaged starting switches. To the right of the steel cabinet is the substation supervisory control cabinet. Pneumatic contactors for shunting converter resistance are shown under the left-hand corner of the balcony. Fig. 81 is an illustration of the d-c. positive feeder, pneumatically operated contactors (one-half of the equipment shown). The equipment in the lower left-hand corner is the negative drainage panel for the drainage of subterranean structures.

Commonwealth Edison Company, Chicago, Ill.—West Lawn Substation

This is an automatically operated mercury-vapor rectifier substation and furnishes 600-volt direct-current energy for traction load. It receives 12,000-volt, 3-phase, 60-cycle energy from the generating station through the underground cable system over two 500,000 c.m. 3-conductor cables. This substation together with another remote-controlled substation form a loop which is fed from the nearest attended substation.

The switching of the 12,000-volt feeders is controlled from the nearest attended substation by means of a telephone relay system which gives indication of the operation of the switches and which operates alarm signals when abnormal operation occurs. The 12,000-volt bus structure is of concrete construction, group-phase type, with one bus installed at this time and space for one future bus in the present building.

The rectifier unit has a capacity of 300 kw. at 600 volts with an overload rating of 150 per cent load for 2 hr. and 200 per cent load for one minute. The unit, which was made by the American Brown-Boveri Electric Corporation, consists of a 4410-kv-a. transformer, the rectifier bowl, an absorption reactance coil, vacuum pumps, ignition and excitation equipment.

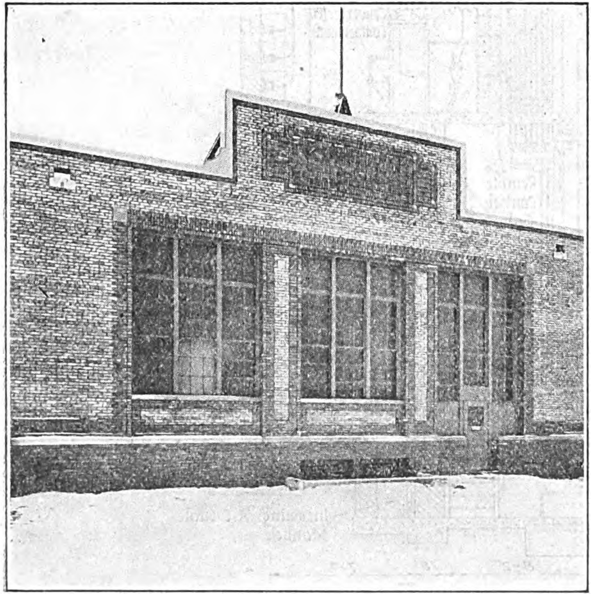


FIG. 84—EXTERIOR, WEST LAWN SUBSTATION.

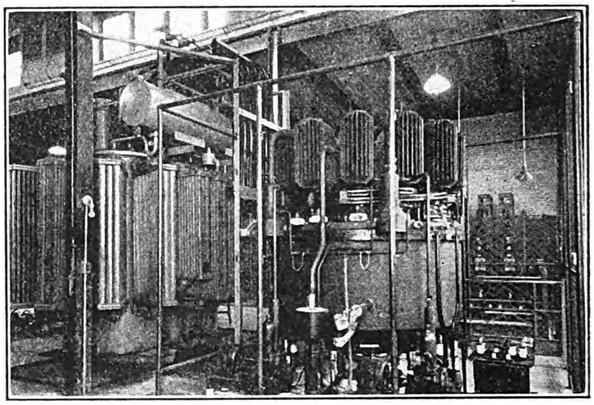


FIG. 85—MERCURY ARC RECTIFIER, WEST LAWN SUBSTATION.

The transformer is oil insulated, self-cooled, indoor type, with cooling radiators and conservator tank. It is 3-phase with the primary winding star connected and having five full taps connected to an internal tap changer, which cannot be operated under load. The secondary winding is double 6-phase fork-connected, giving a pressure of 540 volts which is applied to the rectifier anodes.

The rectifier bowl has twelve water-cooled anodes, two excitation anodes and an ignition anode. It is water-cooled, using city water for this purpose. Ignition and excitation is accomplished by single-phase a-c. low-voltage current applied through a small insulating transformer which also serves to insulate the a-c. feed for the mercury-vapor pumps. The excitation current is dissipated in the form of rectified current through a small external resistance. The excitation system is virtually a small single-phase rectifier within the main unit.

The absorption reactance coil is connected in the

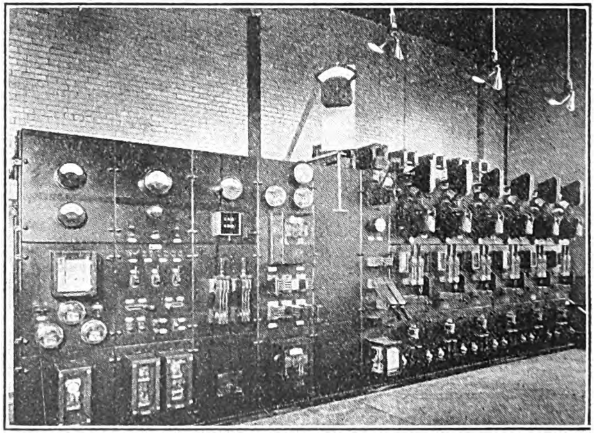


FIG. 86—SWITCHBOARD, WEST LAWN SUBSTATION.

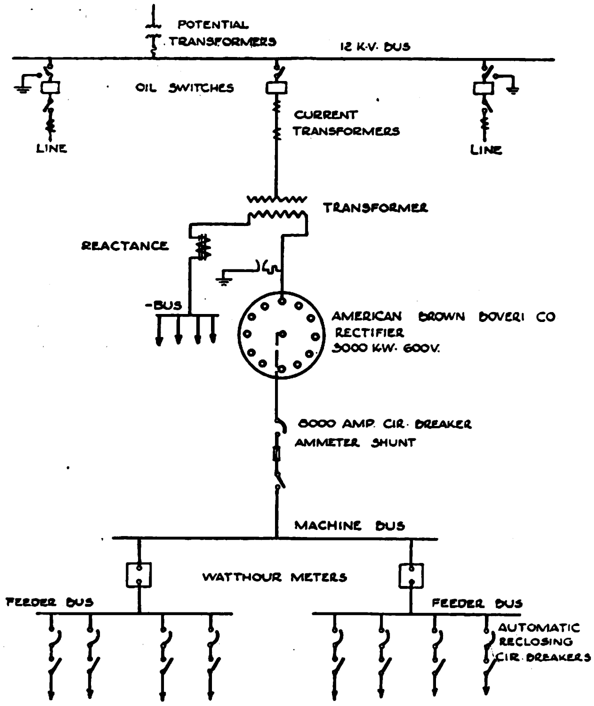

POTENTIAL TRANSFORMERS
12 K.V. BUS
OIL SWITCHES
CURRENT TRANSFORMERS
LINE
LINE
TRANSFORMER
REACTANCE
-BUS
AMERICAN BROWN BOVERI CO RECTIFIER 3000 KW. 600V.
6000 AMP. CIR. BREAKER
AMMETER SHUNT
MACHINE BUS
WATTHOUR METERS
FEEDER BUS
FEEDER BUS
AUTOMATIC RECLOSING CIR. BREAKERS

FIG. 87—Single Line Diagram, West Lawn Substation.

neutral leads of the transformer secondary windings, which also is the 600-volt negative return, and serves to control the voltage regulation of the outfit as well as to dampen the undulations in the rectified voltage.

The rectifier has two complete vacuum pump sets, each consisting of an oil immersed rotary pump, which remove the major portion of air gases from the rectifier, and a mercury-vapor pump which serves to remove the remaining gases.

The control switchboard consists of three panels on which are mounted the necessary control and protective relays. The rectifier is normally started and stopped by means of a time clock which sets in motion the various relays used for this control. By opening certain switches the control can be changed over to hand operation. The rectifier is protected from a-c. and d-c. overload, short circuit, reverse current, overheating, low vacuum, loss of water and continuous overload which is under the definite time overload settings of the relays.

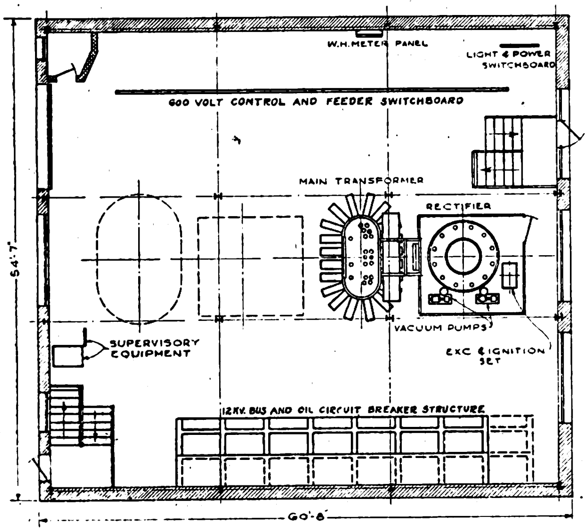

W.H. METER PANEL
LIGHT & POWER SWITCHBOARD
600 VOLT CONTROL AND FEEDER SWITCHBOARD
MAIN TRANSFORMER
RECTIFIER
54'-7"
SUPERVISORY EQUIPMENT
VACUUM PUMPS
EXC. & IGNITION SET
12KV. BUS AND OIL CIRCUIT BREAKER STRUCTURE
60'-6"

FIG. 88—Plan, West Lawn Substation.

Since this substation feeds directly to the customer, metering is required. This is accomplished by three single-phase a-c. watt-hr. meters connected in the primary side of the main transformer and by two Thompson d-c. watt-hr. meters connected between the main 600-volt bus and the 600-volt feeder bus, to which the customer's feeders are connected.

The feeder equipment consists of General Electric Type MC-2 4000-ampere, automatic reclosing air circuit breakers. They open on overload and reclose only when the load current is reduced to a predetermined value. There is no limit to the number of reclosings.

Special Features

Vacuum control is independent of the operation of the unit. By means of an electric hot wire vacuum gage and vacuum control relay, the mercury and rotary vacuum pump are started and stopped dependent on the condition of the vacuum.

The amount of water flowing through the rectifier bowl is controlled by means of a sylphon temperature relay placed in the water discharge system. This relay controls a valve in the cold water line to the rectifier.

The city cooling water is filtered with a gravel filter to eliminate fine silt which, when present, is deposited on the bottom of the rectifier bowl. An auxiliary water pump is installed to compensate for loss of pressure through the filter. It is automatically controlled by means of a pressure regulator.

The basement portion of the substation is heated by a hot water system and an automatic gas-fired water heater regulated to maintain a temperature of approximately 40 deg. fahr.

A 20-pen Bristol operation recorder is used to record starting and stopping of rectifiers, opening and closing of a-c. and d-c. circuit breakers and all feeder circuit breakers.

An annunciator is connected to give a visible signal when excess temperature or low vacuum occurs in the rectifier bowl and when the substation is locked out.

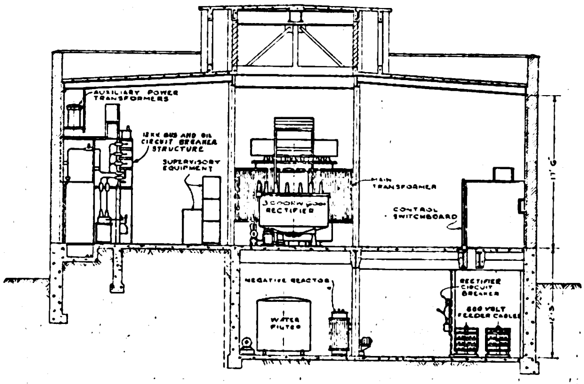

AUXILIARY POWER TRANSFORMERS
12KV BUS AND OIL CIRCUIT BREAKER STRUCTURE
SUPERVISORY EQUIPMENT
3000 KW RECTIFIER
MAIN TRANSFORMER
CONTROL SWITCHBOARD
17'-6"
NEGATIVE REACTOR
WATER FILTER
RECTIFIER CIRCUIT BREAKER
600 VOLT FEEDER CABLES

FIG. 89—Section, West Lawn Substation.

The Denver Tramway Corporation, Denver, Colo.—Colfax Substation

This substation is one of the eleven operated by the Denver Tramway Corp. for street car service. Since this substation is the most modern of the system, the data in this report will apply only to it.

Old Equipment

The equipment in this substation has previously consisted of three 300-kw., Westinghouse rotary converters with three single-phase air blast Westinghouse transformers. The station was operated manually, taking power from the 3-phase, 13,200-volt, 25-cycle, a-c. transmission line and converting it to 600-volt d-c. power for railway service. The switchboard consisted of Westinghouse a-c. and d-c. machine panels and nine feeder panels for 600-volt d-c. railway service.

Recently this substation has been completely rearranged and new equipment added. The three 300-kw. rotary converters with their three single-phase transformers and a-c. and d-c. machine panels have been rearranged as to location in the station. All the old d-c. 600-volt feeders have been removed, and this old equipment is now used only as standby equipment.

New Automatic Equipment

New equipment consisting of a 1000-kw., General Electric rotary converter with a 1050-kv-a. self (oil) cooled General Electric transformer and a complete General Electric switchboard consisting of starting and running panel, d-c. machine panels and four d-c., 600-volt feeder panels for full automatic control of the station, have been installed. In addition to the automatic control feature of the station, supervisory control equipment for control of this station from the Platte Street generating station was incorporated into the design. This supervisory control equipment is of the audible selector type.

A-C. Feeder System

The various substations of the system are on a 3-phase, 25-cycle, 13,200-volt a-c. ring circuit running from the Platte Street generating station. This circuit, under normal operating conditions, is sectionalized at Colfax substation, the circuit thus being divided into a north and a south circuit. Under the old conditions of manually operating the station, this sectionalizing of the circuit was done by means of Maxwell switches mounted outside of the station. This substation normally takes power from the south circuit, but in case of line failure power can be obtained from the north circuit by means of manually sectionalizing the high tension line. Thus by installing automatic control equipment in Colfax substation it was necessary to have some means of sectionalizing the high tension ring circuit by means of remote control. For this reason supervisory control equipment was installed in the station so that the dispatcher at Platte Street generating station can control the sectionalizing of the high tension ring circuit as well as control the station equipment. Included in the new station equipment are two motor-operated oil circuit breakers which are used to sectionalize the high tension circuit. The motors are operated by a storage battery installed in the station. The operation of these oil circuit breakers is controlled from the dispatcher's station of the Platte Street generating station.

Supervisory Control

The Audible Selector Supervisory System has been designed to operate over the two telephone wires now installed between Colfax substation and the dispatcher's station at the Platte Street generating station. The dispatcher at the generating station can perform the following operations at the substation:

1. Open and close two non-automatic oil circuit breakers.
*2. Start and stop the rotary converter.
*3. Close to automatic or trip and hold out the four d-c. 600-volt feeders.
*4. Trip one manually operated oil circuit breaker.

The following indications will be made at the dispatcher's station by means of a high frequency howler:

1. Open and closed position of the two oil circuit breakers used to sectionalize the high tension ring circuit.
2. Running and stopped position of the rotary converter indicated by the closing or opening of the d-c. line contactor.
3. Open and closed position of the four d-c. feeders.
4. Open and closed position of the manually operated oil circuit breaker.

Automatic Control of the 1000-Kw. Rotary Conveyor and D-C. Feeders

The automatic switching equipment functions as follows:

When the indication is given by the supervisory control equipment and on load demand, the rotary converter is connected to partial voltage taps on the power transformer. When synchronous speed is reached, the field is separately excited for a short time to insure correct polarity and is later made self excited. The transfer is then made from the partial to the full voltage taps of the transformer, the brushes are lowered on the commutator and the machine is connected to the d-c. bus through the load limiting resistors if the polarity is correct. These resistors are then successively shunted and the machine takes load.

The rotary converter is shut down within a definite time after the load on it has been reduced below 5 per cent (adjustable from 5 to 20 per cent) of machine rating, and the bus voltage is normal, or by the supervisory control equipment.

---

*These operations have been discontinued as there is danger of the station being shut down unnecessarily due to the dispatcher being unaccustomed to the operation of the supervisory system.

The machine load limiting equipment is included to:

1. Limit the amount of overload and prevent it being carried continuously.
2. Allow the shifting of a portion of the load to other stations feeding into the same network.
3. Prevent the machine from being connected directly to a heavy load in such a way as would cause a disturbance to the system.
4. Shut down the machine when the load limiting resistors tend to overheat and allowing restart only when the resistors have cooled.

The automatic equipment provides protection against:

1. Starting with
- (a) Low a-c. line voltage.
- (b) Single-phase or reverse-phase rotation of a-c. supply.
- (c) D-c. brushes not raised from the commutator.

2. Operating with
- (a) Low a-c. voltage.
- (b) D-c. reverse current or d-c. underloads.
- (c) Overheated rotary converter windings.
- (d) Single or badly unbalanced phases.
- (e) Overheated load limiting resistors.

NOTE: The converter may restart or be reconnected to the d-c. bus when the proper conditions have been re-established.

3. Operating when
- (a) Starting sequence is incomplete.
- (b) A-c. short circuit occurs.
- (c) Rotary converter field fails.
- (d) Rotary converter overspeeds.
- (e) Rotary converter flashes to ground.
- (f) Bearings overheat.

NOTE: Under any one of the above conditions, the equipment will shut down and lock out the station. Manual attention will be required before the converter can be restarted.

The d-c. reclosing feeder equipment with MC-2 Breaker will:

1. Trip at a predetermined current setting in case of a gradual steady increase in load.
2. Reclose on stub or multiple feed from either side.
3. Reclose the feeder within a minimum definite time after the feeder has been disconnected, provided the load is not excessive.

Station Ventilation

Since this substation runs fully automatic, ventilation becomes an important factor. The air is taken from outside the building and brought into the station through an air tunnel terminating at both ends of the converter. The fan action of the revolving armature tends to draw in the air and cause it to flow into the machine parallel to the shaft. Installed on the roof of the station over the rotary converter is a 60-in. Aeolus natural draft ventilator. The combined action of the revolving machine armature and the suction of the roof ventilator ventilates the station very satisfactorily.

The ventilator is so situated on the roof that no station apparatus is directly under the ventilator opening. Thus if any snow is driven in the ventilator, the condensate thus caused cannot drip on any piece of equipment and cause damage. The ventilator is equipped with a damper operated from the floor, and in the air tunnel another damper is installed. By manipulation of these dampers the ventilation of the station can be regulated.

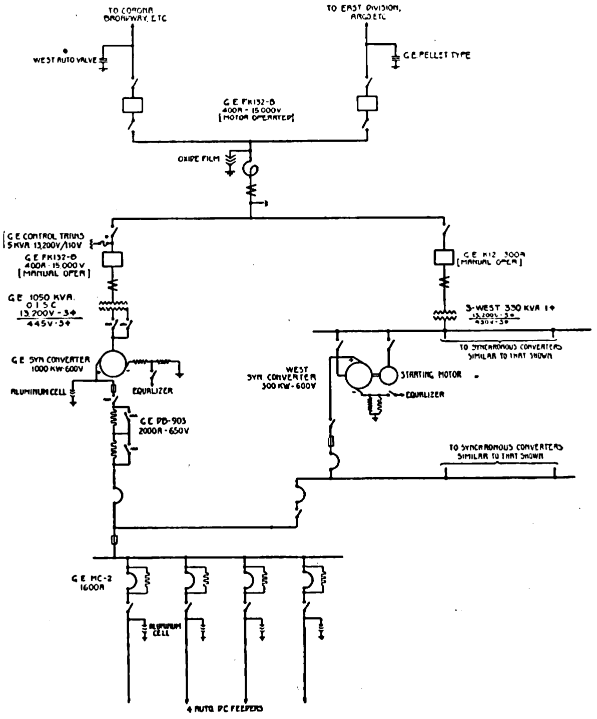

TO CORONA BROADWAY, ETC
TO EAST DIVISION, ARGO ETC
WEST AUTO VALVE
G E PELLET TYPE
G E FK132-B 400A - 15 000V [MOTOR OPERATED]
OXIDE FILM
[G E CONTROL TRANS 5 KVA 13,200V/110V]
G E FK132-B 400A 15 000 V [MANUAL OPER]
G E K12 300A [MANUAL OPER]
G E 1050 KVA. O I S C 13,200V - 3ϕ / 445V - 3ϕ
3-WEST 330 KVA 1ϕ 13,200V - 3ϕ / 430V - 3ϕ
TO SYNCHRONOUS CONVERTERS SIMILAR TO THAT SHOWN
G E SYN CONVERTER 1000 KW 600V
WEST SYN. CONVERTER 300 KW - 600V
STARTING MOTOR
ALUMINUM CELL
EQUALIZER
EQUALIZER
G E PB-903 2000A - 650V
TO SYNCHRONOUS CONVERTERS SIMILAR TO THAT SHOWN
G E MC-2 1600A
ALUMINUM CELL
4 AUTO DC FEEDERS

FIG. 90—SINGLE LINE DIAGRAM, COLFAX SUBSTATION.

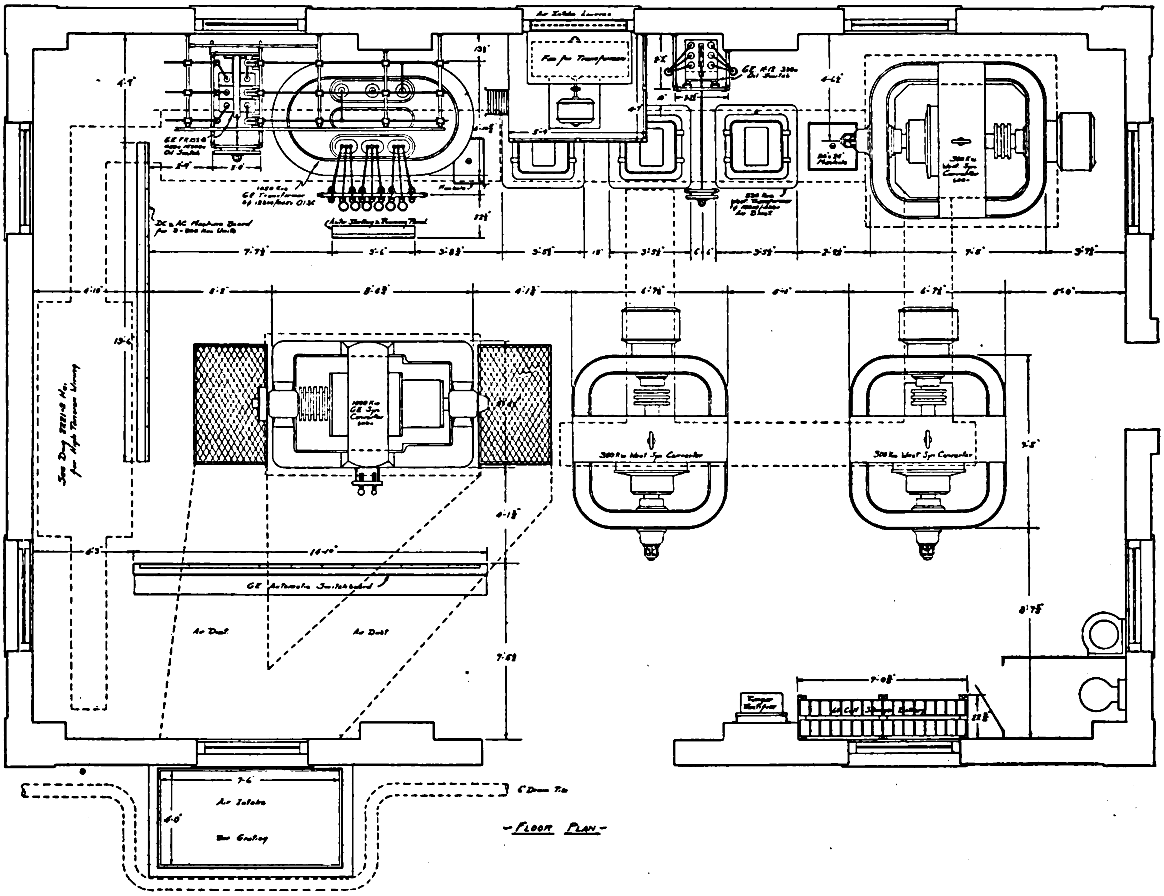

Air Intake Louvres
Fan for Transformer
GE FRA20 Oil Switch
1050 Kva GE Transformer
DC & AC Machine Board for 3-300 Kw Units
Auto Starting & Running Panel
GE K12 Oil Switch
Manhole
300 Kw West Transformer Air Blast
300 Kw West Syn Converter
1000 Kw GE Syn Converter
300 Kw West Syn Converter
300 Kw West Syn Converter
GE Automatic Switchboard
Air Duct
Air Duct
Air Intake
Bar Grating
6" Drain Tile
FLOOR PLAN
7'-6"
6'-0"
7'-7½"
3'-6"
3'-8½"
3'-5½"
3'-5½"
7'-8"
4'-10"
8'-2"
8'-4½"
4'-1½"
6'-7½"
6'-4"
6'-7½"
6'-0"
13'-6"
14'-0"
7'-5"
8'-7½"
7'-5½"
4'-1½"
4'-6½"

FIG. 91—PLAN, COLFAX SUBSTATION.

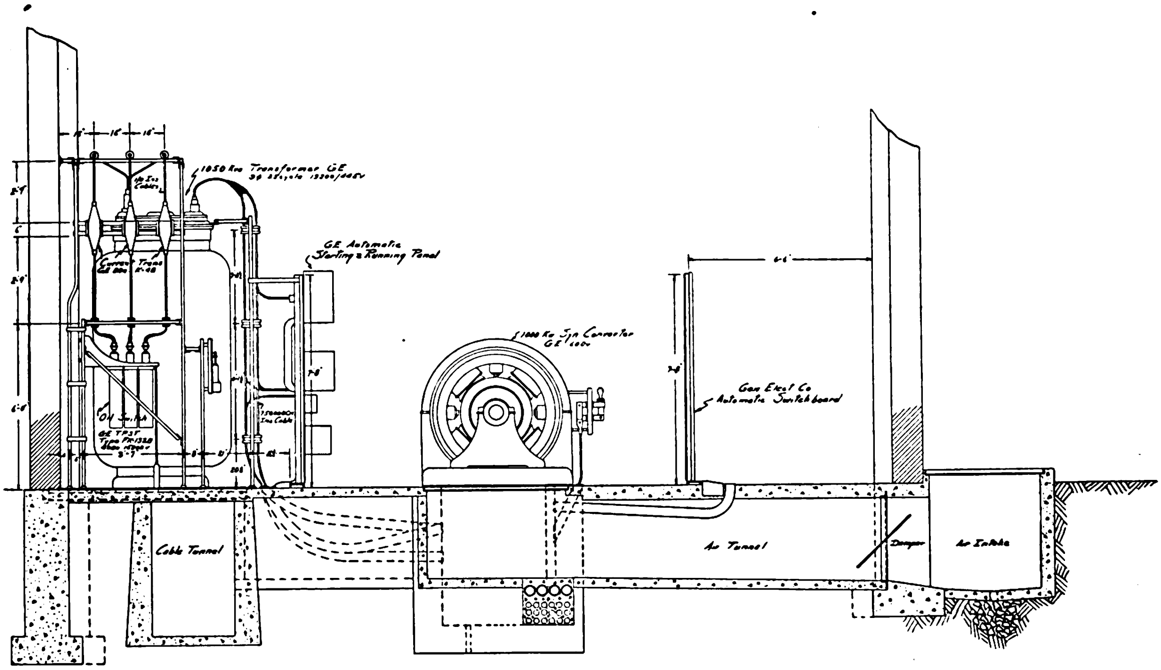

1050 Kva Transformer GE
3φ 25 cycle 13200/445V
Current Trans
Oil Switch
GE TPST
Type FK-132B
GE Automatic
Starting & Running Panel
1000 Kw Syn Converter GE 600v
Gen Elect Co Automatic Switchboard
Cable Tunnel
Air Tunnel
Damper
Air Intake
16"
16"
6'-6"
7'-8"
8'-9"
8'-9"

FIG. 92—END ELEVATION, COLFAX SUBSTATION.

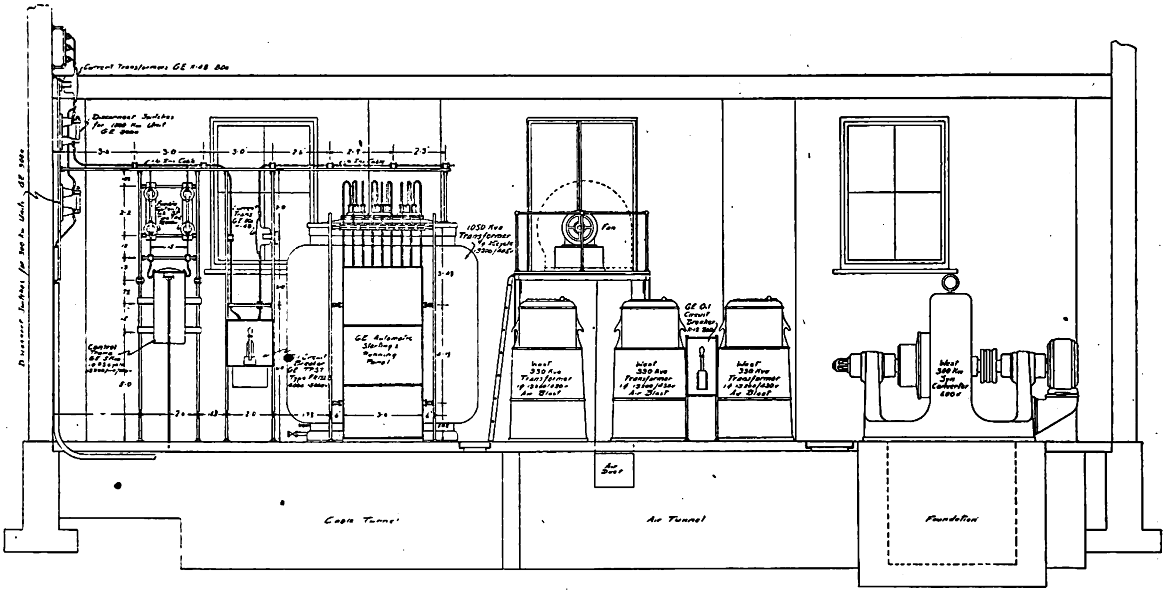

Current Transformers GE
Disconnect Switches for 1000 Kw Unit GE
Disconnect Switches for 300 Kw Unit GE
Control Trans GE
Current Trans GE
Circuit Breaker GE
GE Automatic Starting & Running Panel
1050 Kva Transformer 25 cycle 13200/
Fan
West 330 Kva Transformer Air Blast
GE Oil Circuit Breaker
West 300 Kw Syn Converter 600 v
Air Duct
Cable Tunnel
Air Tunnel
Foundation

FIG. 93—SIDE ELEVATION, COLFAX SUBSTATION.

The Detroit Edison Co., Detroit, Mich.—Roseville Substation

This substation supplies both a-c. distribution to the village of Roseville, and railway power. Data included in these notes apply to the d-c. part of the station only. The automatic rotary converter in this station is one of several located at various points along the route of the Port Huron Division of the Detroit United Railway. These are all identical as regards control and operation. The rotary converter with control was furnished complete by the Westinghouse Electric & Manufacturing Co. and is their standard type of automatically controlled machine.

This substation has no fire protection, except that furnished by fireproof construction and by Pyrene fire extinguishers placed in accessible positions. The entire substation, a-c. and d-c., is designed for operation without attendance, as it is looked after by an operator who is also in charge of several other automatic substations.

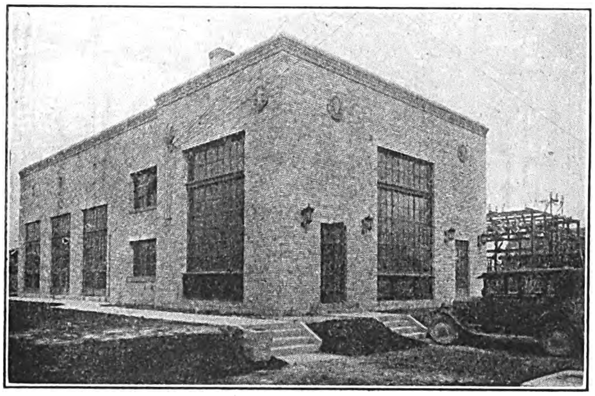


FIG. 94—EXTERIOR, ROSEVILLE SUBSTATION.

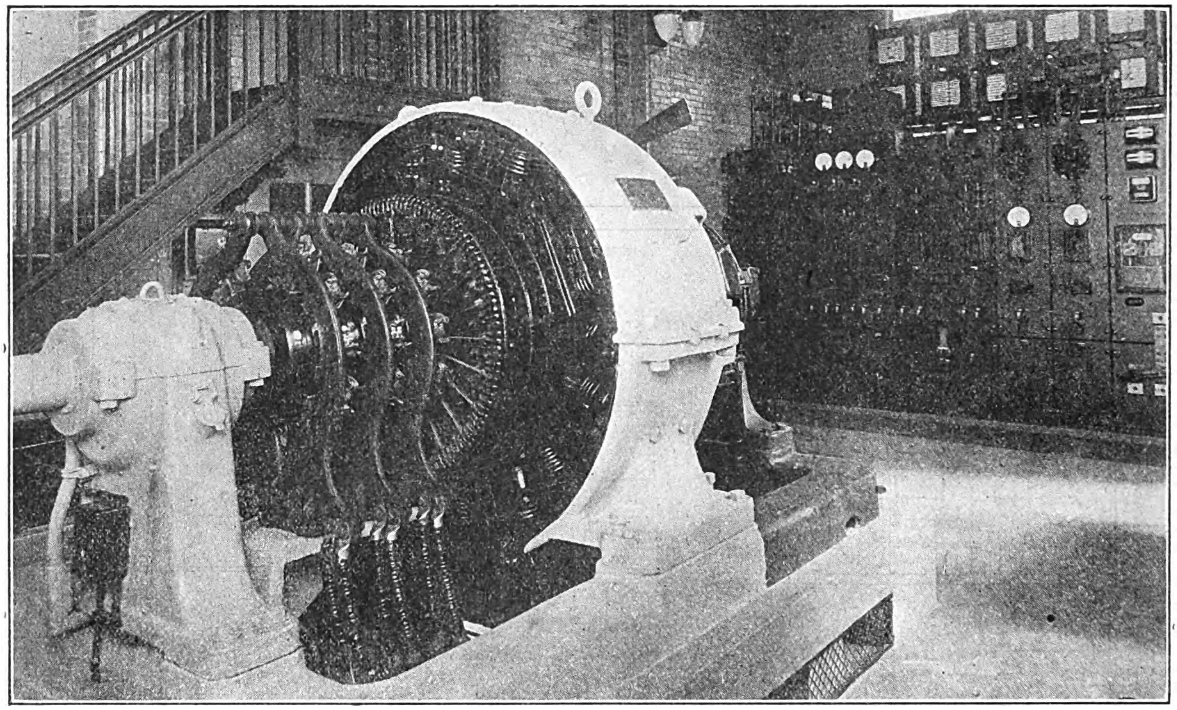


FIG. 95—1000-Kw. Synchronous Converter, Roseville Substation.

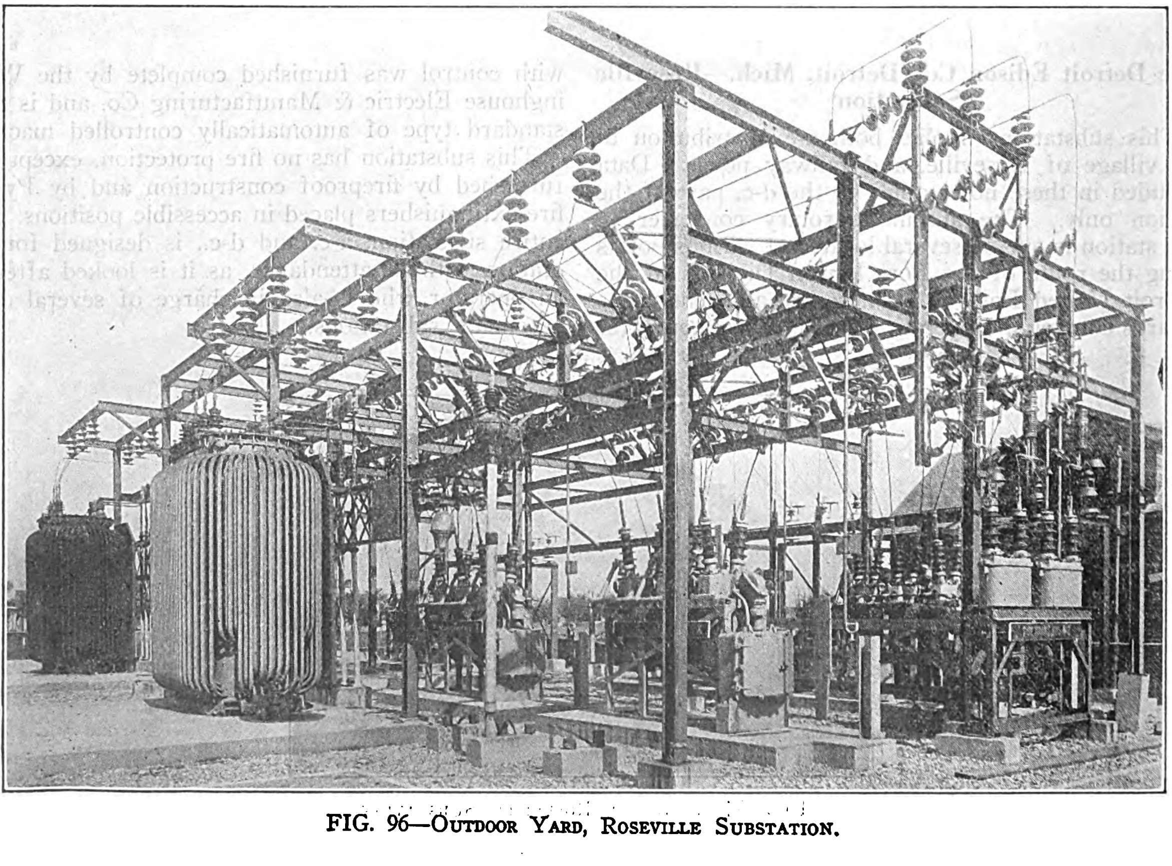


FIG. 96—Outdoor Yard, Roseville Substation.

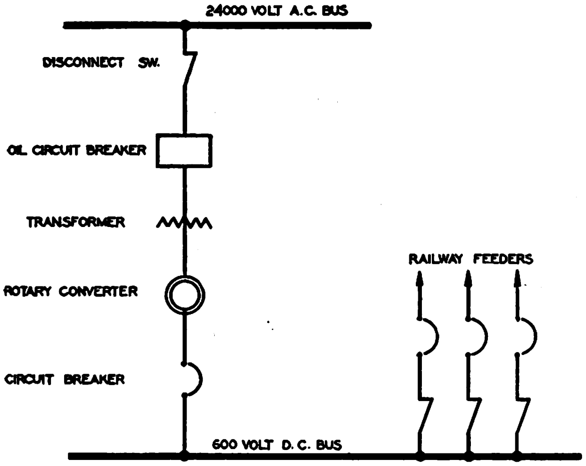

24000 VOLT A.C. BUS
DISCONNECT SW.
OIL CIRCUIT BREAKER
TRANSFORMER
ROTARY CONVERTER
CIRCUIT BREAKER
RAILWAY FEEDERS
600 VOLT D.C. BUS

FIG. 97—Single Line Diagram, Roseville Substation.

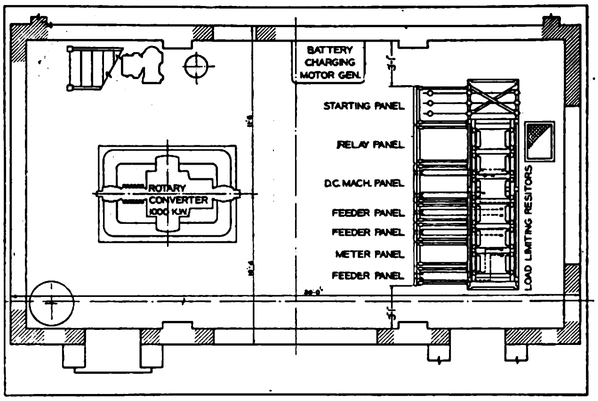

BATTERY CHARGING MOTOR GEN.
STARTING PANEL
RELAY PANEL
D.C. MACH. PANEL
FEEDER PANEL
FEEDER PANEL
METER PANEL
FEEDER PANEL
LOAD LIMITING RESITORS
ROTARY CONVERTER 1000 K.W.

FIG. 98—Plan, Roseville Substation.

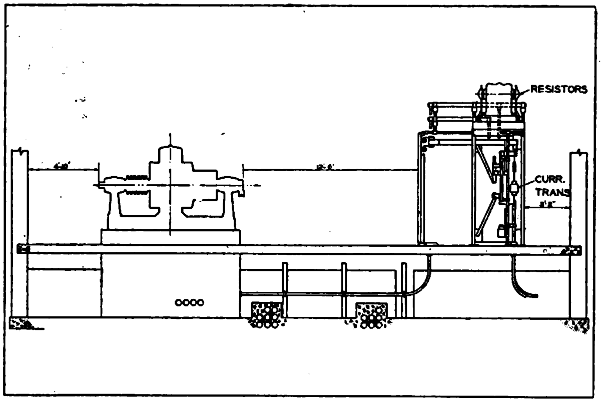

RESISTORS
CURR. TRANS

FIG. 99—Section, Roseville Substation.

Duquesne Light Co., Pittsburgh, Pa.—Maple Substation

This substation consists primarily of two 1000-kw. rotary converters with the necessary switching equipment to furnish service to the Pittsburgh Railways Co.

The energy is received at 22,000 volts over two lines. A feature of the station is that no 22,000-volt oil circuit breakers are used.

The transmission line is sectionalized by means of air break switches, and the rotary converter transformers are connected to these lines by means of air break switches. Automatic switching, in case of rotary converter trouble, is accomplished by oil circuit breakers between the transformers and the rotary converter. The connections are so arranged that the air break switch controlling the transformer will open a predetermined time after the rotary converter is shut down, thus de-energizing the transformer.

The substation is entirely automatic, and uses a battery for the source of control. Indication is provided in the system operator's office to show that the substation is functioning properly.

Special attention has been paid to ventilation and to the reduction of objectionable noise. The intake air is drawn into ducts under the floor from the top of the building through ducts extending up the building wall. The air is drawn into the rotary converter through a grating in the floor at each end of the machine outside of the pedestal. A portion of the air is discharged from the rotary converter through a duct underneath the floor connecting to a duct up the building wall. The remaining portion is discharged into the room and is drawn from the building through a roof ventilator.

The interior walls of the building are of tile. The use of this tile and the method of ventilation have resulted in the elimination of objectionable noise in the vicinity. The ventilation has also been very effective.

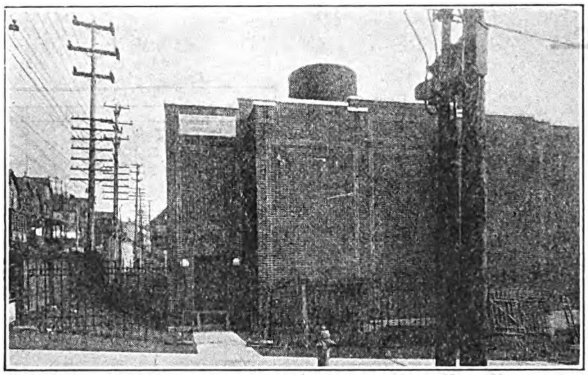


FIG. 100—EXTERIOR, MAPLE SUBSTATION.

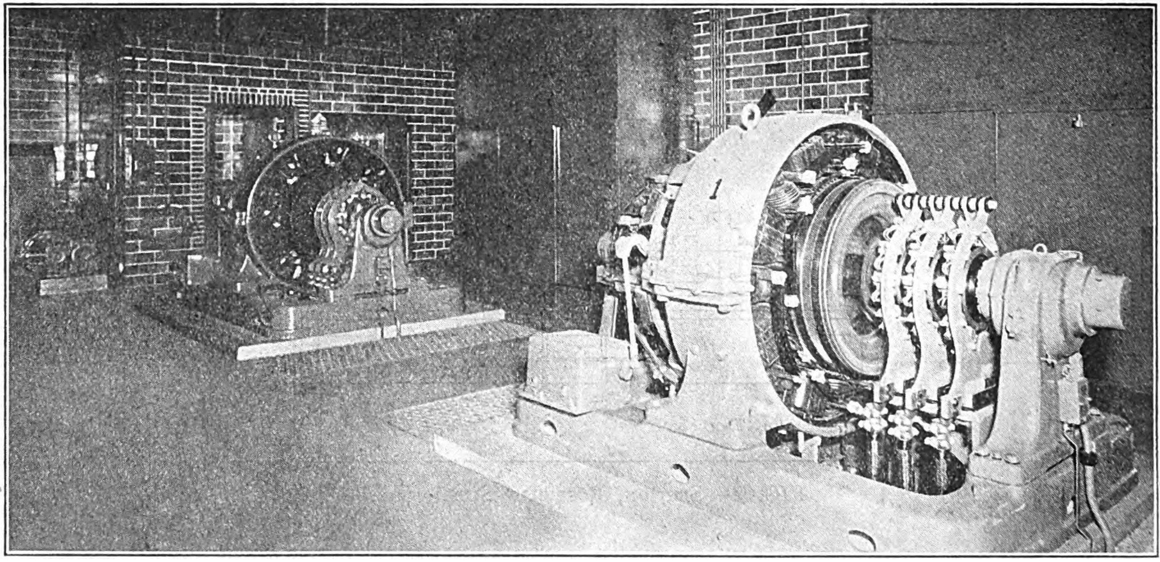


FIG. 101—SYNCHRONOUS CONVERTERS, MAPLE SUBSTATION.

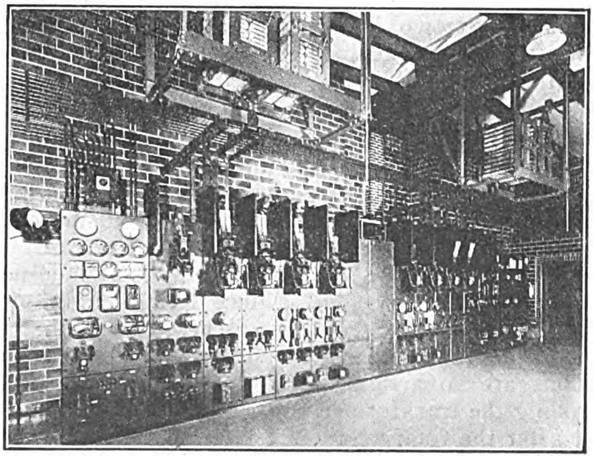


FIG. 102—SWITCHBOARD, MAPLE SUBSTATION.

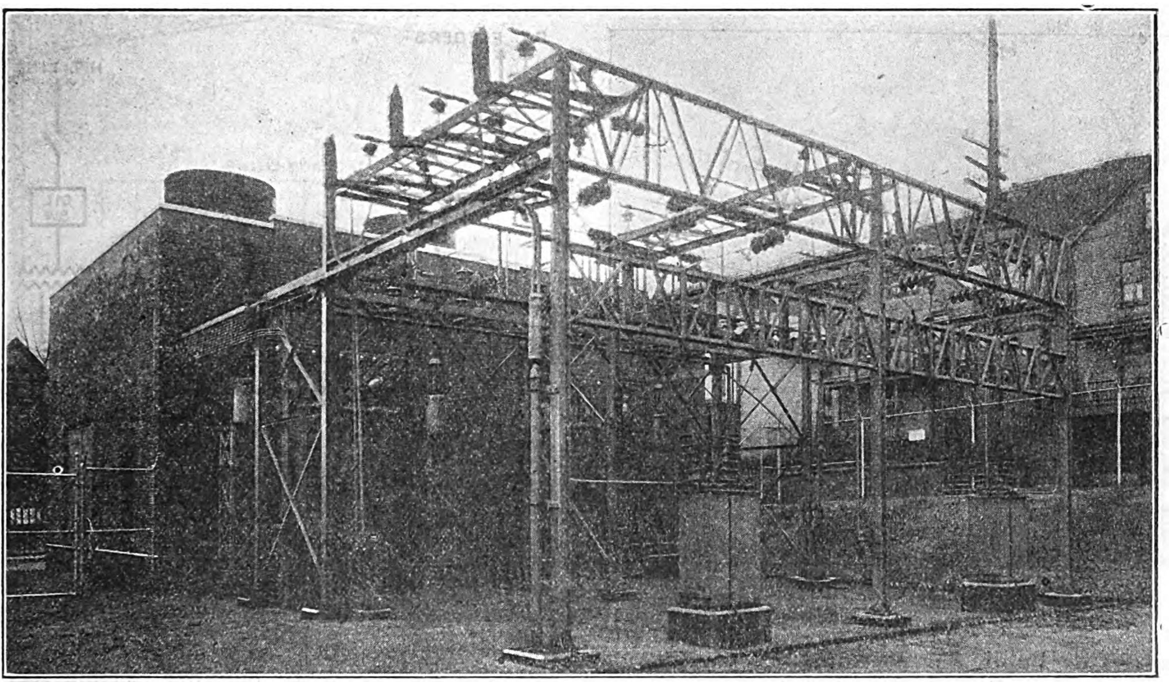


FIG. 103—OUTDOOR YARD, MAPLE SUBSTATION.

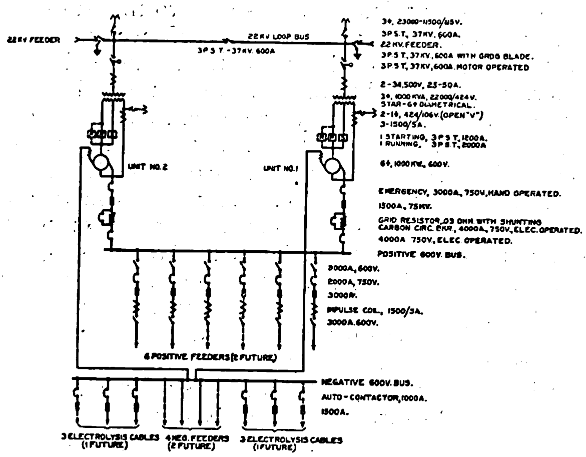

22 KV FEEDER
22 KV LOOP BUS
3 P S T. - 37 KV. 600A
3φ, 23000-11500/115 V.
3 P S T., 37 KV. 600A.
22 KV. FEEDER.
3 P S T., 37 KV., 600A WITH GRDG BLADE.
3 P S T., 37 KV., 600A. MOTOR OPERATED
2-34,500V, 25-50A.
3φ, 1000 KVA, 22000/424 V.
STAR-6φ DIAMETRICAL.
2-1φ, 424/106V. (OPEN "V")
3-1500/5A.
1 STARTING, 3 P S T., 1200A.
1 RUNNING, 3 P S T., 2000A
UNIT NO. 2
UNIT NO. 1
6φ, 1000 KW., 600V.
EMERGENCY, 3000A., 750V., HAND OPERATED.
1500A., 75 MV.
GRID RESISTOR, .03 OHM WITH SHUNTING
CARBON CIRC. BKR., 4000A., 750V., ELEC. OPERATED.
4000A 750V., ELEC. OPERATED.
POSITIVE 600V. BUS.
3000A., 600V.
2000A., 750V.
3000A.
IMPULSE COIL, 1500/5A.
3000A. 600V.
6 POSITIVE FEEDERS (2 FUTURE)
NEGATIVE 600V. BUS.
AUTO-CONTACTOR, 1000A.
1500A.
3 ELECTROLYSIS CABLES (1 FUTURE)
4 NEG. FEEDERS (2 FUTURE)
3 ELECTROLYSIS CABLES (1 FUTURE)

FIG. 104—SINGLE LINE DIAGRAM, MAPLE SUBSTATION.

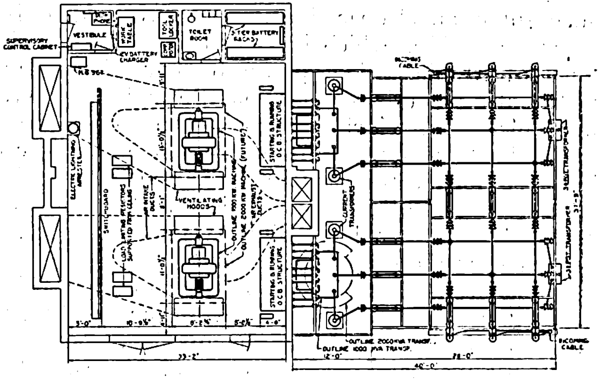

SUPERVISORY CONTROL CABINET
VESTIBULE
WORK TABLE
TOOL LOCKER
TOILET ROOM
STORAGE BATTERY RACKS
BATTERY CHARGER
ELECTRIC LIGHTING ARRESTER
SWITCHBOARD
LOAD LIMITING RESISTORS SUPPORTED FROM CEILING
AIR INTAKE DUCTS
VENTILATING HOODS
OUTLINE 1000 KW. MACHINE
OUTLINE 2000 KW MACHINE (FUTURE)
AIR EXHAUST DUCTS
STARTING & RUNNING O C B STRUCTURE
STARTING & RUNNING O C B STRUCTURE
CURRENT TRANSFORMERS
OUTGOING CABLE
3φ ELECT. TRANSFORMER
3φ P.T. TRANSFORMER
OUTLINE 2000 KVA TRANSF.
OUTLINE 1000 KVA TRANSF.
INCOMING CABLE
5'-0"
10'-9½"
8'-2¾"
5'-6½"
4'-6"
11'-0½"
11'-0½"
33'-2"
12'-0"
28'-0"
40'-0"
31'-9"

FIG. 105—PLAN, MAPLE SUBSTATION.

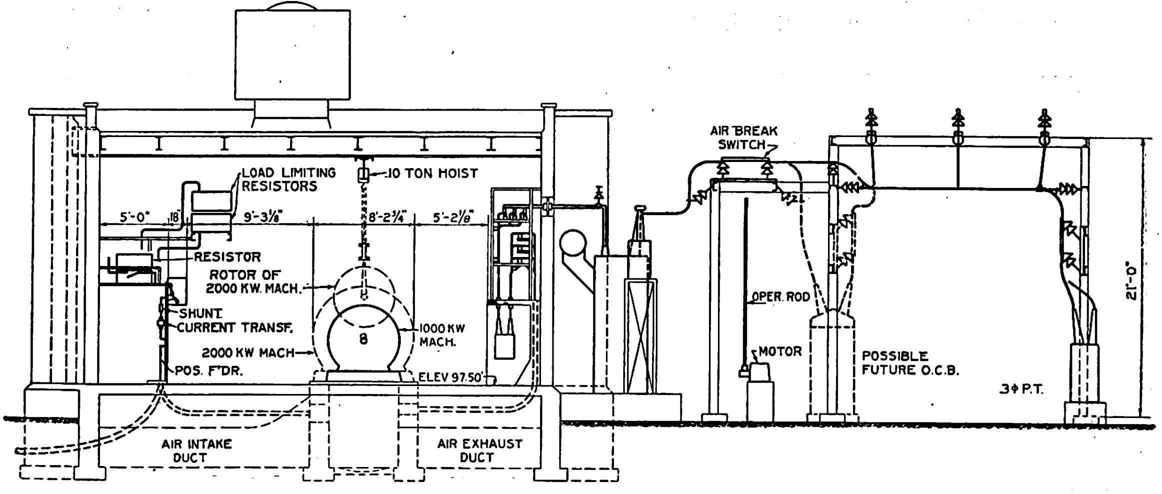

LOAD LIMITING RESISTORS
10 TON HOIST
5'-0"
18
9'-3⅛"
8'-2¾"
5'-2⅛"
RESISTOR
ROTOR OF 2000 KW. MACH.
SHUNT
CURRENT TRANSF.
2000 KW MACH
8
1000 KW MACH.
POS. F'DR.
ELEV 97.50'
AIR INTAKE DUCT
AIR EXHAUST DUCT
AIR BREAK SWITCH
OPER. ROD
MOTOR
POSSIBLE FUTURE O.C.B.
3φ P.T.
21'-0"

FIG. 106—SECTION, MAPLE SUBSTATION.

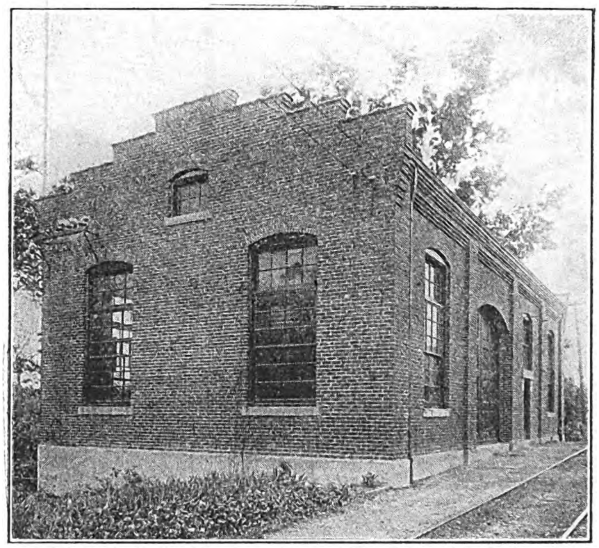


FIG. 107—EXTERIOR, BLUE AVE. SUBSTATION.

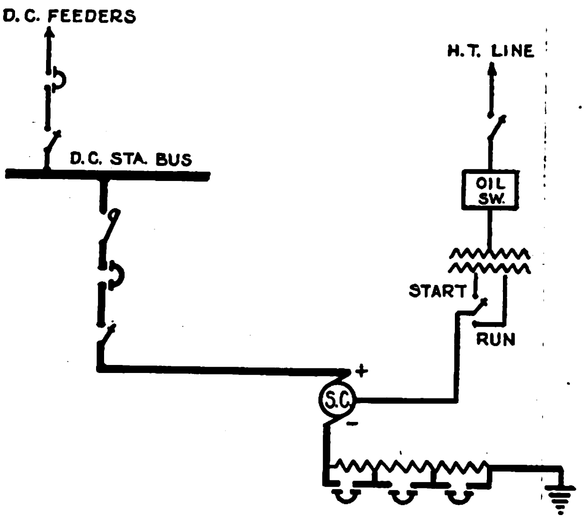


FIG. 109—SINGLE LINE DIAGRAM, BLUE AVE. SUBSTATION.

Kansas City Public Service Company, Kansas City, Mo.—Blue Avenue Substation

Besides operating street cars in Kansas City, the Kansas City Public Service Company also furnishes transportation to several small outlying towns. One such suburban electric line is double-tracked to Independence, Mo., which is located to the east, a distance of 10 miles. D-c. power for operation is furnished at a potential of 600 volts through Blue Avenue substation, which is located three miles from the end of the line. This substation is reinforced by substations in Kansas City and a 500-kw. machine at the west end of the line. This machine, however, runs only 4 hr. per day. Blue Avenue Substation is located near the center of its load.

The substation building is of typical design, being of brick masonry. It has a two-machine capacity and room for housing all of the auxiliary apparatus. In 1908 a manually operated General Electric 1000-kw. rotary converter was installed, and in 1920 this was made automatic, using all General Electric equipment. To date the substation capacity has been found large enough to meet all of the energy demands, and consequently only one machine has been installed.

Power is sent from Kansas City to this substation over an aerial line at 6600 volts, 25 cycles. At the northeast corner of the substation, where the lines enter, are the lightning arresters, the oil switch, power transformers and the operating transformer. The power leads then run to the rotary converter through the controller. From the direct current side of the rotary converter the positive leads run directly to the switchboard, where metering and switching equipment are located. Here distribution is made to the load over five feeders. To the right of the d-c. switchboard is the panel on which are mounted the operating relays and contactors. Current returns to the substation through the rails and parallel copper cable. At the substation a tap from the rails leads directly to the load-limiting resistors located in the center of the room. These are used to prevent a thermal overload on the machine.

The machine automatically comes on the line when the trolley voltage falls below 375 for 5 sec., and shuts down when the current reaches a minimum of 300 amperes for 7 min. It operates approximately 21 hr. a day and has an average load factor of 43 per cent.

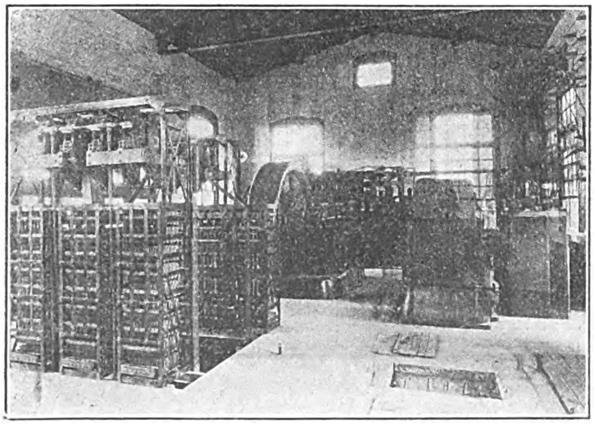


FIG. 108—INTERIOR, BLUE AVE. SUBSTATION.

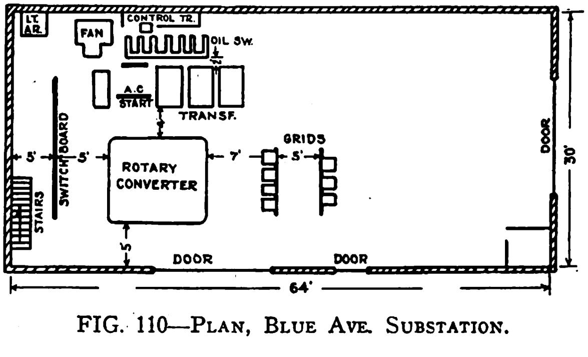


FIG. 110—PLAN, BLUE AVE. SUBSTATION.

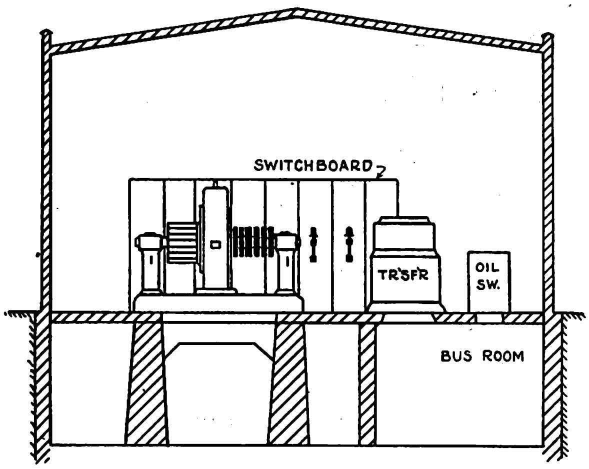

SWITCHBOARD
TR'SFR
OIL SW.
BUS ROOM

FIG. 111—Section, Blue Ave. Substation.

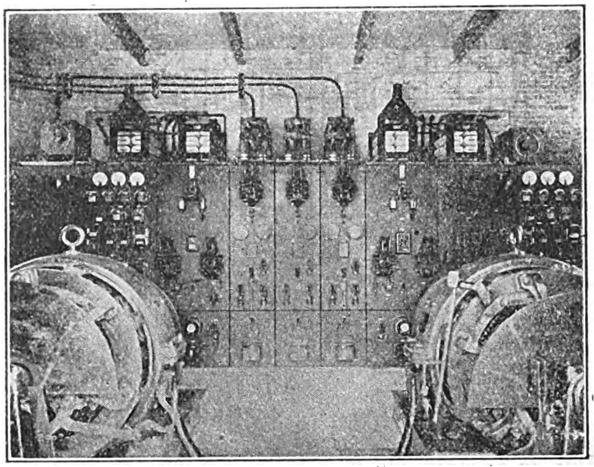


FIG. 113—Synchronous Converters and Switchboard—St. Martins Substation.

The Milwaukee Electric Railway & Light Co., Milwaukee, Wis.—St. Martins Substation

This substation contains two 500-kw., 600-volt, d-c. rotary converters with full automatic operation and three automatic reclosing 600-volt feeders with short-circuit detector type equipment. It is located on one of the interurban railway lines at a point where the line divides into two branches, and consequently feeds the trolley in three different directions. This substation is similar to four other substations on this line which have, however, only one 500-kw. machine each.

The transformers are connected to the 26,400-volt, 60-cycle bus through disconnecting type fuses, and the transformers are normally alive at all times.

One of the features of this substation is its ventilating scheme. Air is brought into the station by means of underground ducts through gratings at each end of the rotary shaft. Hot air is taken out through ventilators in the roof.

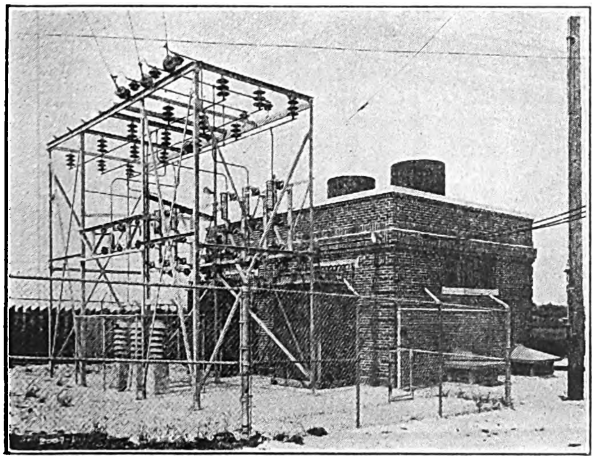


FIG. 112—Exterior, St. Martins Substation.

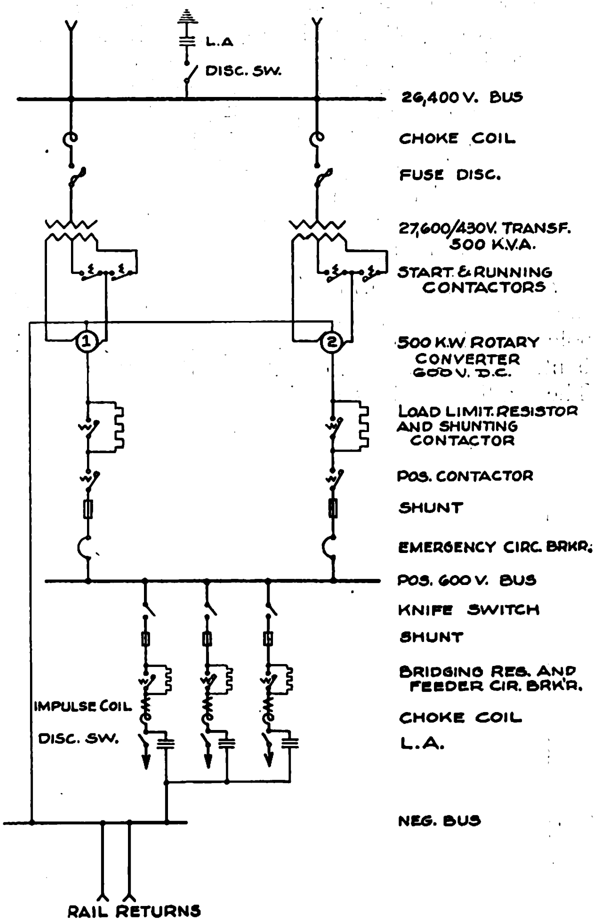

L.A
DISC. SW.
26,400 V. BUS
CHOKE COIL
FUSE DISC.
27,600/430V. TRANSF. 500 K.V.A.
START. & RUNNING CONTACTORS
1
2
500 K.W. ROTARY CONVERTER 600 V. D.C.
LOAD LIMIT. RESISTOR AND SHUNTING CONTACTOR
POS. CONTACTOR
SHUNT
EMERGENCY CIRC. BRKR.
POS. 600 V. BUS
KNIFE SWITCH
SHUNT
BRIDGING RES. AND FEEDER CIR. BRK'R.
IMPULSE COIL
CHOKE COIL
DISC. SW.
L.A.
NEG. BUS
RAIL RETURNS

FIG. 114—Single Line Diagram, St. Martins Substation.

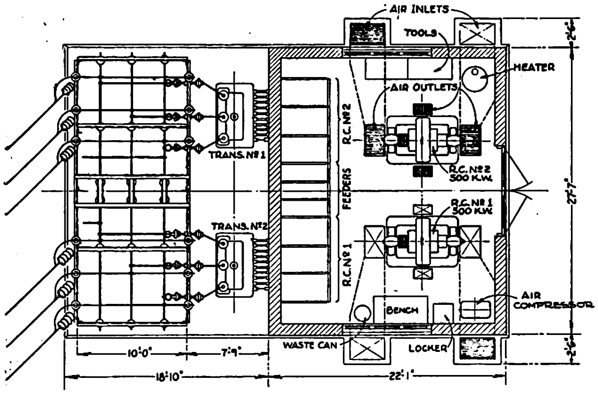


FIG. 115—PLAN, ST. MARTINS SUBSTATION.

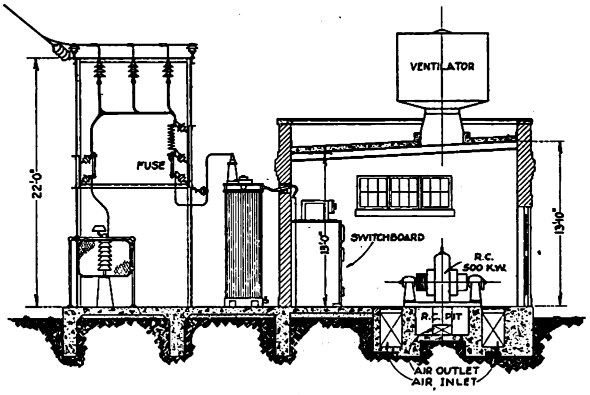


FIG. 116—SECTION, ST. MARTINS SUBSTATION.

Public Service Electric & Gas Co., Newark, N. J.—Miller St. Substation

This is an automatic substation supplying railway, lighting and power loads. Because of its location in a residential district of Newark, special provisions for ventilation and the elimination of noise were necessary.

Major equipment installed in this substation consists of the following:

Four 4000-kv-a., 3-phase transformers arranged as two 8000-kv-a. banks 26,400-13,200/4150Y.
Two 1500-kw. railway motor-generator sets, each consisting of a 4150-volt synchronous motor and a 600-volt compound-wound generator.
Five 13,200-volt incoming feeders.
Ten 4150-volt, 3-phase, 4-wire power and lighting feeders, equipped for automatic reclosing.
Nine 600-volt railway feeders, equipped with automatic high-speed circuit breakers.

The two transformer banks are controlled by automatic switching equipment through a multiple-pole, double-throw switch. By this switch either bank may be made to lead and the other to trail. The trailing bank is cut into service when the load on the leading bank exceeds its rating; with both banks in service the trailing bank is disconnected when the total load is 90 per cent of the capacity of the leading bank.

Automatic protection for the transformers is provided for the following conditions:

Overload.
Grounded or short-circuited windings.
Overheated windings.
Failure of leading bank.
Throwing of changeover switch.

By means of the automatic control equipment for the motor-generator sets, either set may be made to lead or trail. The leading set starts on low bus voltage, and at 150 per cent normal load on this unit the trailing set is started by a contact-making ammeter.

In the event of overload on either set, the series field of the overloaded generator is open-circuited and a load-limiting resistor is connected in the line. The two load-limiting resistors are provided with a thermostat which disconnects the unit when the resistor is overheated. Other protection for the sets includes the following:

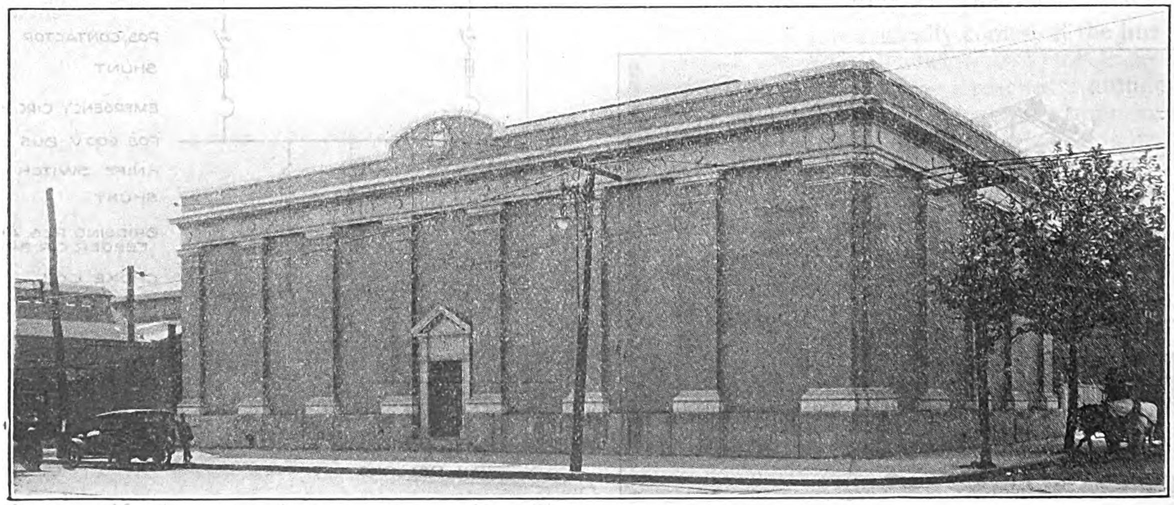


FIG. 117—EXTERIOR, MILLER ST. SUBSTATION.

Grounded generator armature.
Reverse power.
Incorrect generator polarity.
Generator field failure.
Grounded or short-circuited motor windings.
Motor field failure.
Single-phase starting.
Overheated motor windings.
Low a-c. voltage.
Overspeed.
Incomplete starting.
Overheated bearings.

The incoming feeders are provided with reverse power relays. The automatic reclosing equipment for the 4150-volt feeders provides for three reclosures at increasing time intervals and lock-out until reset by hand. The high-speed breakers on railway feeders, when tripped under short circuit, reclose when the feeder is cleared. A thermal relay is also provided which trips the high-speed breaker on sustained overload less than the breaker setting, and which recloses the breaker when the feeder has cooled sufficiently.

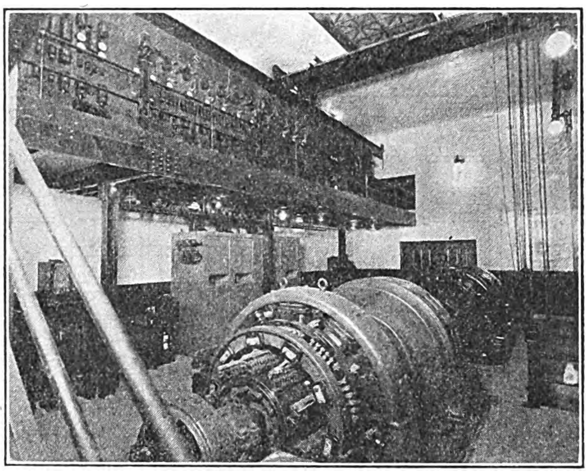


FIG. 118—INTERIOR, MILLER ST. SUBSTATION.

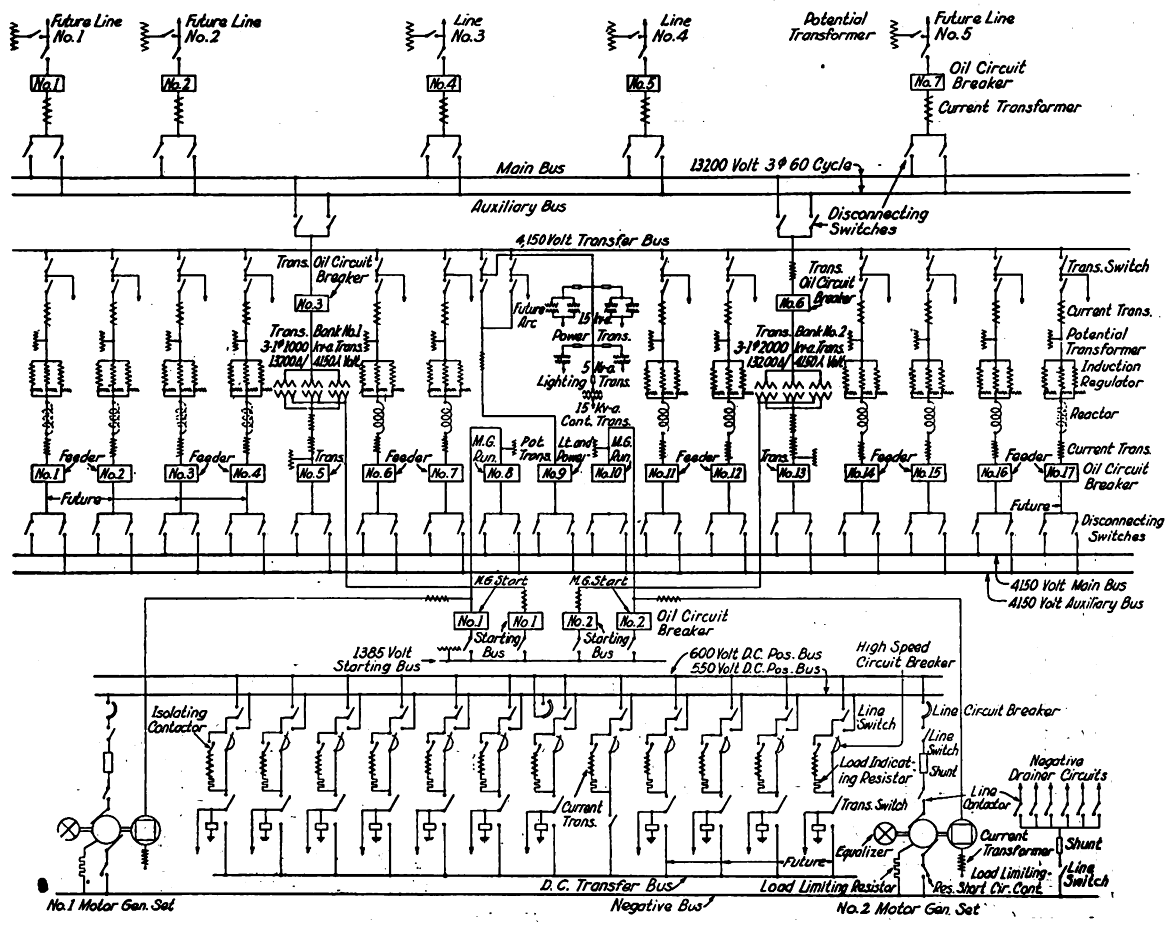

Future Line No. 1
Future Line No. 2
Line No. 3
Line No. 4
Potential Transformer
Future Line No. 5
No. 1
No. 2
No. 4
No. 5
No. 7
Oil Circuit Breaker
Current Transformer
Main Bus
13200 Volt 3φ 60 Cycle
Auxiliary Bus
Disconnecting Switches
4,150 Volt Transfer Bus
Trans. Oil Circuit Breaker
No. 3
Trans. Bank No. 1 3-1φ 1000 kv-a Trans. 13200Δ/4150λ Volt
Future Arc
15 kv-a Power Trans.
5 kv-a Lighting Trans.
15 kv-a Cont. Trans.
Trans. Oil Circuit Breaker
No. 6
Trans. Bank No. 2 3-1φ 2000 kv-a Trans. 13200Δ/4150λ Volt
Trans. Switch
Current Trans.
Potential Transformer
Induction Regulator
Reactor
Current Trans.
Oil Circuit Breaker
Feeder
No. 1
No. 2
No. 3
No. 4
Trans.
No. 5
No. 6
No. 7
M.G. Run.
Pot. Trans.
No. 8
Lt. and Power
No. 9
M.G. Run.
No. 10
No. 11
No. 12
Trans.
No. 13
No. 14
No. 15
No. 16
No. 17
Future
Disconnecting Switches
4150 Volt Main Bus
4150 Volt Auxiliary Bus
M.G. Start
No. 1
No. 1
No. 2
No. 2
Oil Circuit Breaker
Starting Bus
1385 Volt Starting Bus
600 Volt D.C. Pos. Bus
550 Volt D.C. Pos. Bus
High Speed Circuit Breaker
Isolating Contactor
Line Switch
Line Circuit Breaker
Line Switch
Shunt
Load Indicating Resistor
Trans. Switch
Current Trans.
Negative Drainer Circuits
Line Contactor
Equalizer
Current Transformer
Shunt
Load Limiting Res. Short Cir. Cont.
Line Switch
Future
D. C. Transfer Bus
Load Limiting Resistor
Negative Bus
No. 1 Motor Gen. Set
No. 2 Motor Gen. Set

FIG. 119—SINGLE LINE DIAGRAM, MILLER ST. SUBSTATION.

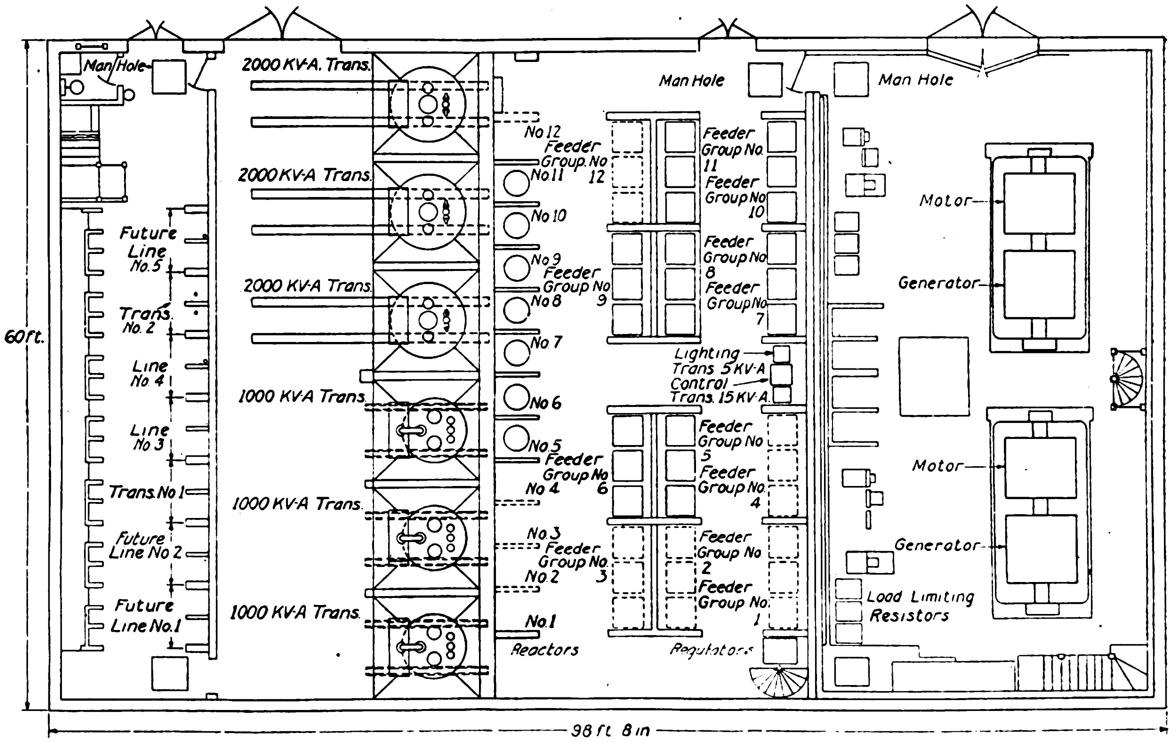

Man Hole
2000 KV-A. Trans.
2000 KV-A Trans.
2000 KV-A Trans.
1000 KV-A Trans.
1000 KV-A Trans.
1000 KV-A Trans.
Future Line No. 5
Trans. No. 2
Line No 4
Line No 3
Trans. No 1
Future Line No 2
Future Line No. 1
No 12
Feeder Group No 12
No 11
No 10
No 9
Feeder Group No 9
No 8
No 7
No 6
No 5
Feeder Group No 6
No 4
No 3
Feeder Group No 3
No 2
No 1
Reactors
Man Hole
Feeder Group No 11
Feeder Group No 10
Feeder Group No 8
Feeder Group No 7
Lighting Trans 5 KV-A
Control Trans. 15 KV-A.
Feeder Group No 5
Feeder Group No 4
Feeder Group No 2
Feeder Group No 1
Regulators
Man Hole
Motor
Generator
Motor
Generator
Load Limiting Resistors
60 ft.
98 ft 8 in

FIG. 120—PLAN, MILLER ST. SUBSTATION.

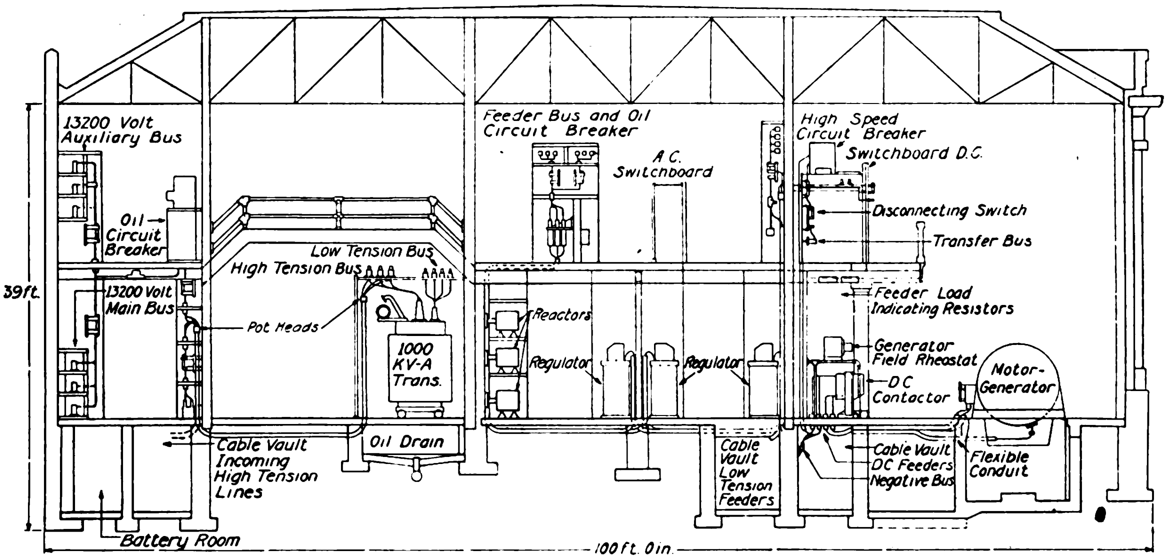

13200 Volt Auxiliary Bus
Oil Circuit Breaker
13200 Volt Main Bus
Pot Heads
Low Tension Bus
High Tension Bus
1000 KV-A Trans.
Oil Drain
Cable Vault Incoming High Tension Lines
Battery Room
Feeder Bus and Oil Circuit Breaker
A.C. Switchboard
Reactors
Regulator
Regulator
Cable Vault Low Tension Feeders
High Speed Circuit Breaker
Switchboard D.C.
Disconnecting Switch
Transfer Bus
Feeder Load Indicating Resistors
Generator Field Rheostat
D C Contactor
Motor-Generator
Cable Vault DC Feeders Negative Bus
Flexible Conduit
39 ft.
100 ft. 0 in.

FIG. 121—SECTION, MILLER ST. SUBSTATION.

Public Service Company of Northern Illinois, Chicago, Ill.—Glen Ellyn Substation

This substation, located at Glen Ellyn, Ill., was placed in service on April 20, 1927, and is one of nine new 60-cycle rotary substations serving the Chicago, Aurora & Elgin Railroad.

The substation structure was arranged, from an architectural standpoint, to fit into the surrounding community and to be attractive to the patrons of the railroad. The building is located in the eastern section of Glen Ellyn and contains one automatic 1500-kw. rotary converter and four feeders to the railroad's third rail.

This substation is unattended and is controlled by a selector supervisory system from the system operator's office at Wheaton, Ill., approximately three miles distant. This supervisory system is capable of starting and stopping the rotary converter, in addition to opening and closing the high-speed breakers on the feeders serving the railroad. When the system operator turns the key for starting the rotary converter under the supervisory system, the rotary converter will start only when the load requirements reach the point when the master switch operates and the sequence of starting follows until the rotary converter is put on the line.

The machine is protected by under-voltage relays on the 33,000-volt side and will trip out due to overheated bearings, overheated load-limiting resistors, reverse power, flash-over or grounded winding and extreme d-c. overload after the load-limiting resistors have cut in but failed to handle the excess load.

All the equipment in this substation is inspected once a day by the operating department and, should any unusual trouble develop, an emergency repairman is immediately sent to the substation to inspect the difficulty and get the machine back on the line as soon as possible.

In order to safeguard the surrounding neighborhood from the characteristic noise of a 60-cycle rotary converter, all the metal doors are lined with a hair and asbestos felt (which is not fire sustaining) and is in turn covered with a fireproofed burlap to afford a mechanical protection to the hair felt. This method of padding the sound-distributing sections of the building has proved to be very satisfactory. The excess heat is discharged through a tower in the roof by means of two exhaust fans, which are operated in multiple when the rotary converter is running, either one of which is capable of being run alone in case of difficulty on the other.

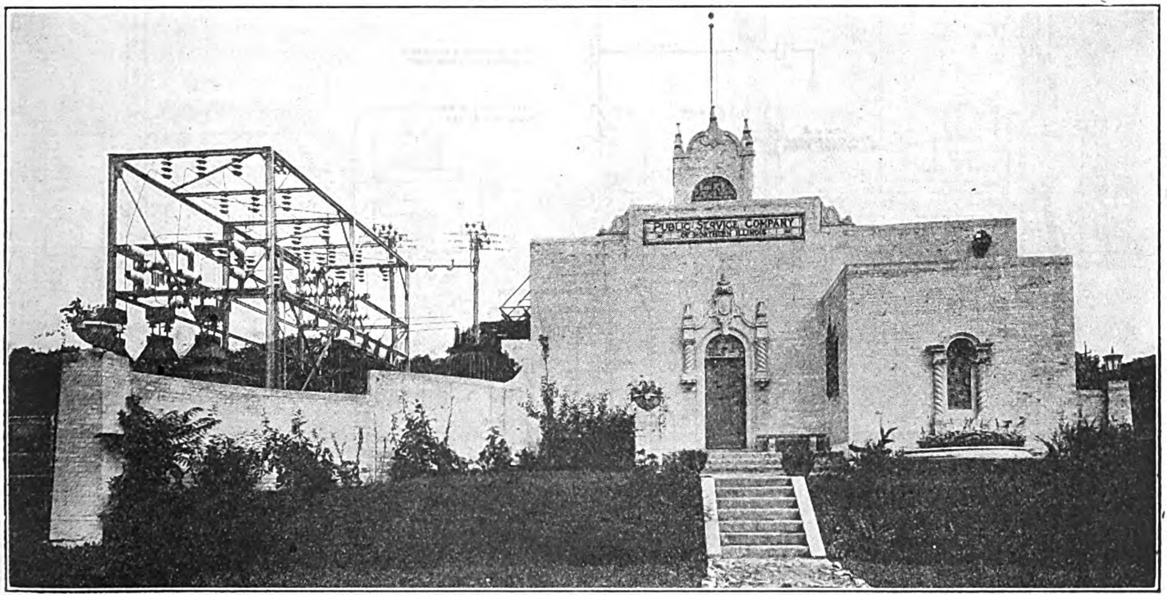


FIG. 122—EXTERIOR, GLEN ELLYN SUBSTATION.

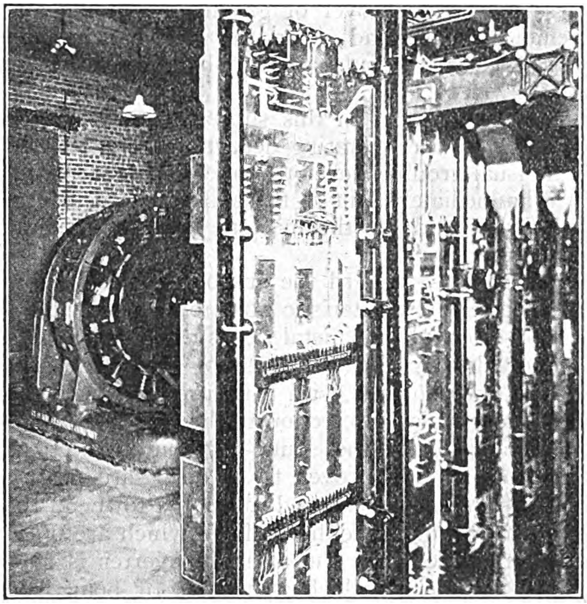


FIG. 123—MACHINE AND SWITCHBOARD, GLEN ELLYN SUBSTATION.

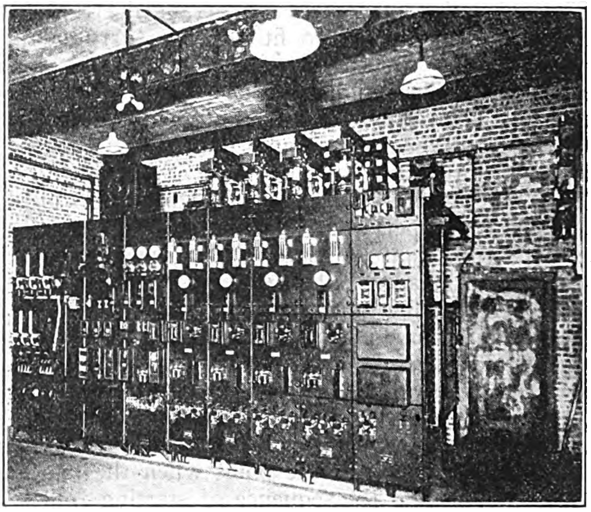


FIG. 124—SWITCHBOARD, GLEN ELLYN SUBSTATION.

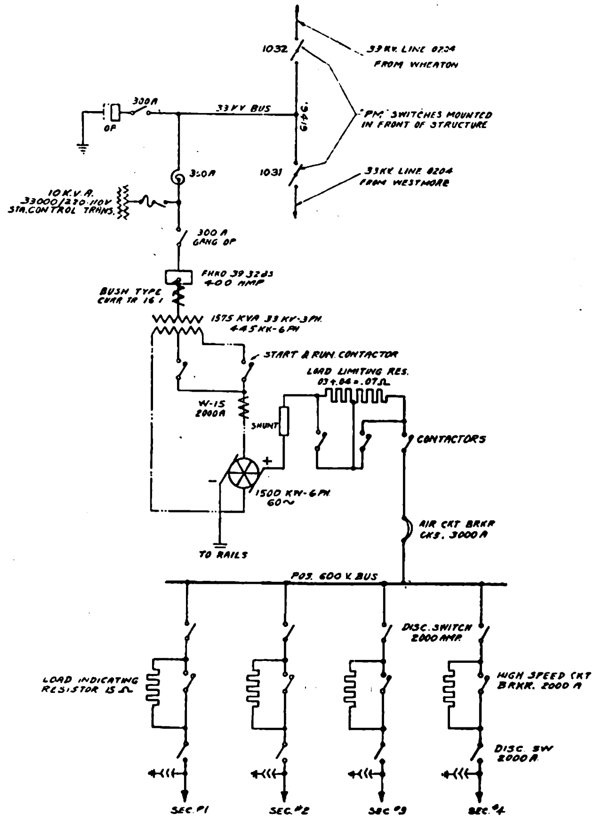

1032
33 KV. LINE 0234
FROM WHEATON
300A
OP
33 KV BUS
6146
"PM" SWITCHES MOUNTED
IN FRONT OF STRUCTURE
300A
1031
33 KV LINE 0204
FROM WESTMORE
10 K.V.A.
33000/220-110V
STA. CONTROL TRANS.
300 A
GANG OP
FHKO 39 3283
400 AMP
BUSH TYPE
CURR TR 16:1
1575 KVA 33 KV-3PH.
445 KV-6PH
START & RUN CONTACTOR
LOAD LIMITING RES.
.03+.04=.07Ω
W-15
2000A
SHUNT
CONTACTORS
+
-
1500 KW-6PH
60~
AIR CKT BRKR
CKS. 3000A
TO RAILS
POS. 600 V. BUS
DISC. SWITCH
2000 AMP.
LOAD INDICATING
RESISTOR 15Ω
HIGH SPEED CKT
BRKR. 2000 A
DISC. SW
2000 A.
SEC. #1
SEC. #2
SEC. #3
SEC. #4

FIG. 125—SINGLE LINE DIAGRAM, GLEN ELLYN SUBSTATION.

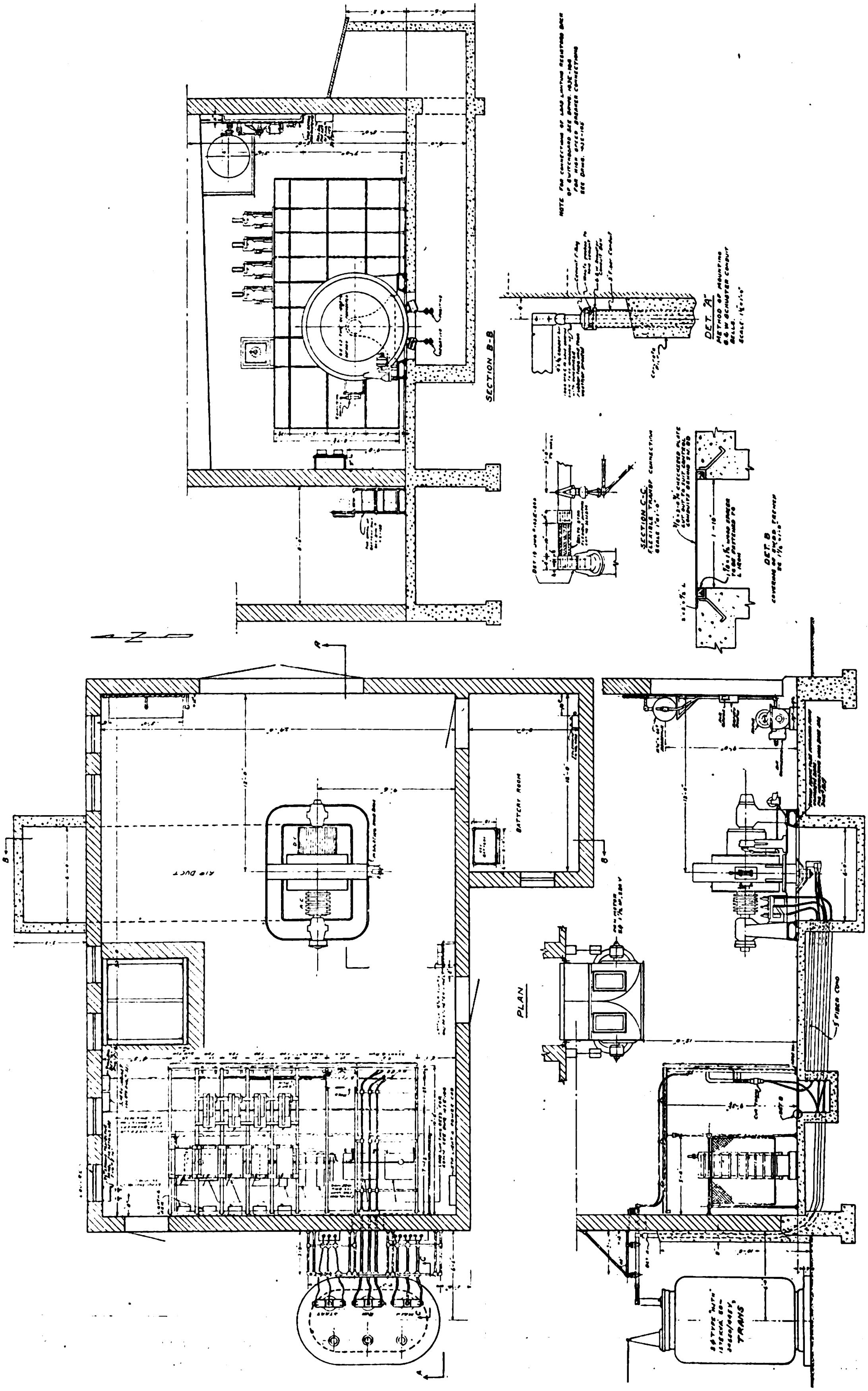

SECTION B-B
BATTERY ROOM
AIR DUCT
PLAN
SECTION A-A
SECTION C-C
DET. "A"
DET. B

FIG. 126—Plan and Section, Glen Ellyn Substation.

SECTION IV

NON-AUTOMATIC RAILWAY SUBSTATIONS

Commonwealth Edison Company, Chicago, Ill.—Laflin Street Substation

This is a 1500-kw., mercury-vapor rectifier substation and furnishes 1500-volts d-c. energy for railway load. It receives 12,000-volt, 60-cycle, 3-phase energy from the generating stations through the company's underground cable system. Due to the use of 500,000 circular mil three conductor cables on the 12,000-volt system, this small load is carried on two loop lines, one of them being a reserve supply. This substation also furnished 4000-volt a-c. distribution to the same customer for light and power use in and around their structures.

The 12,000-volt bus structure consists of four safety inclosed switchboards with removable truck-type panels. These are used for two lines, one rectifier, and one light and power transformer bank.

The rectifier consists of one 1575-kv-a. transformer, two anode reactors, two 750-kw. mercury-arc rectifier tanks, two vacuum pumps, one 3-unit, arc-striking motor-generator set, one positive and one negative high-speed breaker and necessary protective equipment. The negative side, which is the neutral of the transformers, also has one interphase transformer and a negative reactor. The main transformer has full capacity primary taps, and load can be varied with tap switch, but not while under load.

The switchboard consists of control panels for 12,000-volt oil circuit breakers, rectifier, two 1500-volt feeder panels, and necessary panels for the 4000-volt a-c. distribution. The 1500-volt panels are safety-inclosed switchboards with removable truck-type panels, and the type of construction is similar to the 12,000-volt panels.

Special Features

The customer's energy is billed from a watt-hr. meter, shunt type. The shunt is located in the negative lead of the rectifier, and the instrument is located in the basement away from d-c. fields.

The d-c. pressure being 1500 volts makes it objectionable for use on pressure coils on d-c. instruments. Standard 110-volt instruments are used, and the 110-volt service is obtained by using the 110-volt drop on the negative end of a 67,000-ohm resistance. A separate resistance is used for each pressure coil.

An annunciator system is employed which uses standard telephone switchboard parts, and indicates with a light when attention is required. An audible alarm is also used with this device.

The feeder breakers are non-reclosing, but their setting is higher than the machine negative breakers. A short circuit on a feeder opens the negative machine breaker, which shunts a load-limiting resistance. Should the fault be cleared, the relay arrangement recloses this negative breaker automatically. Should the fault persist, the negative will remain open, and the positive breaker will open also. When more capacity is added to this substation, the short circuits on feeders will normally open the feeder breaker only.

Equipment is permanently installed to bake-out rectifier anodes, and ammeters are installed in the negative lead of each tank to indicate whether both tanks are working.

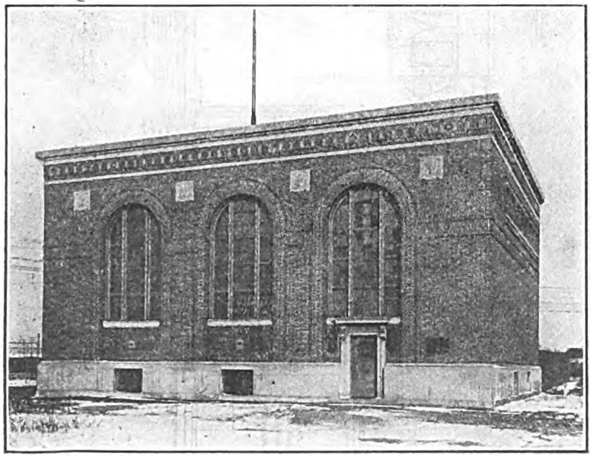


FIG. 127—Exterior, Laflin St. Substation.

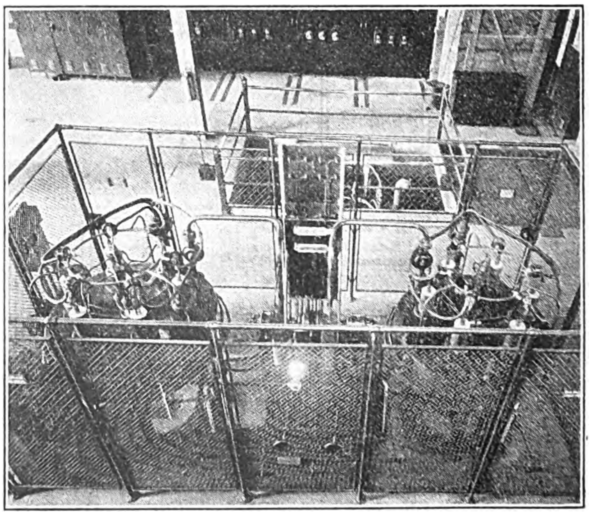


FIG. 128—Mercury Arc Rectifiers, Laflin St. Substation.

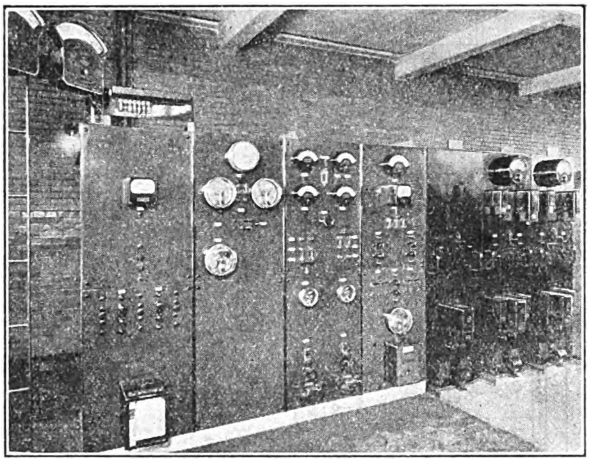


FIG. 129—SWITCHBOARD, LAFLIN ST. SUBSTATION.

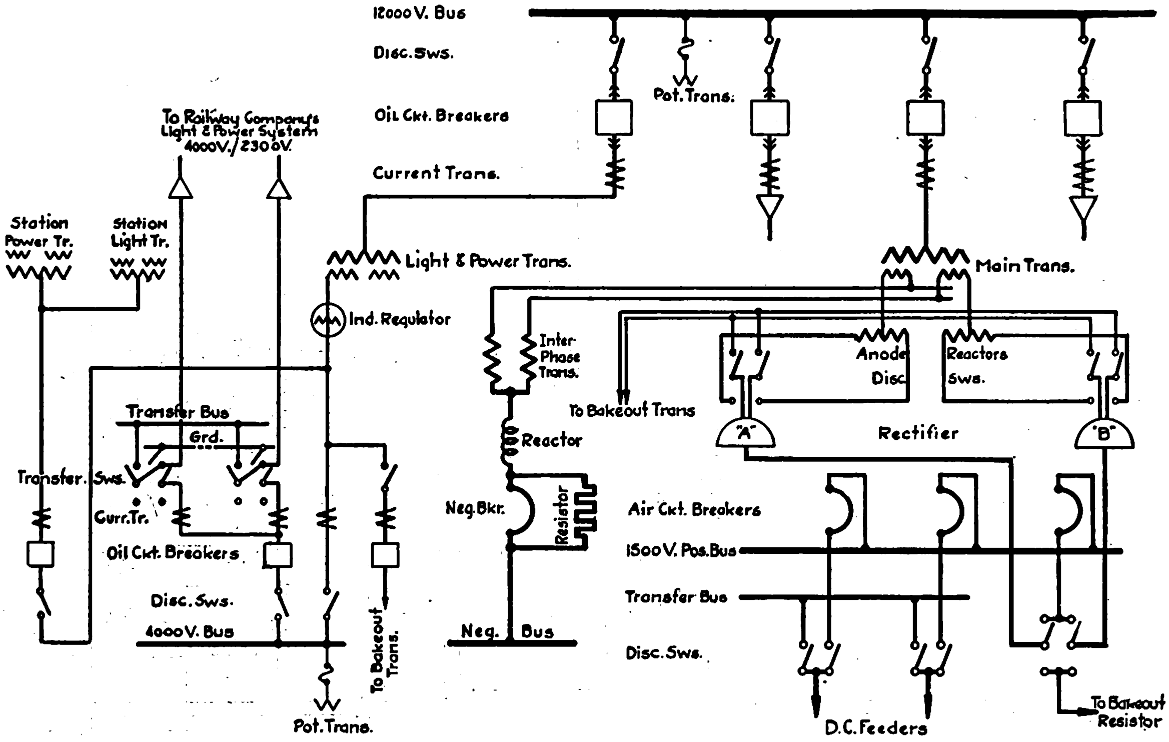

12000 V. Bus
Disc. Sws.
Pot. Trans.
Oil Ckt. Breakers
To Railway Company's Light & Power System 4000V./2300V.
Current Trans.
Station Power Tr.
Station Light Tr.
Light & Power Trans.
Main Trans.
Ind. Regulator
Inter-Phase Trans.
Anode Disc
Reactors Sws.
To Bakeout Trans
Transfer Bus
Grd.
Reactor
"A"
Rectifier
"B"
Transfer. Sws.
Curr. Tr.
Neg. Bkr.
Resistor
Air Ckt. Breakers
Oil Ckt. Breakers
1500 V. Pos. Bus
Disc. Sws.
Transfer Bus
4000 V. Bus
Neg. Bus
Disc. Sws.
To Bakeout Trans.
Pot. Trans.
D.C. Feeders
To Bakeout Resistor

FIG. 130—SINGLE LINE DIAGRAM, LAFLIN ST. SUBSTATION.

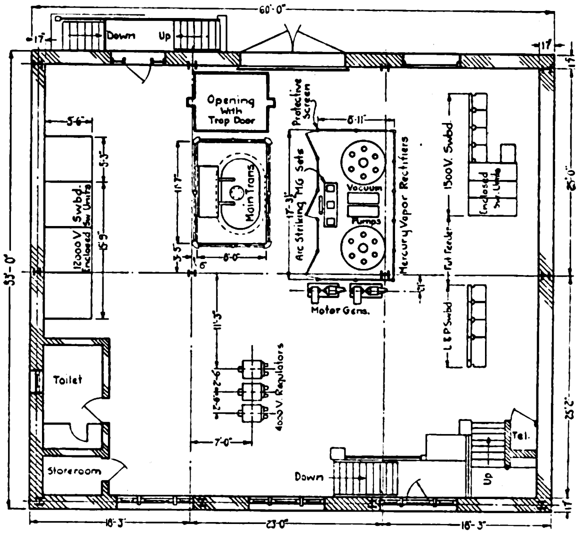

60'-0"
17"
Down
Up
Opening With Trap Door
Protective Screen
5'-6"
6'-11"
5'-3"
11'-7"
Main Trans.
17'-3½"
Arc Striking MG Sets
Vacuum
Pumps
Mercury Vapor Rectifiers
1500V. Swbd
Enclosed Sw. Units
25'-0"
12000 V Swbd. Enclosed Sw Units
15'-9"
3'-5"
8'-0"
6"
53'-0"
Fut Feeder
Motor Gens.
11'-5"
L & P Swbd
2'-6" 2'-6" 2'-6"
4000 V. Regulators
Toilet
7'-0"
25'-2"
Tel.
Storeroom
Down
Up
18'-3"
23'-0"
18'-3"

FIG. 131—PLAN, LAFLIN ST. SUBSTATION.

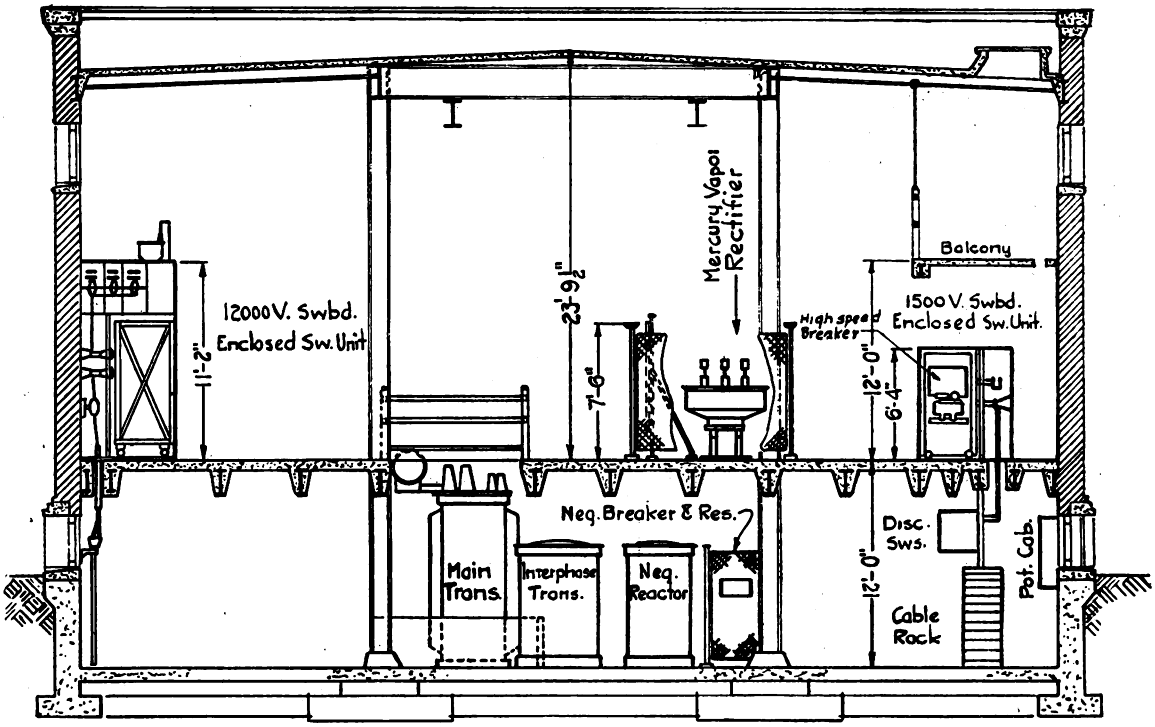

12000V. Swbd.
Enclosed Sw. Unit
11'-2"
23'-9½"
7'-6"
Mercury Vapor Rectifier
High speed Breaker
Balcony
1500 V. Swbd.
Enclosed Sw. Unit
12'-0"
6'-4"
Neg. Breaker & Res.
Main Trans.
Interphase Trans.
Neg. Reactor
Disc. Sws.
12'-0"
Cable Rack
Pot. Cab.

FIG. 132—SECTION, LAFLIN ST. SUBSTATION.

Dallas Power & Light Company, Dallas, Texas—Typical Substations

The d-c. substations are constructed as part of the a-c. substations, and the direct current is used to serve only the city's street railway system. Thus the same building houses both a-c. and d-c. equipment, and the same high tension buses serve the transformers for a-c. service and the conversion equipment for d-c. service.

Alternating current is delivered through 13,000-volt transmission lines to the substation 13,000-volt buses, to which are connected motor-generator sets. Each set consists of a 13,200-volt, 3-phase, synchronous motor directly connected to a 600-volt, compound-wound d-c. generator, with a continuous output rating of 1000 kw. There are three such sets to a substation, feeding a common d-c. railway bus, from which the necessary number of railway feeders are taken.

Starting of the synchronous motor is accomplished, in the majority of installations, through a starting compensator which provides approximately 60 per cent of full voltage for this purpose. However, the more recently installed sets are constructed for full voltage starting. These are connected directly across the 13,000-volt buses for starting. On full voltage starting they come up to synchronous speed in an average time of 4.5 sec., and require a starting current of approximately five times full load running current. At starting, the average maximum drop in voltage on the 13,000-volt bus at the generating station is 3 per cent.

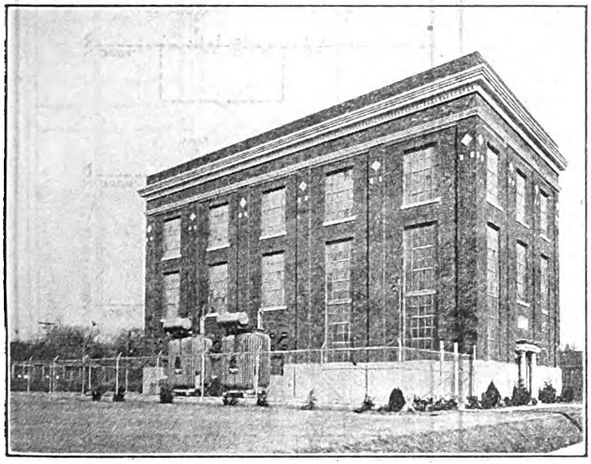


FIG. 133—EXTERIOR, SOUTH DALLAS SUBSTATION, DALLAS POWER & LIGHT CO.

Installations which utilize a starting compensator are provided with necessary relays which prevent the operator leaving the motor running on the starting tap longer than a predetermined interval, as at the expiration of this starting interval the motor is automatically disconnected from the a-c. buses. Such installations also have the starting, magnetizing and running oil circuit breakers so interlocked that it is impossible to have a starting and running breaker closed at the same time.

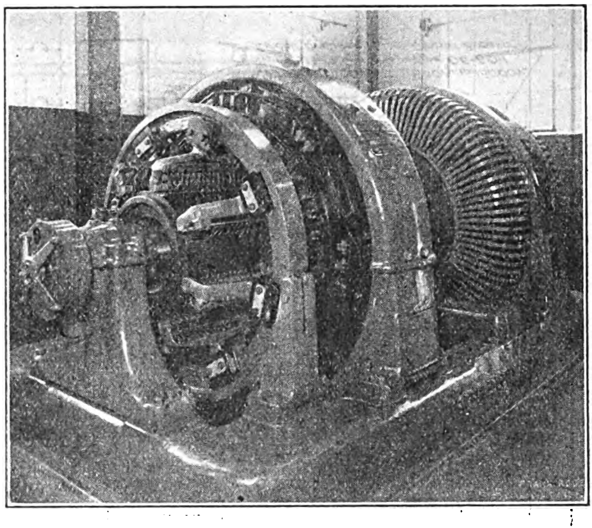


FIG. 134—1000-KW. MOTOR-GENERATOR SET, DALLAS POWER & LIGHT CO.

All sets are equipped with Type CO induction relays on the motor side; and on the generator side the air carbon circuit breaker has overload and undervoltage trip coils.

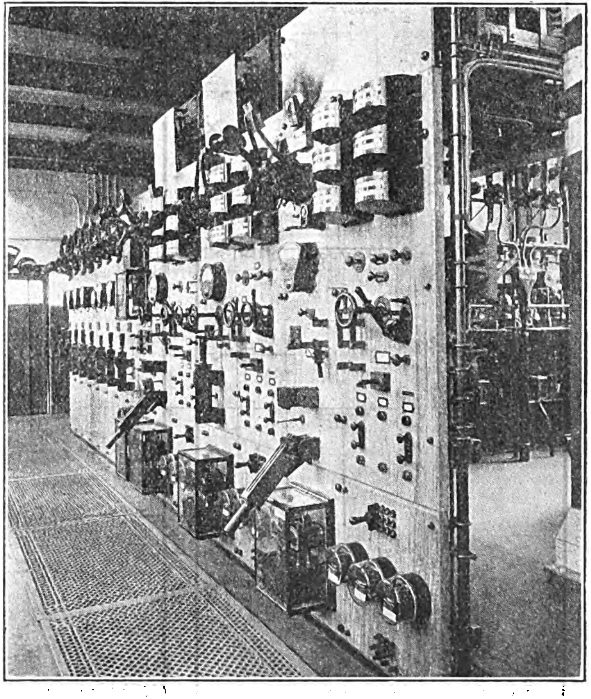


FIG. 135—RAILWAY SWITCHBOARD, DALLAS POWER & LIGHT CO.

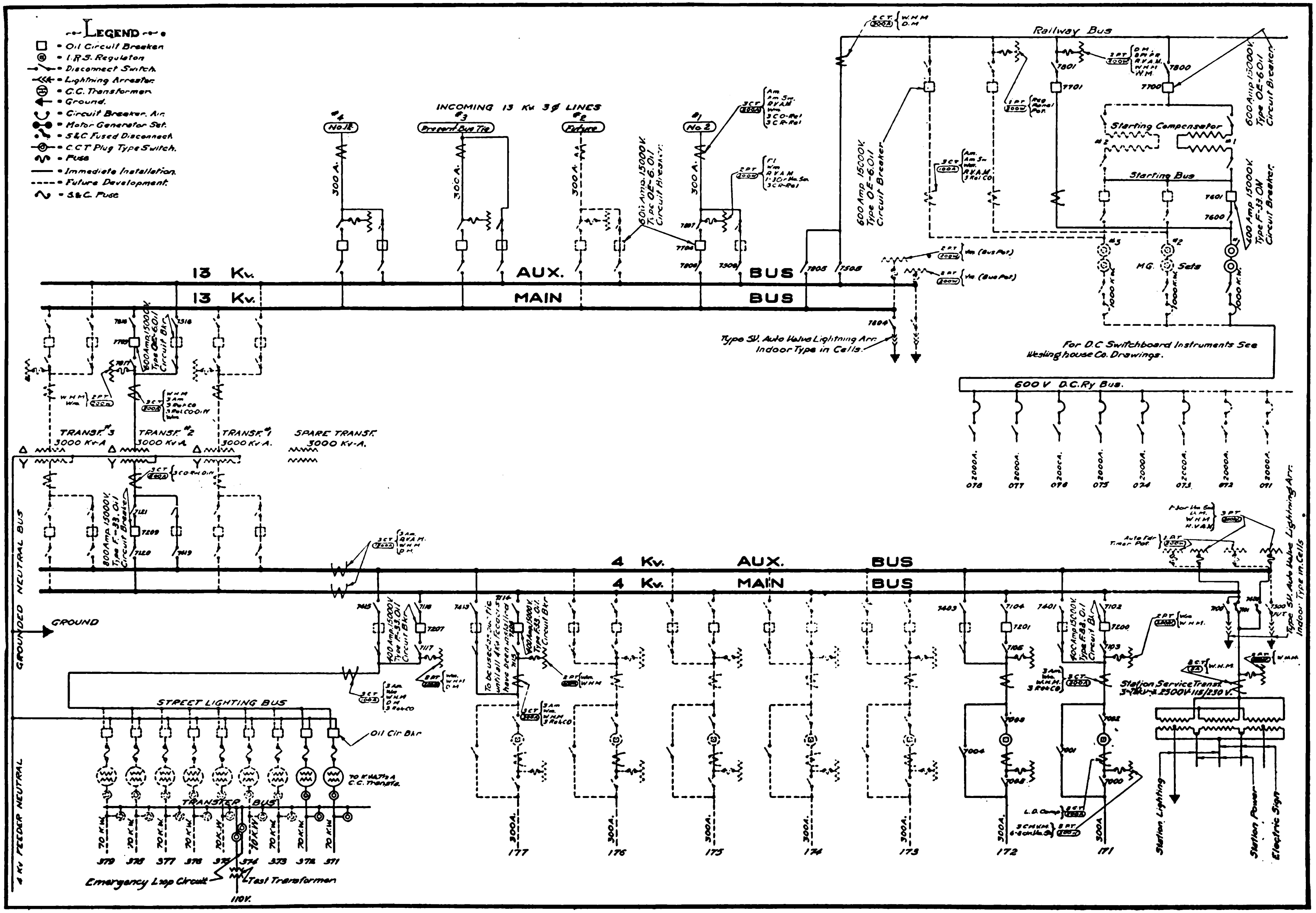

LEGEND
Oil Circuit Breaker
I.R.S. Regulator
Disconnect Switch
Lightning Arrester
C.C. Transformer
Ground.
Circuit Breaker, Air
Motor Generator Set.
S&C Fused Disconnect
C.C.T Plug Type Switch.
Fuse
Immediate Installation.
Future Development.
S&C Fuse
INCOMING 13 Kv 3Ø LINES
#4 No.12
#3 Present Bus Tie
#2 Future
#1 No.2
300 A.
600 Amp. 15000V. Type OE-6. Oil Circuit Breaker
13 Kv. AUX. BUS
13 Kv. MAIN BUS
Type SV. Auto Valve Lightning Arr. Indoor Type in Cells.
Railway Bus
Starting Compensator
Starting Bus
600 Amp 15000V. Type F-33 ON Circuit Breaker
M.G. Sets
1000 K.W.
For D.C Switchboard Instruments See Westinghouse Co. Drawings.
600 V D.C. Ry Bus.
2000A.
078 077 076 075 074 073 072 071
TRANSF. #3 3000 Kv-A.
TRANSF. #2 3000 Kv-A.
TRANSF. #1 3000 Kv-A.
SPARE TRANSF. 3000 Kv-A.
800 Amp. 15000V. Type F-33. Oil Circuit Breaker
4 Kv. AUX. BUS
4 Kv. MAIN BUS
GROUNDED NEUTRAL BUS
GROUND
400 Amp. 15000V. Type F-33. Oil Circuit Bkr.
To be used as bus tie until all 4 Kv. feeders have been installed
STREET LIGHTING BUS
Oil Cir. Bkr.
70 K.W. 7½ A C.C. Transfs.
TRANSFER BUS
70 K.W.
579 578 577 576 575 574 573 572 571
Emergency Loop Circuit
Test Transformer
110V.
4 Kv FEEDER NEUTRAL
300A.
177 176 175 174 173 172 171
Station Service Transf. 3-75 Kv-A 2300V/115/230V.
Station Lighting
Station Power
Electric Sign

FIG. 136—SINGLE LINE DIAGRAM, TYLER ST. SUBSTATION, DALLAS POWER & LIGHT CO.

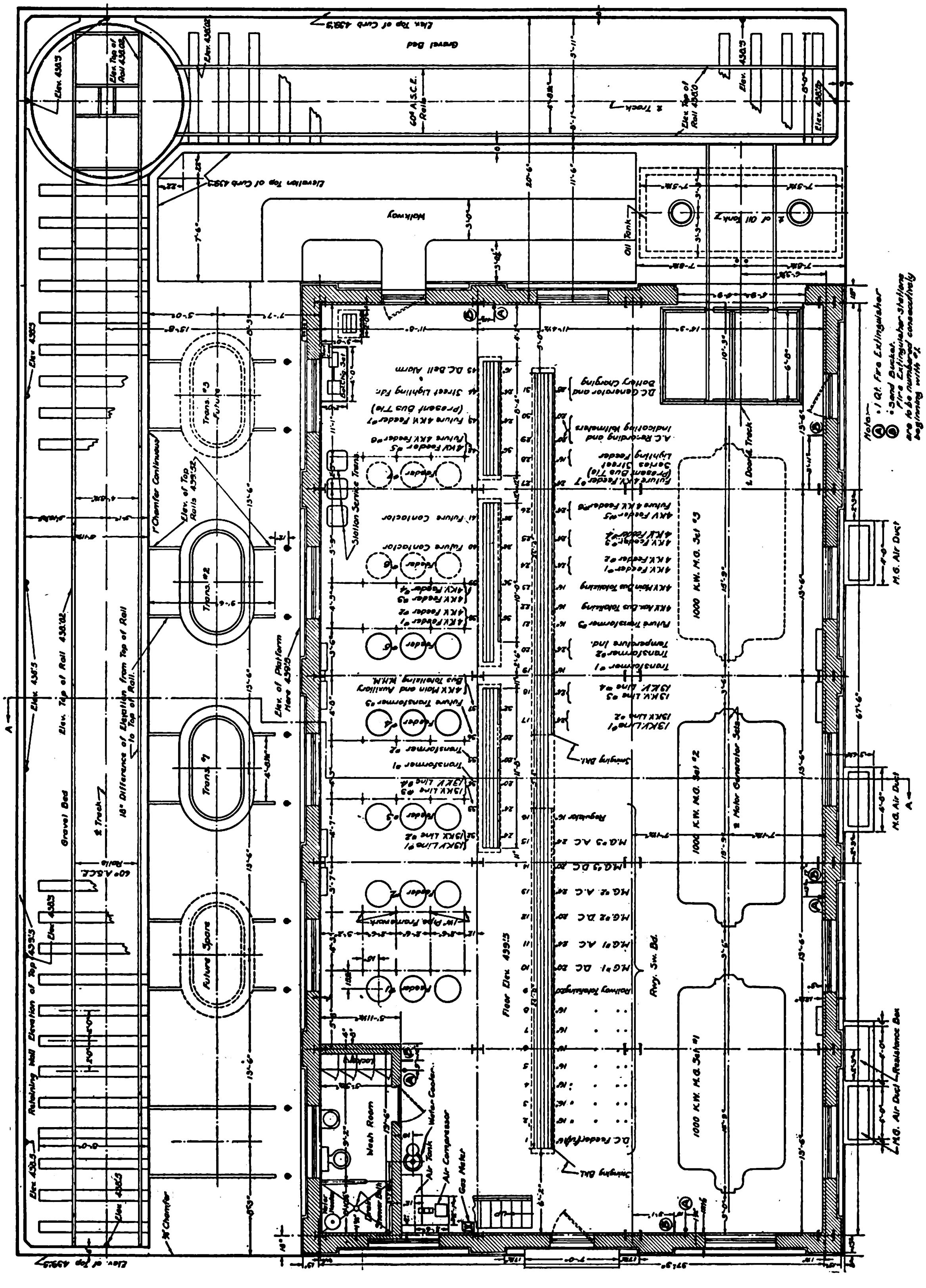

Elev. Top of Curb 439.5
Gravel Bed
60# A.S.C.E. Rails
℄ Track
Elev. Top of Rail 439.02
Elevation Top of Curb 439.5
Walkway
Oil Tank
℄ of Oil Tanks
Trans. #3 Future
Trans. #2
Trans. #1
Future Spare
1" Chamfer Continuous
Elev. of Top Rails 439.32
Elev. of Platform Here 439.5
18" Difference of Elevation from Top of Rail to Top of Rail
Retaining Wall Elevation of Top 439.5
Station Service Trans.
Battery Set
43 D.C. Bell Alarm
44 Street Lighting Fdr.
D.C. Generator and Battery Charging
A.C. Recording and Indicating Voltmeters
Swinging Bkt.
Regulator
Floor Elev. 439.5
Rwy. Sw. Bd.
D.C. Feeders
Wash Room
Water Cooler
Air Tank
Air Compressor
Gas Meter
1000 K.W. M.G. Set #1
1000 K.W. M.G. Set #2
1000 K.W. M.G. Set #3
℄ Motor Generator Sets
℄ Double Track
M.G. Air Duct
Resistance Box
Motor
1 Qt. Fire Extinguisher
Sand Bucket
Fire Extinguisher Stations are to be numbered consecutively beginning with #1.

FIG. 137—PLAN, SOUTH DALLAS SUBSTATION, DALLAS POWER & LIGHT CO.

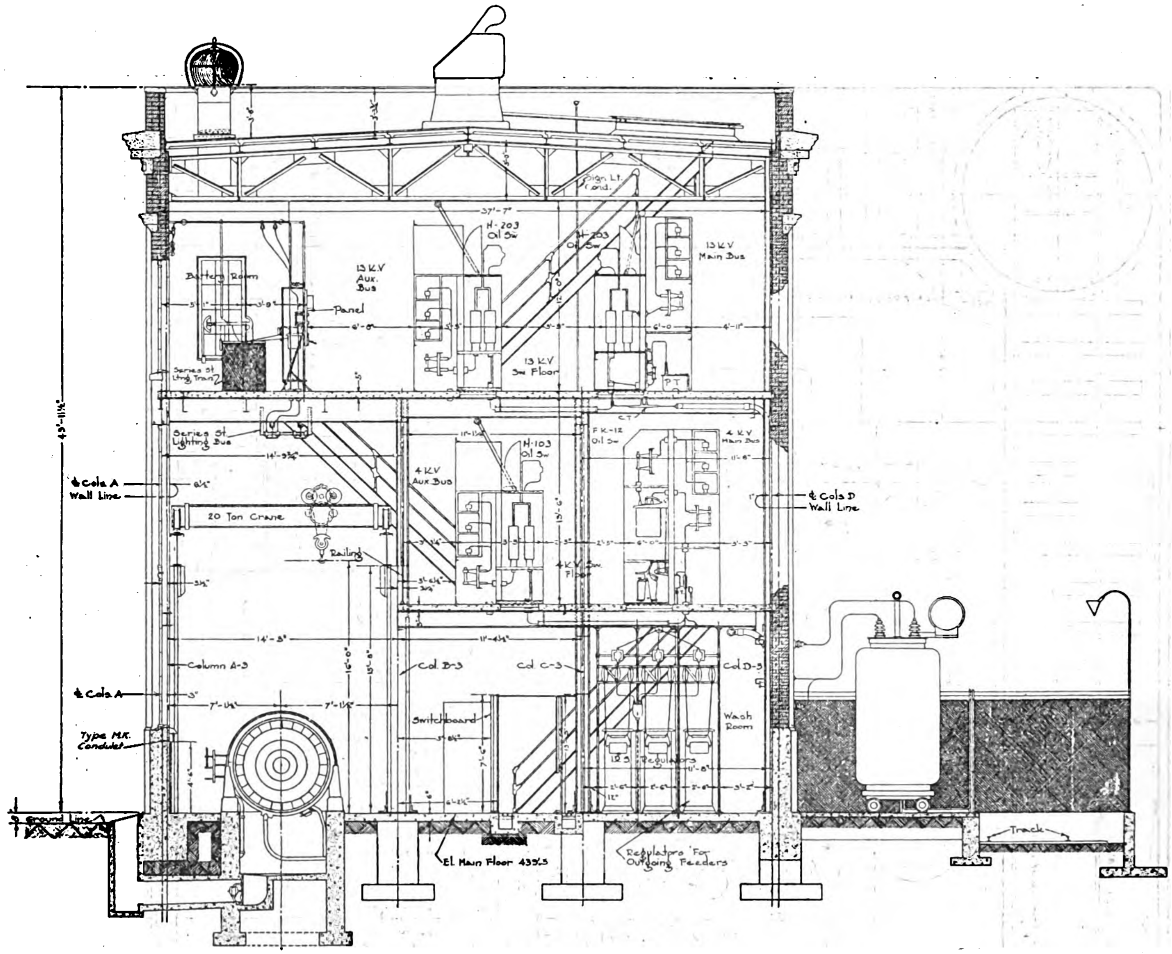

43'-11½"
Sign Lt. Cond.
37'-7"
H-203 Oil Sw
H-203 Oil Sw
13 K.V Main Bus
Battery Room
13 K.V Aux. Bus
Panel
Series St Ltng. Tran
13 K.V Sw Floor
P T
C T
Series St Lighting Bus
11'-1½"
H-103 Oil Sw
F K-12 Oil Sw
4 K.V Main Bus
4 K.V Aux Bus
℄ Cols A
Wall Line
℄ Cols D
Wall Line
20 Ton Crane
Railing
4 K.V Sw. Floor
14'-3"
11'-4½"
Column A-3
Col. B-3
Col. C-3
Col. D-3
℄ Cols A
Switchboard
Wash Room
Type M.K. Condulet
Regulators
Ground Line
El. Main Floor 435.5
Regulators For Outgoing Feeders
Track

FIG. 138—SECTION, SOUTH DALLAS SUBSTATION, DALLAS POWER & LIGHT CO.

The Delaware County Electric Company, Philadelphia, Pa.—Crosby Substation

This substation of the Delaware County Electric Company, a subsidiary of the Philadelphia Electric Company, is located in the city of Chester, about 14 miles southwest of Philadelphia.

This substation is a combined a-c. distribution and railway substation. As will be noted from the accompanying single-line diagram, the 13,200-volt buses and feeders are common to both classes of service. While most of the distribution load is at 2400 volts, there is also some at 13,200 volts. The railway load, at 600 volts, is delivered to two street railway companies operating in the vicinity.

The substation is not now fully developed. Three of four ultimate rotary converters and two of four ultimate distribution transformers, together with three incoming and one outgoing 13,200-volt lines, are installed at the present time. In order to reduce short circuit duty, each 13,200-volt bus, ultimately, will be operated with bus sectionalizing switch open, giving four separate bus sections. Each section will then supply a portion of the railway and a-c. distribution loads.

Relay protection is provided as follows:

Incoming 13,200-volt lines—Reverse power relays.
Rotary converters:
  A-c. side—Overload relays (connected on 13,200-volt side of converter transformers).
  D-c. side—Overload, reverse current, and low-voltage trip.
D-c. feeders—Overload trip.

The electric sign on the top of the station (shown in the accompanying exterior view) faces a railroad carrying heavy passenger traffic. This sign was erected and is maintained by the Delaware County Electric Company as a part in the development of its public relations policies.

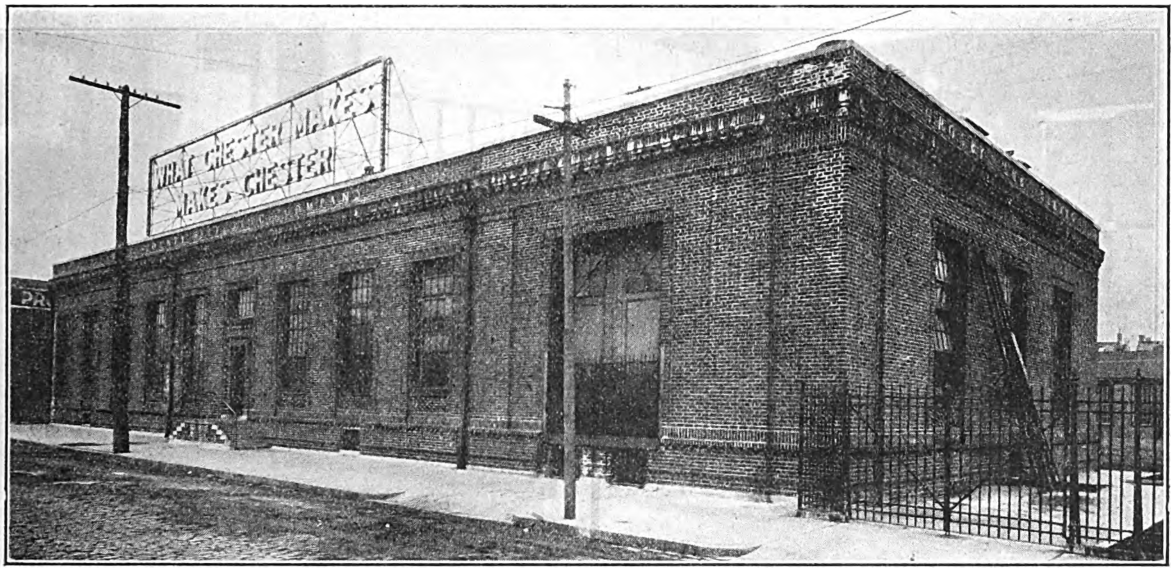

WHAT CHESTER MAKES
MAKES CHESTER

FIG. 139—Exterior, Crosby Substation.

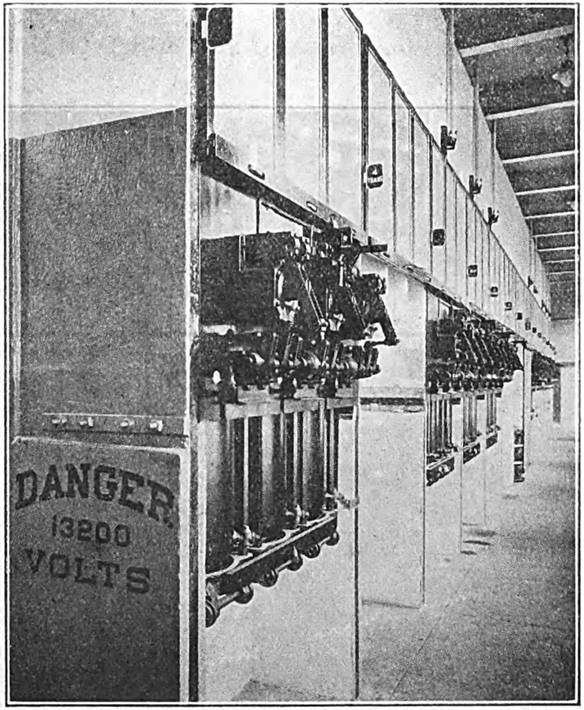

DANGER
13200
VOLTS

FIG. 140—13,200-Volt Oil Circuit Breakers and Bus Structure, Crosby Substation.

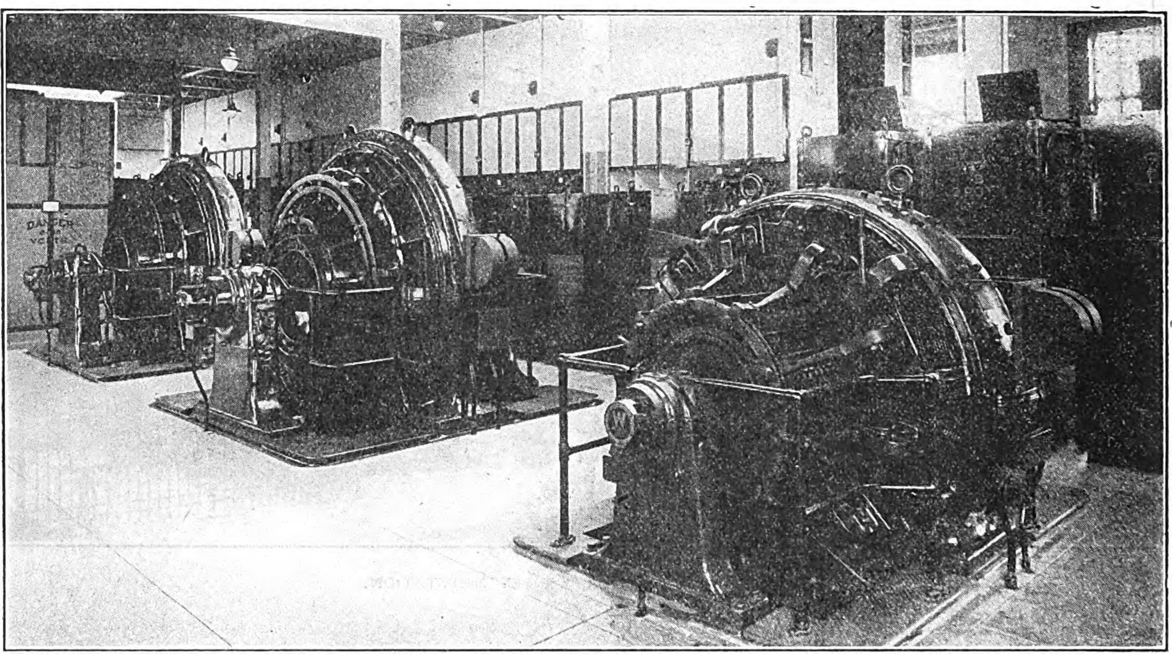


FIG. 141—1500-Kw. Synchronous Converters, Crosby Substation.

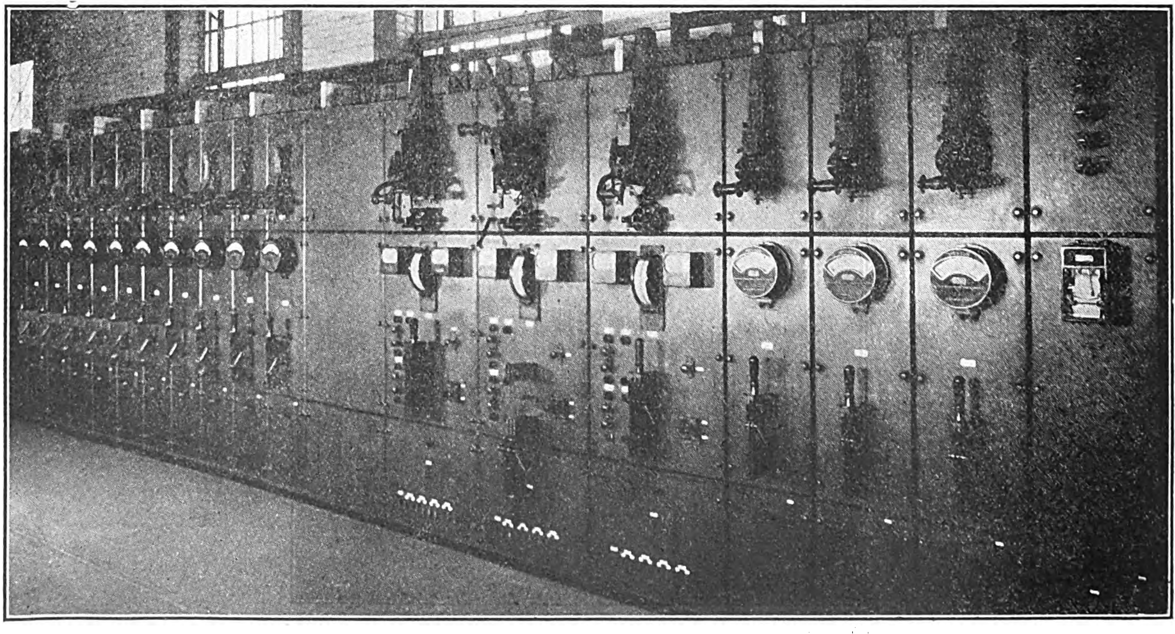


FIG. 142—Railway Switchboard, Crosby Substation.

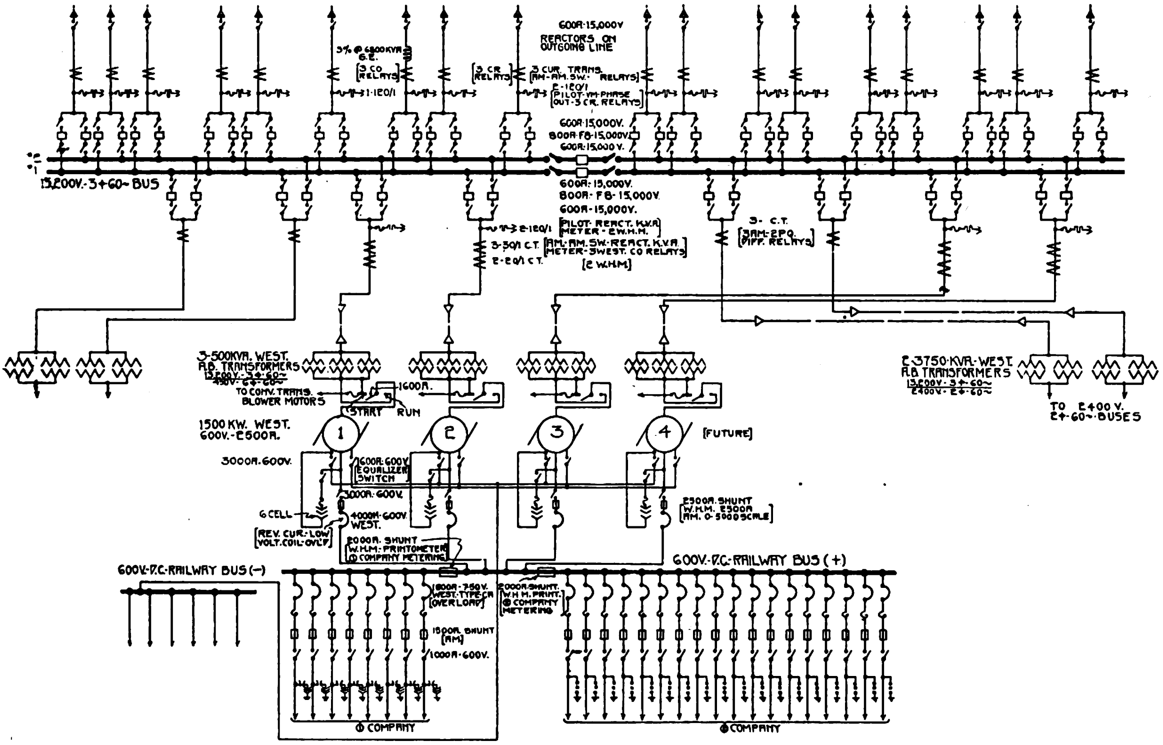

600A·15,000V
REACTORS ON OUTGOING LINE
3% @ 6800KVA G.E.
[3 CO RELAYS]
1·120/1
[3 CR RELAYS]
3 CUR. TRANS. [AM-AM.SW.- RELAYS]
2-120/1 [PILOT-VM-PHASE OUT-3 CR. RELAYS]
600A·15,000V.
800A·F8·15,000V.
600A·15,000 V.
13,200V.-3φ60~ BUS
600A·15,000V.
800A·F8·15,000V.
600A-15,000V.
2-120/1
[PILOT·REACT. K.V.A. METER - 2W.H.M.]
3-30/1 C.T. [AM·AM.SW·REACT. K.V.A. METER·3WEST. CO RELAYS]
2-20/1 C.T.
[2 W.H.M]
3- C.T. [3AM-2PO. DIFF. RELAYS]
3-500KVA. WEST. A.B. TRANSFORMERS 13,200V.-3φ·60~ / 430V.-6φ·60~
TO CONV. TRANS. BLOWER MOTORS
1600A.
START
RUN
1500 KW. WEST. 600V.-2500A.
1
2
3
4
[FUTURE]
3000A.600V.
1600A·600V [EQUALIZER SWITCH]
3000A·600V.
6 CELL
4000A·600V. WEST.
[REV. CUR.·LOW VOLT.COIL·OVLD]
2000A. SHUNT [W.H.M.·PRINTOMETER] [Φ COMPANY METERING]
2500A. SHUNT [W.H.M. 2500A] [AM. 0-5000 SCALE]
2-3750·KVA·WEST. A.B TRANSFORMERS 13,200V·3φ·60~ / 2400V·2φ·60~
TO 2400 V. 2φ·60~·BUSES
600V·D.C·RAILWAY BUS (−)
600V.·D.C·RAILWAY BUS (+)
1800A·750V. WEST. TYPE·CR [OVERLOAD]
2000A.SHUNT. [W.H.M. PRINT.] [Φ COMPANY METERING]
1500A. SHUNT [AM]
1000A·600V.
Φ COMPANY
Φ COMPANY

FIG. 143—Single Line Diagram, Crosby Substation.

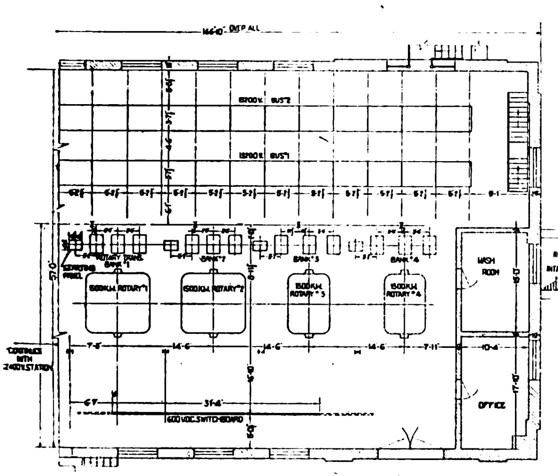

146'-10" OUT'D ALL
13200 V. BUS 2
13200 V. BUS 1
57'-0"
ROTARY TRANS. BANK 1
BANK 2
BANK 3
BANK 4
STARTING PANEL
1500 K.W. ROTARY 1
1500 K.W. ROTARY 2
1500 K.W. ROTARY 3
1500 K.W. ROTARY 4
7'-8"
14'-6"
14'-6"
14'-6"
7'-11"
10'-4"
31'-4"
600 V.D.C. SWITCHBOARD
WASH ROOM
OFFICE
AIR INTAKE
CONTINUES WITH 2400 V. STATION

FIG. 144—Plan, Crosby Substation.

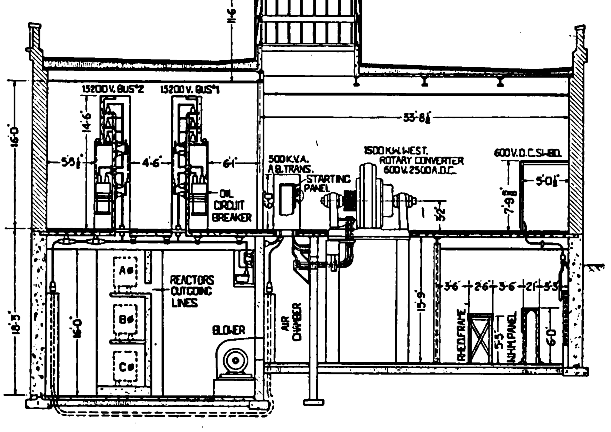

13'-0"
11'-6"
16'-0"
13200 V. BUS 2
13200 V. BUS 1
14'-6"
5'-5½"
4'-6"
6'-1"
53'-8½"
OIL CIRCUIT BREAKER
500 K.V.A. A.B. TRANS.
STARTING PANEL
1500 K.W. WEST. ROTARY CONVERTER 600 V. 2500 A.D.C.
600 V.D.C. SWBD.
5'-0½"
7'-9⅛"
3'-2"
18'-3"
16'-0"
Aφ
Bφ
Cφ
REACTORS OUTGOING LINES
BLOWER
AIR CHAMBER
15'-9"
3'-6"
2'-6"
3'-6"
2'-1"
3'-3"
RHEO. FRAME
5'-5"
W.H.M. PANEL
6'-0"

FIG. 145—Section, Crosby Substation.

New Orleans Public Service, Inc., New Orleans, La.—Polymnia Substation

This substation, located in a semi-commercial district, has its main bus operating at 13,200 volts. Power from the main generating station is brought into the bus through three underground feeders, and from this bus two outgoing feeders tie it to the other substations.

Two 6-phase rotary converters, supplied from the 13,200-volt bus through transformers, furnish power to the 600-volt d-c. railway system through ten railway feeders.

Power is supplied from the 13,200-volt bus through one bank of transformers to nineteen mercury-arc rectifier circuits for street lighting.

There is also a 4000-volt bus in this substation connected through two 3000-kv-a. transformer banks to the 13,200-volt bus. From the 4000-volt bus are five outgoing feeders for local distribution and two Whiteway circuits for street lighting. All feeders from the substation are brought out underground.

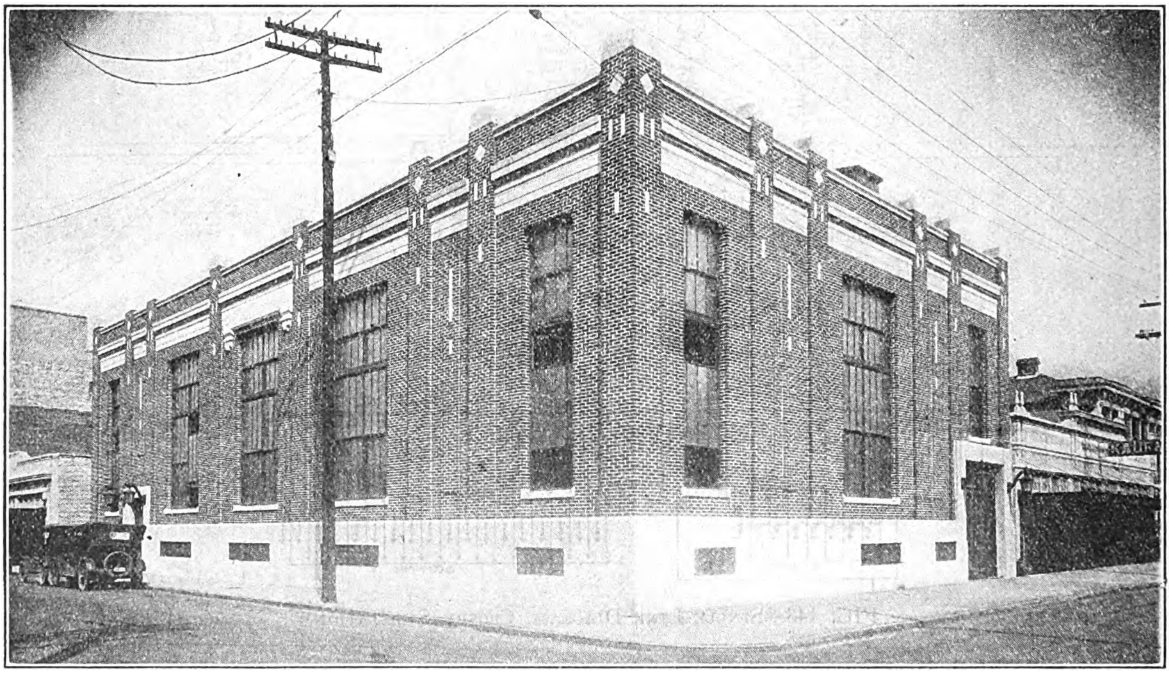


FIG. 146—EXTERIOR, POLYMNIA SUBSTATION.

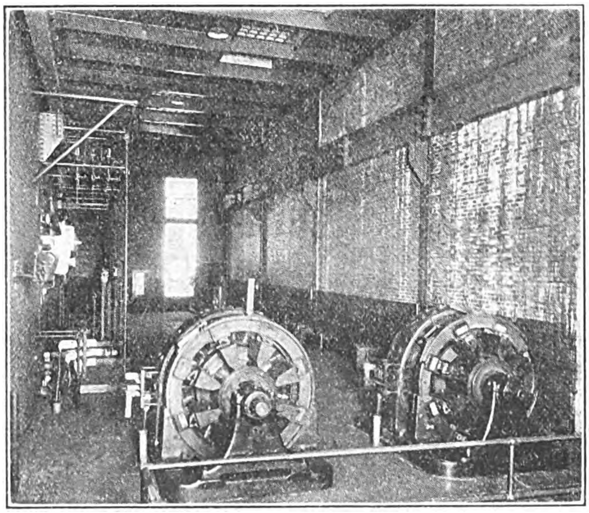


FIG. 147—SYNCHRONOUS CONVERTERS, POLYMNIA SUBSTATION.

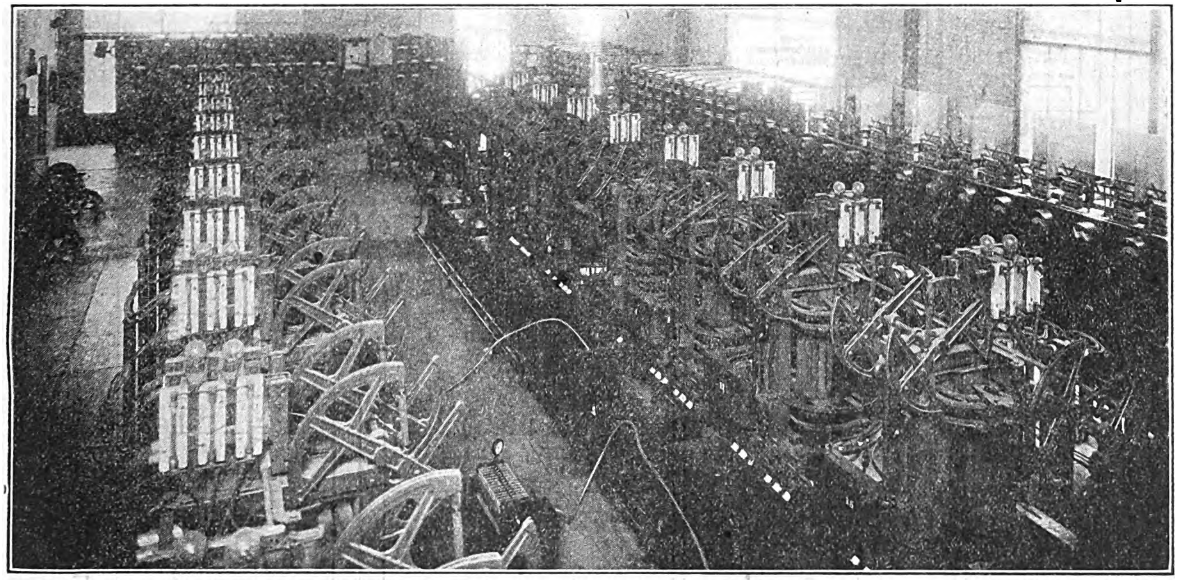


FIG. 148—RAILWAY SWITCHBOARD (IN REAR) AND STREET LIGHTING MERCURY ARC RECTIFIERS, POLYMNIA SUBSTATION.

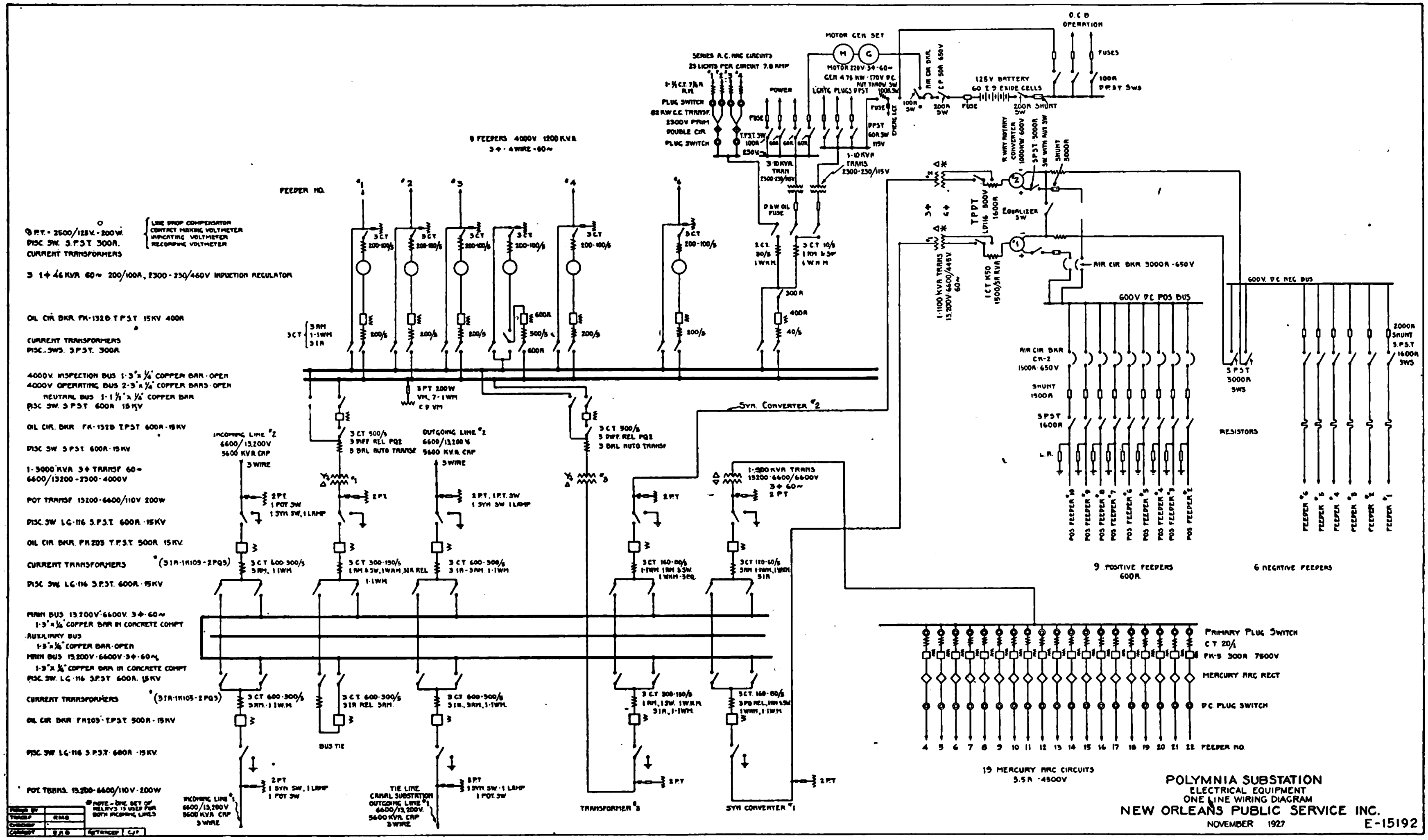

3 P.T. - 2500/125V. - 200W.
DISC SW. S.P.S.T 300A.
CURRENT TRANSFORMERS
LINE DROP COMPENSATOR
CONTACT MAKING VOLTMETER
INDICATING VOLTMETER
RECORDING VOLTMETER
3 1φ 46 KVA 60~ 200/100A, 2300-230/460V INDUCTION REGULATOR
OIL CIR. BKR. FK-132B T.P.S.T 15KV 400A
CURRENT TRANSFORMERS
DISC. SWS. S.P.S.T. 300A.
4000V. INSPECTION BUS 1-3" x 1/4" COPPER BAR - OPEN
4000V OPERATING BUS 2-3" x 1/4" COPPER BARS - OPEN
NEUTRAL BUS 1-1 1/2" x 1/4" COPPER BAR
DISC SW. S.P.S.T 600A 15KV
OIL CIR. BKR FK-132B T.P.S.T 600A - 15KV
DISC SW S.P.S.T 600A - 15KV
1-3000 KVA 3φ TRANSF 60~
6600/13200-2300-4000V
POT TRANSF 13200-6600/110V 200W
DISC. SW LG-116 S.P.S.T 600A - 15KV
OIL CIR. BKR. FH 203 T.P.S.T 500A 15KV.
CURRENT TRANSFORMERS
(3 1A-1 R105-2 PQ3)
DISC SW. LG-116 S.P.S.T. 600A - 15KV
MAIN BUS 13,200V-6600V. 3φ-60~
1-3" x 1/4" COPPER BAR IN CONCRETE COMPT
AUXILIARY BUS
1-3" x 1/4" COPPER BAR - OPEN
MAIN BUS 13,200V-6600V-3φ-60~
1-3" x 1/4" COPPER BAR IN CONCRETE COMPT
DISC. SW. LG-116 S.P.S.T 600A. 15KV
CURRENT TRANSFORMERS
(3 1A-1 R105-2 PQ3)
OIL CIR BKR FH203-T.P.S.T 500A - 15KV
DISC. SW LG-116 S.P.S.T. 600A - 15KV.
POT. TRANS. 13,200-6600/110V - 200W
NOTE - ONE SET OF RELAYS IS USED FOR BOTH INCOMING LINES
TRACED RMG
CORRECT BAB
RETRACED CJP
FEEDER NO.
8 FEEDERS 4000V 1200 KVA
3φ - 4 WIRE - 60~
1
2
3
4
6
3 CT 200-100/5
200/5
500/5
600A
40/5
400A
300A
3 CT {3 RM 1-1WM 3 1A
3 PT 200W
VM, 7-1WM
C D VM
3 CT 500/5
3 DIFF REL PQ2
3 BAL AUTO TRANSF
INCOMING LINE #2
6600/13,200V
5600 KVA CAP
3 WIRE
OUTGOING LINE #2
6600/13,200V
5600 KVA CAP
3 WIRE
#1
#3
2 PT
1 POT SW
1 SYN SW, 1 LAMP
2 PT, 1 PT. SW
1 SYN SW 1 LAMP
3 CT 600-300/5
3 RM, 1 IWM
3 CT 300-150/5
1 RM & SW, 1 WRM, 3 1A REL
1-1WM
3 CT 600-300/5
3 1A-3 RM 1-1WM
3 CT 160-80/5
1-1WM 1RM & SW
1 WRM-3 PQ
3 CT 120-60/5
3 RM 1-1WM, 1 WRM
3 1A
3 CT 600-300/5
3 RM-1 IW.M.
3 C.T. 600-300/5
3 1A REL 3 RM.
3 CT 600-300/5
3 1A, 3 RM, 1-1WM.
3 CT 300-150/5
1 RM, 1 SW, 1 WRM.
3 1A, 1-1WM.
3 CT 160-80/5
3 PQ REL, 1 RM & SW
1 WRM, 1-1WM
BUS TIE
INCOMING LINE #1
6600/13,200V
5600 KVA CAP
3 WIRE
TIE LINE
CANAL SUBSTATION
OUTGOING LINE #1
6600/13,200V.
5600 KVA CAP
3 WIRE
1 SYN SW - 1 LAMP
1 POT SW
TRANSFORMER #3
SYN CONVERTER #1
SYN. CONVERTER #2
1-1500 KVA TRANS
13200-6600/6600V
3φ 60~
2 PT
SERIES A.C. ARC CIRCUITS
25 LIGHTS PER CIRCUIT 7.8 AMP
1-1/2 C.T. 7/5 A
R.M.
PLUG SWITCH
82 KW C.C. TRANSF.
2300V PRIM
DOUBLE CIR
PLUG SWITCH
POWER
FUSE
T.P.S.T. SW
100A
230V
60A
3-10 KVA.
TRAN
2300-230/115V
D & W OIL FUSE
2 C.T.
30/5
1 W.H.M.
3 C.T. 10/5
1 RM & SW
1 W.H.M.
MOTOR GEN SET
M
G
MOTOR 220V 3φ-60~
GEN 4.75 KW - 170V DC.
LGHTG PLUGS DPST
AUT THROW SW
100A SW
DPST
60A SW
115V
EMERG LGT.
1-10 KVA
TRANS.
2300-230/115V
AIR CIR BKR.
C P 50A 650V
100A SW
200A SW
125V BATTERY
60 E-9 EXIDE CELLS
200A SW
SHUNT
O.C.B.
OPERATION
FUSES
100A
DPST SWS
1-1100 KVA TRANS
13,200V-6600/445V
60~
3φ
6φ
TPDT
LD116 500V
1600A
1 CT K50
1500/5A KVA
R WAY ROTARY
CONVERTER
1000 KW 600V
SPST 3000A
SW WITH AUX SW
SHUNT
3000A
EQUALIZER SW
AIR CIR BKR 3000A - 650V
600V DC POS BUS
AIR CIR BKR
CR-2
1500A 650V
SHUNT
1500A
S.P.S.T
1600A
L.R.
POS FEEDER #10
POS FEEDER #9
POS FEEDER #8
POS FEEDER #7
POS FEEDER #6
POS FEEDER #5
POS FEEDER #4
POS FEEDER #3
POS FEEDER #2
9 POSITIVE FEEDERS
600A.
600V. DC NEG BUS
S.P.S.T
3000A
SWS
RESISTORS
2000A
SHUNT
S.P.S.T
1600A
SWS.
FEEDER #6
FEEDER #5
FEEDER #4
FEEDER #3
FEEDER #2
FEEDER #1
6 NEGATIVE FEEDERS
PRIMARY PLUG SWITCH
C.T. 20/5
FK-5 300A 7500V
MERCURY ARC RECT
DC PLUG SWITCH
4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 FEEDER NO.
19 MERCURY ARC CIRCUITS
5.5A - 4500V
POLYMNIA SUBSTATION
ELECTRICAL EQUIPMENT
ONE LINE WIRING DIAGRAM
NEW ORLEANS PUBLIC SERVICE INC.
NOVEMBER 1927
E-15192

FIG. 149—SINGLE LINE DIAGRAM, POLYMNIA SUBSTATION.

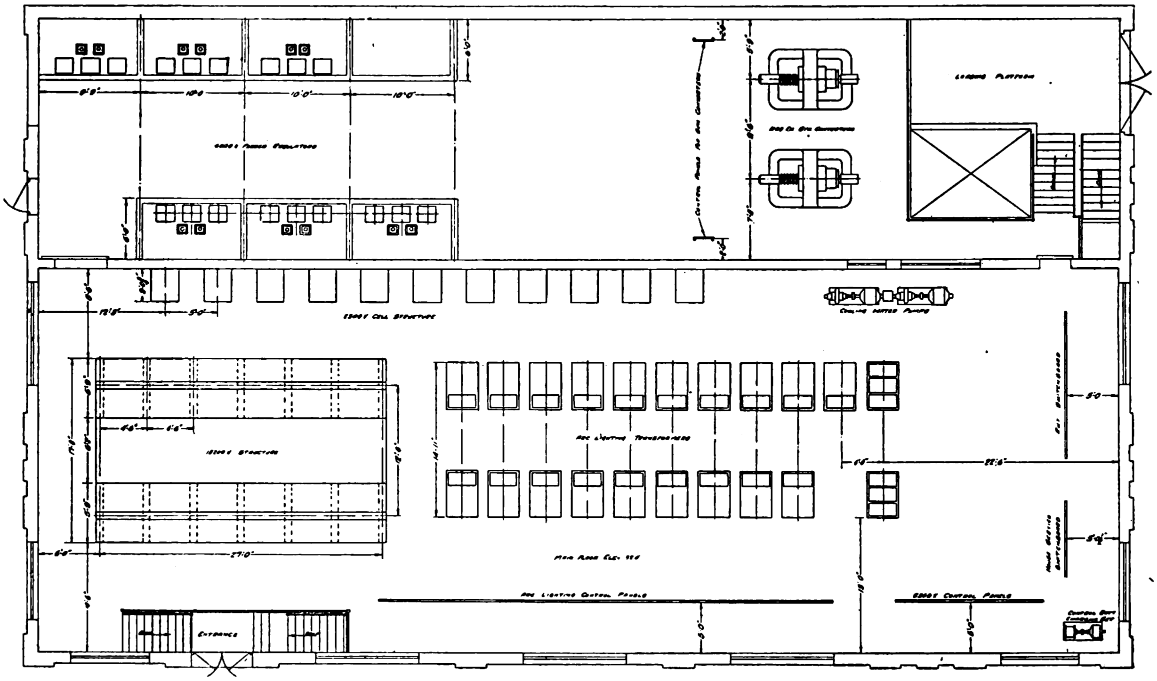
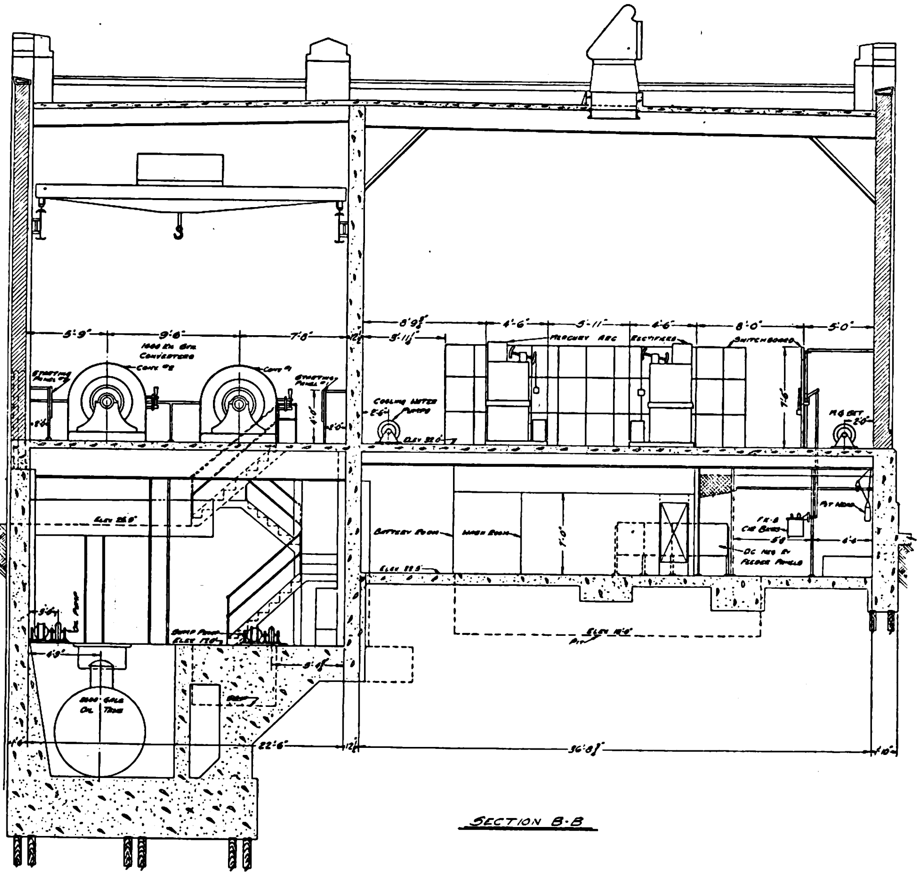
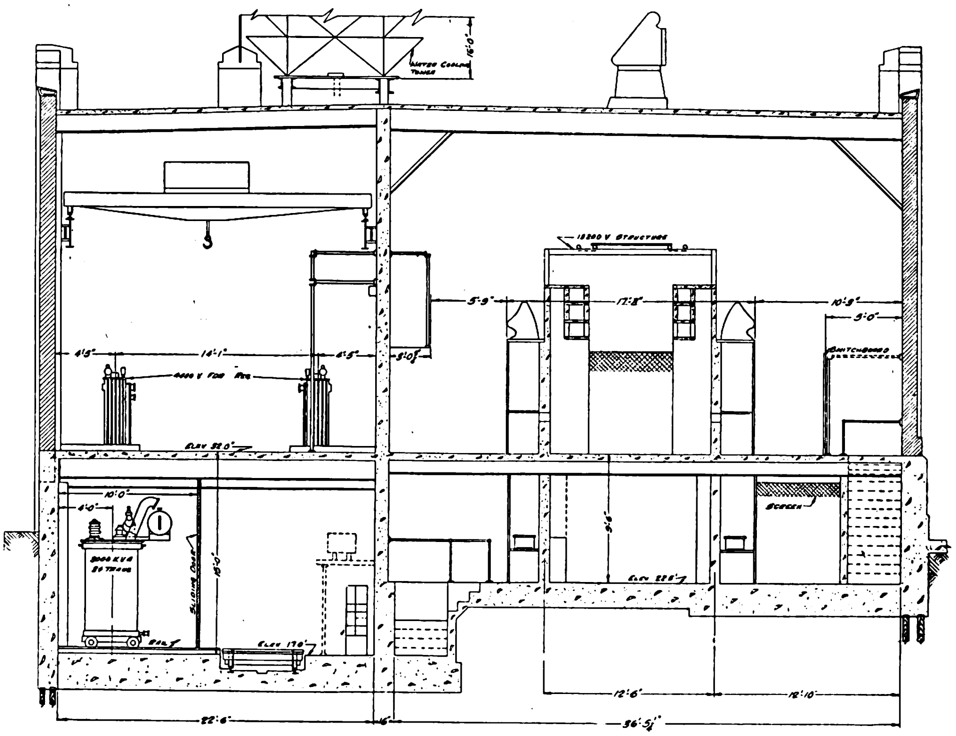

10'0"
10'0"
10'0"
6'0"
Loading Platform
Cooling Water Pumps
2300 V Cell Structure
12'8"
5'0"
4'6"
6'6"
13200 V Structure
27'0"
Arc Lighting Transformers
22'6"
5'0"
Main Floor Elev.
Arc Lighting Control Panels
2300 V Control Panels
18'0"
8'0"
5'0"
Entrance

FIG. 150—PLAN, POLYMNIA SUBSTATION.


5'-9"
9'-6"
7'-8"
1000 Kw Syn. Converters
Conv. #2
Conv. #1
Starting Panel #2
Starting Panel #1
8'-9¾"
5'-11½"
4'-6"
5'-11"
4'-6"
8'-0"
5'-0"
Mercury Arc Rectifiers
Switchboard
Cooling Water Pumps
2'-6"
M.G. Set
2'-0"
7'-6"
Elev. 32.0'
Elev. 25.6'
Battery Room
Wash Room
7'-0"
F.K.-8 Cir. Bkrs.
5'-9"
6'-4"
Pot Head
D.C. Neg. & Feeder Panels
Elev. 22.5'
Elev. 16.0'
Pit
Oil Pump
Sump Pump
Elev. 17.0'
6'-9"
8'-0"
2000 Gals. Oil Tank
22'-6"
12"
36'-8½"
10"

SECTION B-B


16'-0"
Water Cooling Tower
13200 V Structure
5'-9"
17'-8"
10'-9"
5'-0"
Switchboard
4'-5"
14'-1"
4'-5"
3'-0½"
4000 V for Rec.
Elev. 32.0'
10'-0"
4'-0"
3000 K.V.A. 3φ Trans.
Sliding Door
15'-0"
Rail
Elev. 17.0'
9'-6"
Screen
Elev. 22.5'
12'-6"
12'-10"
22'-6"
16"
36'-5¼"

SECTION A-A

FIG. 151—SECTIONS, POLYMNIA SUBSTATION.

Utica Gas and Electric Co., Utica, N. Y.—Whitesboro and New Hartford Substations

These substations are located approximately four miles from the center of the city of Utica and are combination railway and distribution substations.

Whitesboro substation is supplied by two 44,000-volt circuits from Washington Street station, and in general consists of a distribution transformer bank, two distribution circuits with necessary switching equipment, including induction regulators, and two 500-kw., General Electric synchronous converters. The New Hartford substation is very similar to the Whitesboro substation, except that there is only one commercial circuit and the railway equipment is of Westinghouse manufacture. This substation is also supplied by a 44,000-volt feeder from Washington Street substation.

Relay protection is provided as follows: The machines are protected against flashover with flashover and overload relays. The current transformers for the overload protection are located in the low-voltage leads, and both the flashover and overload relays trip the high tension breaker. This breaker has an auxiliary contact which, when the breaker opens, opens the d-c. machine breaker. The machines are protected against low voltage by low-voltage relays connected in the low-voltage leads of the a-c. supply. These relays trip the high tension breaker, which in turn, as previously explained, opens the d-c. breaker. Other protection consists of the usual reverse current on the d-c. side, d-c. overload and overspeed protection.

Because of the similarity of these substations, drawings and photographs of Whitesboro substation only are reproduced in this report.

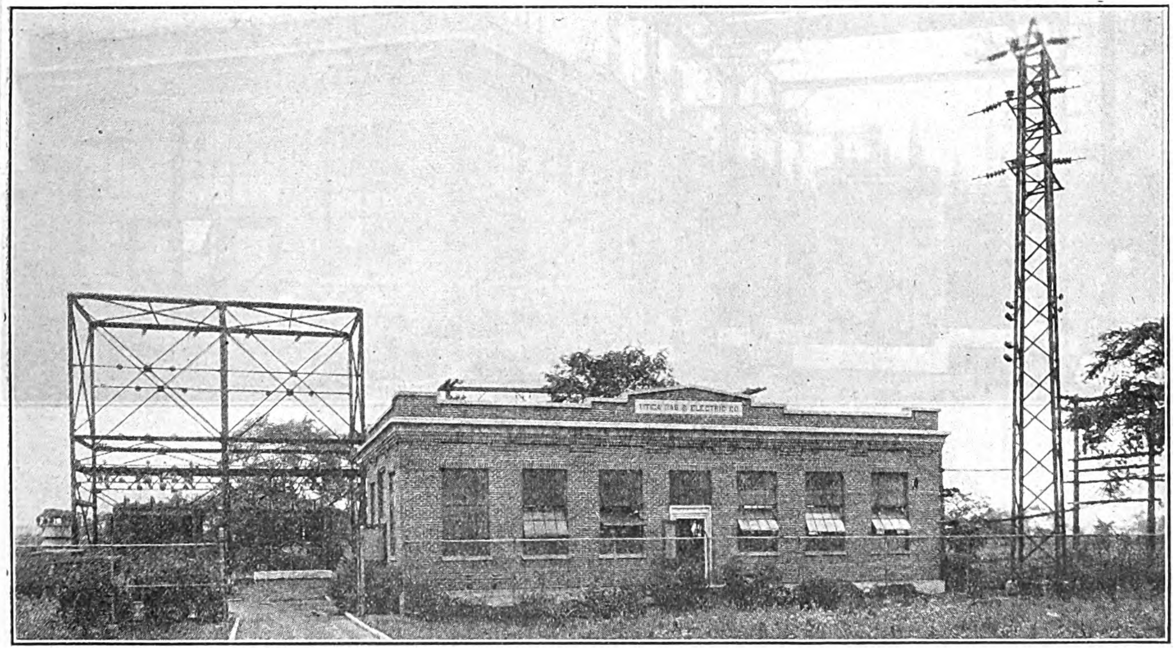


FIG. 152—EXTERIOR, WHITESBORO SUBSTATION.

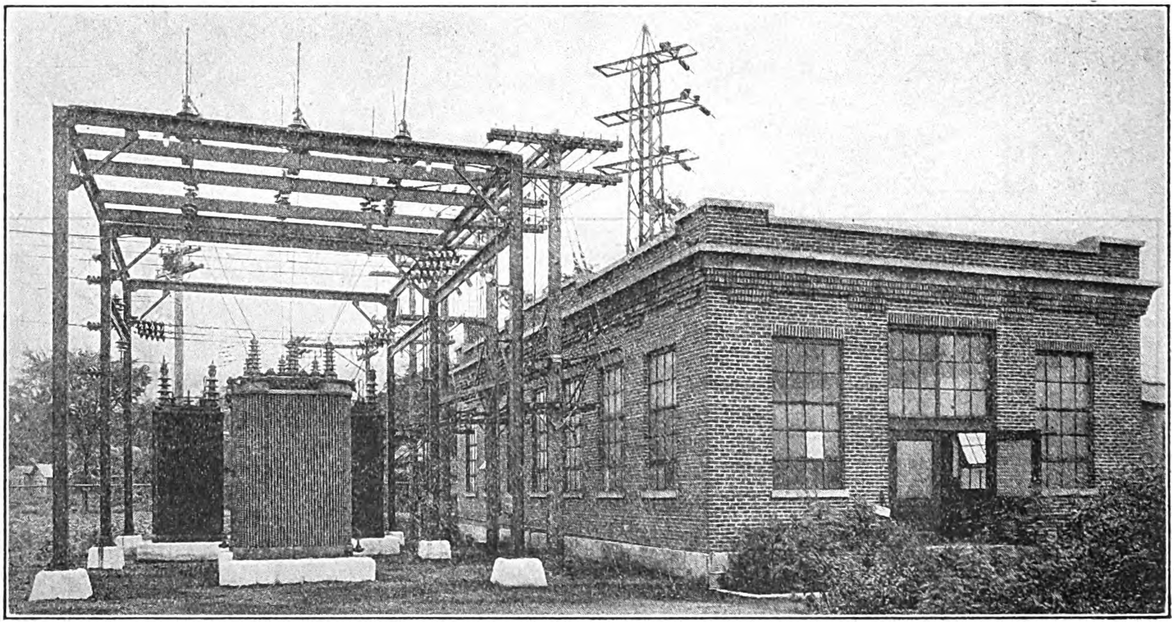


FIG. 153—EXTERIOR, WHITESBORO SUBSTATION.

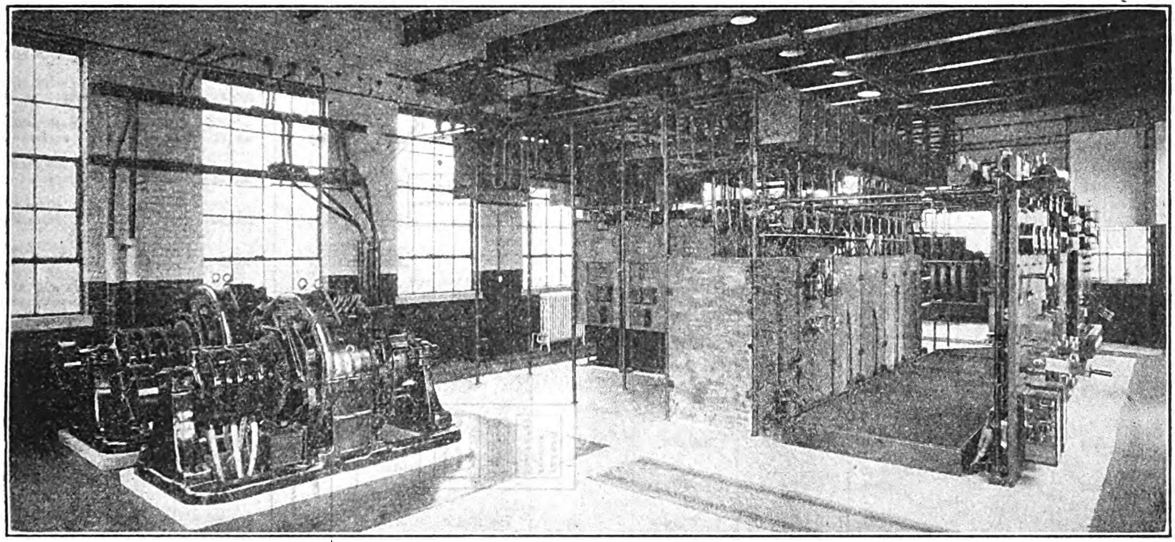


FIG. 154—GENERAL INTERIOR VIEW, WHITESBORO SUBSTATION.

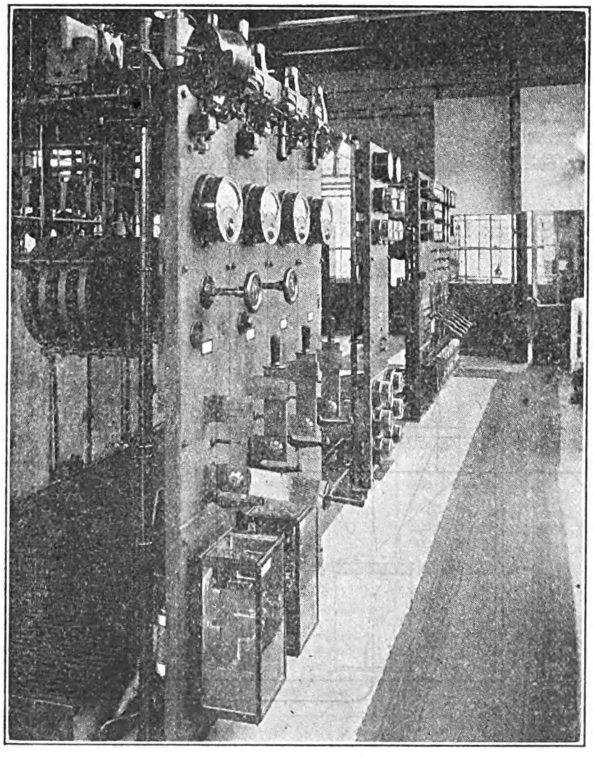


FIG. 155—SWITCHBOARD, WHITESBORO SUBSTATION.

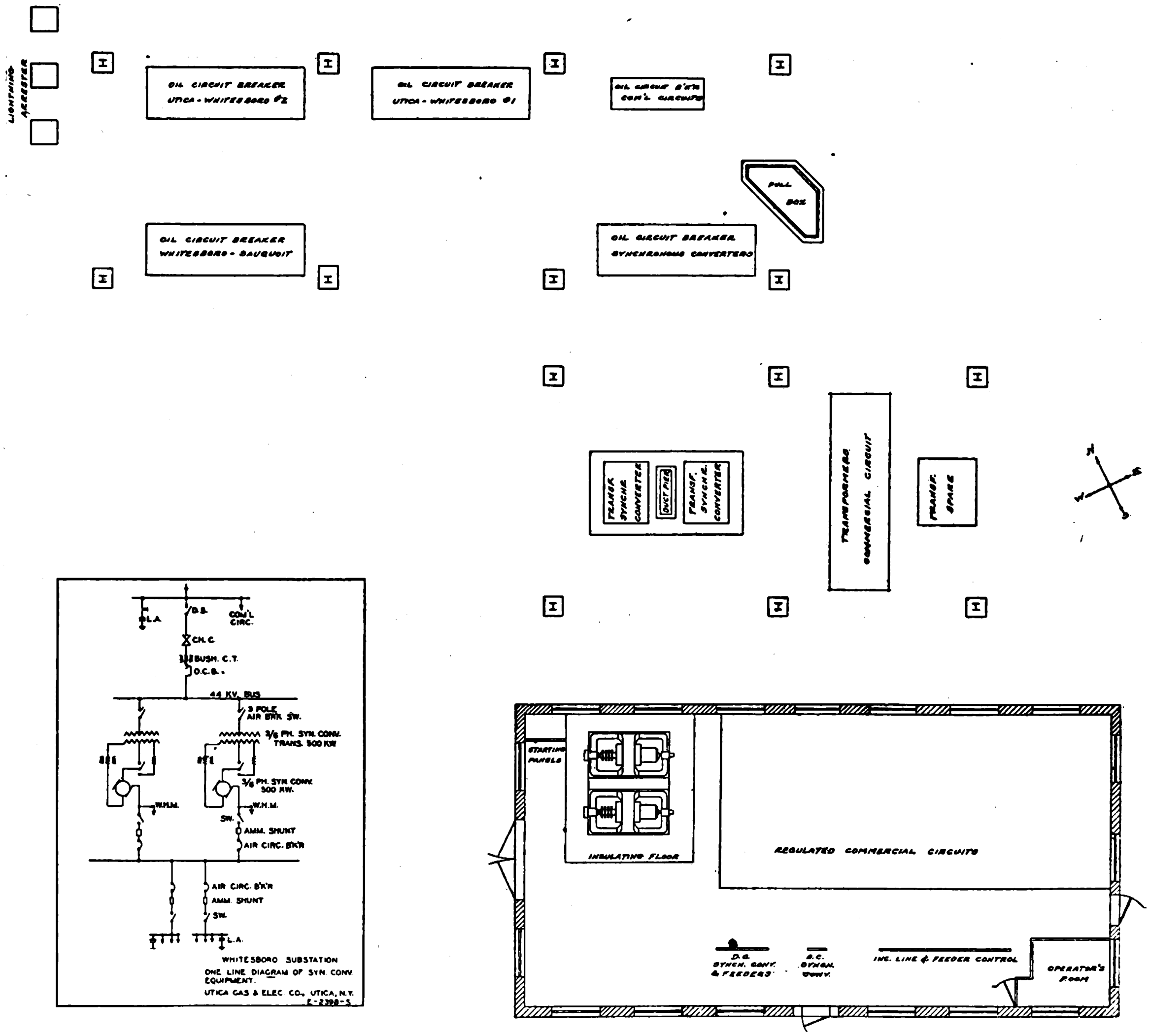

LIGHTNING ARRESTER
OIL CIRCUIT BREAKER UTICA-WHITESBORO #2
OIL CIRCUIT BREAKER UTICA-WHITESBORO #1
OIL CIRCUIT B'K'R COM'L CIRCUITS
PULL BOX
OIL CIRCUIT BREAKER WHITESBORO-SAUQUOIT
OIL CIRCUIT BREAKER SYNCHRONOUS CONVERTERS
TRANSF. SYNCH. CONVERTER
DUCT PIER
TRANSF. SYNCH. CONVERTER
TRANSFORMERS COMMERCIAL CIRCUIT
TRANSF. SPARE
N
E
W
S
D.S.
L.A.
COM'L CIRC.
CH. C.
BUSH. C.T.
O.C.B.
44 KV. BUS
3 POLE AIR BRK. SW.
3/6 PH. SYN. CONV. TRANS. 500 KW
3/6 PH. SYN CONV. 500 KW.
W.H.M.
W.H.M.
SW.
AMM. SHUNT
AIR CIRC. BK'R
AIR CIRC. B'K'R
AMM. SHUNT
SW.
L.A.
WHITESBORO SUBSTATION
ONE LINE DIAGRAM OF SYN. CONV. EQUIPMENT.
UTICA GAS & ELEC. CO., UTICA, N.Y.
E-2398-S
STARTING PANELS
INSULATING FLOOR
REGULATED COMMERCIAL CIRCUITS
D.C. SYNCH. CONV. & FEEDERS
A.C. SYNCH. CONV.
INC. LINE & FEEDER CONTROL
OPERATOR'S ROOM

FIG. 156—SINGLE LINE DIAGRAM AND PLAN, WHITESBORO SUBSTATION.

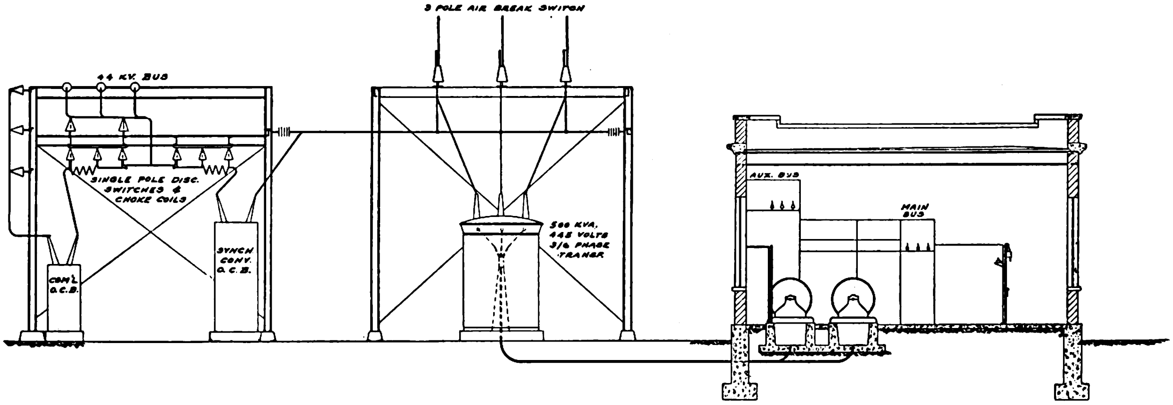

3 POLE AIR BREAK SWITCH
44 KV. BUS
SINGLE POLE DISC. SWITCHES & CHOKE COILS
COM'L O.C.B.
SYNCH. CONV. O.C.B.
500 KVA. 445 VOLTS 3/6 PHASE TRANSF.
AUX. BUS
MAIN BUS

FIG. 157—SECTION, WHITESBORO SUBSTATION.

TABLE II

TABULATION OF DATA

RAILWAY SUBSTATIONS

For Key to Abbreviations, See List Accompanying Table I

HIGH TENSION

	Feeders							Oil Circuit Breakers		
Substations	Voltage	Frequency	Location	Pres. No.	Ultimate No.	Pres. Size	Ultimate Size	Mfr. & Type	Rated Volts	Operation
AUTOMATIC										
Cleveland Railway Co. Std. 2-Unit Auto Station	11,000	60	U.G.	2	2	4/0	4/0	W-CO-11	25,000	Elec.
Commonwealth Edison Co. West Lawn Substation	12,000	60	U.G.	2	5	500 MCM	500 MCM	Con-F11	15,000	Elec.
Denver Tramway Corp. Colfax Substation	13,200	25	O.H.	2	2	2/0 Al.	2/0 Al.	GE-FK 132 B	15,000	Manual
Detroit Edison Co. Roseville Substation	24,000	60	O.H.	2	4	1/0	1/0	W-O-221	37,000	Elec.
Duquesne Light Co. Maple Substation	22,000	60	U.G.	2	2	350 MCM	350 MCM	None	-	-
Kansas City Public Serv.Co. Blue Ave. Substation	6,600	25	O.H.	1	1	2/0	2/0	GE-FH 3	15,000	Elec.
Milwaukee El.Ry.& Lt.Co. St. Martins Substation	27,600	60	O.H.	1	2	2	2	None	-	-
Public Serv.Elec. & Gas Co. Miller St. Substation	13,200	60	U.G.	5	8	350 MCM	350 MCM	GE-FH 203	15,000	Elec.
Public Service Co. of No.Ill. Glen Ellyn Substation	33,000	60	O.H.	1	4	3/0	3/0	GE- FHKD-30-32-B	37,000	Elec.
NON-AUTOMATIC										
Commonwealth Edison Co. Laflin St. Substation	12,000	60	U.G.	2	5	500 MCM	500 MCM	W-OE6	15,000	Elec.
Dallas Power & Light Co. Typical Substation	13,200	60	Combin- ation	4	4	2/0	2/0	GE-H803 W-OE6	15,000	Elec.
Delaware County El.Co. Crosby Substation	13,200	60	U.G.	3 In 1 Out	18	350 MCM	350 MCM	Con-F6	15,000	Elec.
New Orleans Public Serv.Inc. Dryades Substation			See Dryades Substation under Non Automatic Edison Substations							
New Orleans Public Serv.Inc. Polymnia Substation	13,200	60	U.G.	3 In 2 Out	3 In 2 Out	350 MCM	350 MCM	GE-FH-203	15,000	Elec.
Utica Gas & Elec. Co. New Hartford Substation	44,000	60	O.H.	1	2	2/0	2/0	W-O-11	73,000	Man. close Elec. Trip
Utica Gas & Elec. Co. Whitesboro Substation	44,000	60	O.H.	2	2	2/0	2/0	GE- FHKO-39	50,000	Elec.

HIGH TENSION

	Air Break Switches			Disconnecting Switches				Potential Transformers			Current Transf.			Lightning Arresters	
Substations	Mfr. & Type	Rated Volts	Rated Amps.	Mfr.	Rated Volts	Rated Amps.	Operation	Mfr. & Type	Ratio	No. per Circuit	Mfr. & Type	Ratio	No. per Circuit	Location	Mfr. & Type
AUTOMATIC															
Cleveland Railway Co. Std. 2-Unit Auto Station	None	-	-	W	15,000	400	Hook Stick	W-VC	100/1	2	W-KB	150/5 150/5 200/5	2 Conv. 2) Line 3)	None	-
Commonwealth Edison Co. West Lawn Substation	None	-	-	And.	15,000	600	Hook Stick	GE-E115	100/1	3 per bus	GE-K48	600/5	3	None	-
Denver Tramway Corp. Colfax Substation	None	-	-	GE	15,000	400	Hook Stick	GE-H	120/1	2	GE-K48	100/5	3	Old Line ID	W-Auto Valve GE-OF
Detroit Edison Co. Roseville Substation	None	-	-	Elpeco	35,000	600	Gang	W-VC	200/1	2	None	-	-	OD	W-SV
Duquesne Light Co. Maple Substation	Delta Star PM-2	37,000	600	Delta Star	37,000	600	Gang	Special W-3 Phase	200/1	1	W-OA	50/5	2	None	-
Kansas City Public Serv.Co. Blue Ave. Substation	None	-	-	GE	13,200	300	Hook Stick	None	-	-	GE-K48	300/5	2	ID Line	GE-OF
Milwaukee El.Ry.& Lt.Co. St. Martins Substation	None	-	-	E.E.E.Co	37,000	300	Hook Stick	None	-	-	None	-		OD Bus	W-SV
Public Serv. Elec. & Gas Co. Miller St. Substation	None	-	-	GD & F	15,000	300	Hook Stick	GE	120/1	2	GE	400/5	3	None	-
Public Service Co. of No.Ill. Glen Ellyn Substation	R&IE IB2	37,000	200	R&IE	37,000	300	Gang	None	-	-	GE- Bush	80/5	3	OD Line	GE-OF
NON-AUTOMATIC															
Commonwealth Edison Co. Laflin St. Substation	None	-	-	W	15,000	600	Hook Stick	GE-E115	100/1	3 per bus	W-KB	600/5	3	None	-
Dallas Power & Light Co. Typical Substation	None	-	-	GE	15,000	400	Hook Stick	W-VC GE-EM13	120/1	2	GE-K48 W-KB	300/5	3	ID Bus	GE-OF W-SV
Delaware County El. Co. Crosby Substation	None	-	-	R&IE	15,000	600	Hook Stick	GE-EMB	120/1	1 Out 2 In	GE-K48	300/5 400/5	3	None	-
New Orleans Public Serv.Inc. Dryades Substation					See Dryades Substation under Non Automatic Edison Substations										
New Orleans Public Serv.Inc. Polymnia Substation	None	-	-	GE	15,000	600	Hook Stick	GE-EM13	120/1	2	GE-K48	150- 300/5	3	OD Line	GE-Pellet
Utica Gas & Elec. Co. New Hartford Substation	R&IE- EVS	50,000	300	E.E.E.	60,000	300	Hook Stick	Packard Metering		2	W-Bush	150/5	3	OD	W-SV
Utica Gas & Elec. Co. Whitesboro Substation	R&IE- T.T.L.	50,000	600	E.E.E.	60,000	200	Hook Stick	None	-	-	GE-Bush	300/5 200/5	3	OD	W-SV

---

1. Voltage rating of taps 11690, 11330, 10960, 10590, 10290.
2. The two transformer banks supply 4150-volt commercial feeders in addition to the motor-generator sets.
3. Voltage rating of each bank is 26400-25911-25422-24933-24444-23956 -23467-13200-12711-12222-11733/4150Y.

TABLE II--(Continued)

TRANSFORMERS

Substations	Location	Mfg.	Bank or 3φ KVA Rating		Single or 3 Phase Units	Cooling	Primary Phase Voltage	Primary Connections	Secondary Connections	Voltage Rating of Taps	Full or Reduced Capacity	External Tap Changer	Transf. de-energized when Conv. Equipt. is Idle	Method of Starting
			Continuous	2 Hour										
AUTOMATIC														
Cleveland Railway Co. Std. 2-Unit Auto Station	Semi O.D.	W	1650	150%	1	OISC	11000	Delta	6 ph.dia.	3-4% 4-2½%	F.C.	No	Yes	HV Taps
Commonwealth Edison Co. West Lawn Substation	I.D.	ABB	4410	150%	3	OISC	12000	Star	Double 6 ph.fork	3-See Note 1	F.C.	No	Yes	Ignition cir. on rect.
Denver Tramway Corp. Colfax Substation	I.D.	GE	1050	150%	3	OISC	13000	Delta	Dia.	2-2½%	F.C.	No	No	HV Taps
Detroit Edison Co. Roseville Substation	O.D.	W	1000	150%	1	OISC	24000	Delta	6 ph.dia.	4-2½%	F.C.	No	No	HV Taps
Duquesne Light Co. Maple Substation	O.D.	W	1000	150%	3	OISC	22000	Star	6 ph.dia.	2-2½% above 4-2½% below	F.C.	Yes	Yes	HV Taps
Kansas City Public Serv. Co. Blue Ave. Substation	I.D.	GE	1125	100%	1	Air Blast	6600	Delta	Delta	4-2½%	F.C.	No	Yes	HV Taps
Milwaukee El.Ry.& Lt.Co. St. Martins Substation	O.D.	W	500	150%	3	OISC	27600	Star	6 ph.dia.	4-2½%	F.C.	Yes	No	HV Taps
Public Serv. El. & Gas Co. Miller St. Substation	I.D.	GE	2-8000 See Note 2	100%	1	OISC	26400	Delta	Star	See Note 3	F.C.	Yes	No	Y Delta
Public Service Co. of No.Ill. Glen Ellyn Substation	O.D.	GE	1575	150%	3	OISC	33000	Delta	Dia.	3-5%	F.C.	No	Yes	HV Taps
NON-AUTOMATIC														
Commonwealth Edison Co. Laflin St. Substation	I.D.	GE	1575	150%	3	OISC	12000	Star Delta Tert.	6 ph.dia.	1-5%	F.C.	Yes	Yes	Ignition cir. on rect.
Dallas Power & Light Co. Typical Substation	None	-	-	-	-	-	-	-	-	-	-	-	-	HV Taps & Full Voltage
Delaware Co. Elec. Co. Crosby Substation	I.D.	W	1500	150%	1	Air Blast	13200	Delta	Dia.	4-2½%	F.C.	No	Yes	HV Taps
New Orleans Public Serv.Inc. Dryades Substation	I.D.	W	1000	100%	3	(See Dryades Substation Under Non-Automatic Edison Substation)								
New Orleans Public Serv.Inc. Poylmnia Substation	I.D.	GE	1100	150%	3	Water	13200	Delta	Double Delta	10-2½%	F.C.	No	Yes	HV Taps
Utica Gas & Elec. Co. New Hartford Substation	O.D.	W	500	150%	1	OISC	44000	Delta	6 ph.dia.	2-7½%	F.C.	Yes	Yes	HV Taps
Utica Gas & Elec. Co. Whitesboro Substation	O.D.	GE	500	150%	3	OISC	44000	Star	6 ph.dia.	4-2½%	F.C.	Yes	Yes	HV Taps

CONVERSION APPARATUS

Substation	No. & Class	Mfg.	RPM	Continuous Rating K.W.	2 Hour Rating	Normal D.C. Volts	Operating D.C. Volts		Wound	Excited	Foundations Integral With Sta. Floor	Special Sound-Proofing	Special Ventilation	Provision for Handling Converter Parts
							Max.	Min.						
AUTOMATIC														
Cleveland Railway Co. Std. 2-Unit Auto Station	2 Syn C	W	514	1500	150%	600	615	585	Comp.	Self	Yes	No	No	Crane
Commonwealth Edison Co. West Lawn Substation	1 Rect.	ABB	-	3000	150% (200%-1 min.)	600			-	-	No Special Foundation	No	-	Truck
Denver Tramway Corp. Colfax Substation	1 Syn C	GE	750	1000	150%	600	600	550	Comp.	Self	No	No	Yes	Crane
Detroit Edison Co. Roseville Substation	1 Syn C	W	900	1000	150%	650	650	525	Comp.	Self	Yes	No	No	Chain fall
Duquesne Light Co. Maple Substation	2 Syn C	W	900	1000	150%	600	660	570	Shunt	Self	No	Yes	Yes	Monorail
Kansas City Public Serv.Co. Blue Ave. Substation	1 Syn C	GE	375	1000	100%	600	625	575	Comp.	Self	Yes	No	No	Portable Monorail
Milwaukee El.Ry. & Lt.Co. St. Martins Substation	2 Syn C	W	1200	500	150%	600	630	560	Shunt	Self	Yes	No	Yes	None
Public Serv.El.& Gas Co. Miller St. Substation	2 Syn MG	GE	600	1500	150%	600	600	550	Comp.	Dir.conn. Exciter	No	Yes	Yes	Hand Crane
Public Service Co. of No.Ill. Glen Ellyn Substation	1 Syn C	GE	720	1500	150%	600	650	570	Comp.	Self	Yes	Yes	Yes	None
NON-AUTOMATIC														
Commonwealth Edison Co. Laflin St. Substation	1 Rect.	GE	-	1500	150% (200%-1 min.)	1500	1560	1420	-	-	No Special Foundation	No	-	Monorail
Dallas Power & Light Co. Typical Substation	3 Syn MG	GE	720	1000	150%	600	600	600	Flat Comp.	Dir.conn. Exciter	No	No	Yes	Crane
Delaware Co. Elec. Co. Crosby Substation	3 Syn C	W	720 1mch 514 2 "	1500	150%	600	600	600	Flat Comp.	Self	No	No	No	Portable Tackle
New Orleans Public Serv.Inc. Dryades Substation	2 Syn C	W	900	1000	100%	600	625	575	Comp.	Self	Yes	No	No	Crane
New Orleans Public Serv.Inc. Polymnia Substation	2 Syn C	GE	900	1000	150%	600	625	575	Comp.	Self	Yes	No	No	Crane
Utica Gas & Elec. Co. New Hartford Substation	2 Syn C	W	1200	500	150%	600	600	600	Comp.	Self	Yes	No	No	None
Utica Gas & Elec. Co. Whitesboro Substation	2 Syn C	GE	1200	500	150%	630	600	600	Comp.	Self	Yes	No	No	None

TABLE II—(Continued)

SWITCHBOARD

Substation	Auto or Manual	Source of Control Current	Battery Charging Source	AIR CIRCUIT BREAKERS (MACHINE)				AIR CIRCUIT BREAKERS (FEEDER)				KNIFE SWITCH	
				High Speed	Mfg. & Type	Rated Volts	Rated Amps.	High Speed	Mfg. & Type	Rated Volts	Rated Amps.	Mfg.	Rated Amps.
AUTOMATIC													
Cleveland Railway Co. Std. 2-Unit Auto Sta.	Auto	Batt	MG	No	W-UP-180	600	3000	No	W-UP-115	600	1500	W	2000
Commonwealth Edison Co. West Lawn Substation	Auto	Batt Transf.	MG	No	W-CA	600	8000	Semi	GE-MC-2	600	4000	GE	2-4000 mch. 2-2000 fdr.
Denver Tramway Corp. Colfax Substation	Sup. Auto	Transf.	Tungar	Semi	GE-DB-903A	650	2000	Semi	GE-MC-2	600	1600	GE	1600
Detroit Edison Co. Roseville Substation	Auto	Tertiary of Rot.Tr. 10 KVA	-	No	W-CA		2000	No	W-100C		2000	ME&MCo	2000
Duquesne Light Co. Maple Substation	Auto	Batt	MG	No Semi	W-CA W-CH	750 750	3000 4000	Semi	W-CH	750	2000	W	3000
Kansas City Public Serv.Co. Blue Ave. Substation	Auto	Cont. Trans.	-	No	GE-C Form K	600	4000	No	ARCBCo DHD	600	1200	GE	1200
Milwaukee El.Ry. & Lt.Co. St. Martins Substation	Auto	Tertiary 440 V 110 V	-	No	W-100-C-4	600	1600	No	W-100-C-4	600	1600	W	1200
Public Serv. El. & Gas Co. Miller St. Substation	Auto	Batt	MG		GE	600	4700	No	GE	600	2000	GE	3000 mch. 1200) 2000) fdrs.
Public Service Co. of No.Ill. Glen Ellyn Substation	Sup. Auto	Transf.	-	No	GE-CK3	650	3000	Yes	GE-JR10	600	2000	GE	3000 mch. 2000 fdrs.
NON-AUTOMATIC													
Commonwealth Edison Co. Laflin St. Substation	Manual	Batt	MG	Yes	GE	1500	1250	Yes	GE	1500	2000	And.	2000
Dallas Power & Light Co. Typical Substation	Manual	Batt	MG	No No	W-CA GE-CK2	600	3000	No No	W-CA GE-CK2	600	3000	W GE	3000
Delaware County Elec. Co. Crosby Substation	Manual	Batt	MG	No	W-CA	600	4000	No	W-CA	750	1600	And. Walker	3000 mch. 1000 fdrs.
New Orleans Public Serv.Inc. Dryades Substation	Manual	Batt	MG	No	W-CA	600	3000	No	GE-CK2	650	1500	W GE	2400 mch. 1600 fdrs.
New Orleans Public Serv.Inc. Polymnia Substation	Manual	Batt	MG	No	GE-CK2	650	3000	No	GE-CK2	650	1500	GE	3000 mch. 1600 fdrs.
Utica Gas & Elec. Co. New Hartford Substation	Manual	Batt	Tungar	No	W-CA	750	1200	No	W-CA	750	800	W	1200 mch. 800 fdrs.
Utica Gas & Elec. Co. Whitesboro Substation	Manual	Batt	Tungar	No	GE-CK2	750	1200	No	GE-CK2	750	1200	GE	1200

Substations	SWITCHBOARD					LOW TENSION & D.C. SIDE							
	Auto Re-closing Features	Swbd. Framed Insu-lated	Ins. Fl. Mat. Around Mch. & Swbd.	Load Lim. Res.		OIL CIRCUIT BREAKERS				STARTING SWITCHES			
				Min.	Amp.	Mfg. & Type	Rated Volts	Rated Amps.	Auto or Non Auto	Kind	Mfr. & Type	Rated Volts	Rated Amps.
AUTOMATIC													
Cleveland Railway Co. Std. 2-Unit Auto Sta.	Yes	Yes	Swbd.	Cont.	3800	None	-	-	-	OCB	W-B2	7500	2000
Commonwealth Edison Co. West Lawn Substation	Yes-contr'd. by ld.res.	Yes	Both	None	-	None	-	-	-	-	-	-	-
Denver Tramway Corp. Colfax Substation	Yes	No	Both	5	2500	None	-	-	-	Contactor	GE-LD	600	1000
Detroit Edison Co. Roseville Substation	Yes	No	Swbd.	5	2300	None	-	-	-	Contactor	W-F		500
Duquesne Light Co. Maple Substation	Yes	Yes	Swbd.	5	4250	None	-	-	-	OCB	W-B2	7500	(Stg.)1200 (Run.)2000
Kansas City Public Serv.Co. Blue Ave. Substation	Yes	No	No	No Data		None	-	-	-	Contactor	GE- CR2810-307-C7	440	1500
Milwaukee El.Ry. & Lt.Co. St. Martins Substation	Yes	Yes	Both	150° C. Thermal Cutout		None	-	-	-	Contactor	W-F2	600	500 Stg. 750 Run.
Public Serv. El. & Gas Co. Miller St. Substation	Yes	Yes	Swbd.	5	3750	GE-FK32C	7500	1200	Auto	OCB	Run.GE-FK32C St.GE-FK132A	1500	600 400
Public Service Co. of No.Ill. Glen Ellyn Substation	Yes	Yes	Swbd.	5	3750	None	-	-	-	Contactor	GE-CR-2810	600	1000 Stg. 2000 Run.
NON-AUTOMATIC													
Commonwealth Edison Co. Laflin St. Substation	On Rect. neg.bkr.	No	Both	5 sec.	2400	None	-	-	-	-	-	-	
Dallas Power & Light Co. Typical Substation	None	4-No 1-Yes	Swbd.	None	-	None	-	-	-	OCB	St.(GE-FK12 (W-F33 Run(GE-FH203 (W-OE6	15000	300 400 500 600
Delaware County Elec. Co. Crosby Substation	None	Yes	Swbd.	None	-	None	-	-	-	Knife	Pringle-1 Own Mk.-2		1600
New Orleans Public Serv.Inc. Dryades Substation	None	No	Both	None	-	None	-	-	-	Knife	W-TPDT	500	1000
New Orleans Public Serv.Inc. Polymnia Substation	None	No	Swbd.	None	-	None	-	-	-	Knife	GE-TPDT	500	1600
Utica Gas & Elec. Co. New Hartford Substation	None	Yes	Both	None	-	None	-	-	-	Knife	W-A	500	600
Utica Gas & Elec. Co. Whitesboro Substation	None	Yes	Both	None	-	None	-	-	-	Knife	GE-LD116	600	600

TABLE II—(Concluded)

LOW TENSION & D.C. SIDE

	POT. TRANS.		CURRENT TRANS.			D.C. FEEDERS					LIGHTNING ARRESTERS	
Substations	Mfr. & Type	Ratio	Mfr. & Type	Ratio	No. per Circuit	Location	Pres. Number	Ult. Number	Present Size	Ultimate Size	Mfr. & Type	Location
AUTOMATIC												
Cleveland Railway Co. Std. 2-Unit Auto Sta.	None	-	W-FB	1500/5 2000/5 3000/5	3-AC 2-AC 1-DC	O.H.	9	9	1,000 MCM	1,000 MCM	W-K1 W-KS GE-MD	Mach.ID DC Bus ID Fdrs. OD
Commonwealth Edison Co. West Lawn Substation	None	-	None	-	-	U.G.	7		1,000 MCM	1,000 MCM	None	-
Denver Tramway Corp. Colfax Substation	None	-	GE-W5	1500/5	1	O.H.	4	4	1,000 MCM	1,000 MCM	GE-K1	I.D.
Detroit Edison Co. Roseville Substation	W-VS	4/1	W-FB	1500/5	3	U.G.	3	3	1,000 MCM	1,000 MCM	W-AR	D.C. Fdrs.
Duquesne Light Co. Maple Substation	W-VS	4/1	W-FB	1500/5	3	U.G.	4	6	2,000 MCM	2,000 MCM	W-A	I.D. Bus
Kansas City Public Serv.Co. Blue Ave. Substation	None	-	GE	300/5	2	O.H.	6	6	1,000 MCM	1,000 MCM	GE-K1	I.D. Bus
Milwaukee El.Ry. & Lt.Co. St. Martins Substation	W-VS	4/1	W-FS	750/5	3	O.H.	3	3	500 MCM	500 MCM	W-KS	I.D. Line
Public Service El. & Gas Co. Miller St. Substation	Mach. GE	40/1	Mach. GE	600/5	3	U.G.	9 and 1 Transfer Bus Fdr.	11 and 1 Transfer Bus Fdr.	7-1,000 MCM 2-2,000 MCM	2,000 MCM	GE-K1	I.D. Line
Public Service Co. of No.Ill. Glen Ellyn Substation	None	-	GE-W	2000/5	1	U.G.	4	4	1,500 MCM	1,500 MCM	GE-K1	D.C. Fdrs. I.D.
NON-AUTOMATIC												
Commonwealth Edison Co. Laflin St. Substation	None	-	None	-	-	U.G.	2	5	960 MCM	1,466 MCM	GE-K1	I.D.
Dallas Power & Light Co. Typical Substation	None	-	None	-	-	Comb.	8	8	2,000 MCM	2,000 MCM	GE-MDS	D.C. Fdrs. O.D.
Delaware County Elec. Co. Crosby Substation	None	-	None	-	-	U.G.	13	26	2-500 MCM 10-1000 MCM 1-1500 MCM		GE-K1 G & D-AG	I.D.
New Orleans Public Serv.Inc. Dryades Substation	None	-	None	-	-	U.G.	17	17	1,000 MCM	1,000 MCM	None	-
New Orleans Public Serv.Inc. Polymnia Substation	None	-	None	-	-	U.G.	10	10	1,000 MCM	1,000 MCM	None	-
Utica Gas & Elec. Co. New Hartford Substation	None	-	W-FS	750/5	1	O.H.	2	4	500 MCM	1,000 MCM	W-MP	I.D.
Utica Gas & Elec. Co. Whitesboro Substation	None	-	W-FS	600/5	3	O.H.	3	5	1,000 MCM	1,000 MCM	W-MP	I.D.

UNIFORM RECORDS OF ELECTRICAL OPERATION OF POWER SYSTEMS

This report describes typical forms for recording, analyzing and summarizing, on a uniform basis, the electrical operation of power systems under abnormal conditions.

Purpose

Records of interruptions, equipment troubles, operating mistakes, relay performance, etc., have progressed to the point where the practice of several companies may be correlated and set down for the information and suggested guidance of the industry. This correlation is a stage between description and standardization. There is now sufficient uniformity of definition, method and uses as to permit coordination without attempting a standardization that might, at this time, be restrictive of progress as well as limited in acceptance.

Scope

The effects of abnormal conditions are measurable in damage to property, injury to persons and interruptions to service—all of vital interest to the management.

The histories of abnormal conditions are essential in determining how these undesirable effects may be minimized or prevented when the conditions recur.

General information relative to abnormal conditions which occurred without causing any trouble is necessary in determining percentage of successful operation.

Detailed information relative to abnormal conditions which resulted in damage, injury or interruption is essential.

The scope of the abnormal operation report is the extent of the system and its performance during fault conditions. The report is not limited to relays and their accessories. It does not assume that the design of the system and the methods of operating it are above suspicion or beyond improvement, nor does it assume that incorrect operations always result from deficiencies in relays and their accessories, or from any inadequacy in the present state of the art of protection. Neither does it assume that system design and operation should always be such as to give the best protection. The cost of an interruption may be less than the cost of preventing it. This is seldom the case, however, and where the limitations and possibilities of relay protection are known and considered in system planning and in system operating, it is possible (as far as protection is concerned) to generate power economically, to provide good voltage regulation, to minimize equipment damage and to give adequate service, all without excessive investment or abnormal operating costs.

Basic Factors

Many abnormal conditions never reach the stage of "cases of trouble," and many "cases of trouble" never injure plant, personnel or service, because good management or good fortune intervenes. It would, therefore, be desirable to develop an efficiency factor—a ratio between the uncontrollable opportunities for trouble and the resulting effects. But in general many causes of abnormal conditions, such as storms, are measurable only by their effects on the power system. It is all the more important, therefore, to measure these effects quantitatively, since, if trouble cannot be measured as an instantaneous ratio, it must be accumulated for a period and compared with itself over other time intervals, or with the accumulated total on other systems for a common interval.

Of the three effects of abnormal operating conditions, only "interruptions to customers" has lacked an agreed quantitative basis. Damage to property has always been measurable in dollars and cents. Injuries to persons have been measurable for some time, using methods developed by the Accident Prevention Committee.

There has also been lacking a common basis for classifying the accuracy of functioning of the various elements that make up system performance.

This report, therefore, will deal primarily with records of the accuracy of system performance under abnormal conditions, including records of interruption to customers.

It is intended that those adopting these records may take such liberties with them as are necessary to fit their respective organizations, but that the essential results will be kept on a uniform basis.

Fundamental Features

The basic features of these records are as follows:

1. A complete periodic report on the accuracy or legitimacy of performance of the system under abnormal electrical conditions is provided for the department heads responsible for system planning, system operation, electrical design, relaying, load dispatching, maintenance, construction, public relations, commercial activities, etc.
2. Correct performances are summarized. Incorrect performances are tabulated individually, with adequate sub-classifications, accompanied by an analysis of cause, responsibility, effect and remedy.
3. The definition of "correct" performance is based upon an economic balance between the various factors in design and operation. "To perform correctly, the system, including equipment, personnel and routine, must clear up an abnormal condition with less damage and interruption than any other economically justifiable system."

Publication No. 289-52, Serial Report, Electrical Apparatus Committee.

4. A classification of incorrect system performance has been developed that distinguishes between man failure and equipment failure, between errors within and without the relay department, between individual defects and group defects of equipment, and between poor planning, designing, construction, operation and maintenance.
5. A running record of incorrect relay operations is available by location, enabling the relay engineer to study the effects of changes in protection.
6. There is included a periodic report on interruptions to customers which is sufficiently quantitative to be comparative from time to time as well as between companies.
7. Results may be classified by station, customer, voltage, circuit, cause, origin, time, etc.
8. A brief periodic summary may be prepared for executives.
9. A typical set of coordinated daily operating records is shown herewith for the purpose of illustrating the economy in clerical work which may be accomplished by coordinating all operating records at their sources.
10. Tentative definitions relating to performance are included in this report, pending completion by the A. I. E. E. and N. E. L. A. of standard nomenclature.

Typical Records

To illustrate the essential features of a uniform report on "System Performance Under Fault Conditions," typical records from one company are presented. The forms represent the latest practice of this company, including all revisions made from time to time to coordinate its records with those of other companies.

The report is called the "Monthly Trouble Report" by some companies. The actual name is immaterial. Other names are suggested below:

"Disturbance Report"
"System Operation Report"
"Relay Operation Report"
"Protection Report"
"Interruption Report"
"Service Report"

The first page of the "Monthly Trouble Report" is a summary. The system performance is measured by three factors: cases of trouble, relay operations and interruptions. Some companies have been using only two of these three factors, and, as it has been impossible to come to an agreement on which two to use, if only two are selected, all have been included for use until further experience is available. Each has its advantages, and the inclusion of all three meets all objections, and represents the latest practice of the largest companies.

The third factor, interruptions, may be defined as to quantity, duration or extent, or preferably as to all of these. The loss of revenue load in kilowatt-hours (or kilowatt-minutes, for convenience) is a true measure of an interruption, detached from its individual peculiarities. Such a measure permits addition of interruptions, with each individual interruption affecting the total in proportion to its size. While the spoilage of goods in process, loss of time, etc., are more important to many industrial customers than the loss of revenue to the power company, such factors are best considered in connection with each individual interruption, as they are not susceptible of the quantitative measurement required in compiling periodic summaries.

"Kilowatt-minute" totals may be divided by the total system load in kilowatts to get "system minutes," or minutes of equivalent interruption to the entire system. The kilowatt load interrupted may be set up, on a demand, installed or consumption basis. The latter is preferable and is used in the forms herewith. The kilowatts used for each customer or substation interrupted is the yearly average kilowatts, which is obtained by dividing the yearly kilowatt-hour consumption of a given customer by 8760. In this method, the same kilowatt figure is used regardless of the time of day when the interruption occurs. This gives satisfactory results on the assumption that interruptions are independent of load, which is sufficiently accurate for localities where most interruptions are due to storms.

If sufficient data are available, the kilowatts may be tabulated for each customer and for each substation for each period of the day, requiring considerably more work in computing interruption records. Another method is to use the actual average kilowatts normally required by the customer at the time of the interruption, but this information is available only on systems with very complete graphic records on feeders, or with constant station attendance and complete indicating meter facilities, checked by the operator's and load dispatcher's knowledge of the customers' requirements.

The three factors outlined above, amount of trouble, amount of protective equipment operation, and amount of interruption to service, serve to throw light on system performance from slightly different angles.

While it would be desirable to follow the performance of the system through each case of trouble, this task is beyond the scope or ability of any one department. In the present state of the art of collecting and reporting operating statistics, about all that can be readily accomplished is to analyze trouble as to cause, interruptions as to cause and amount, and relaying as to cause, amount and accuracy. For some time the operation of protective equipment has been reported more completely than any other technical function. Furthermore, this function is a part of electrical operation, so that it is practicable for a report on electrical operation of the system under abnormal conditions to describe the operation of protective equipment more adequately than the performance of equipment under the jurisdiction of departments not responsible for electrical operation.

Recognizing the above limitations, the following specific definitions have been used in the preparation of the typical records herewith.

1. A case of trouble is legitimate if it originated outside of the system, that is, due to weather conditions, other companies, customers, public, etc. It is illegitimate if it originated within the company, that is, due to defective equipment, mistake by employee, or other inadequacy of routine or facilities. This definition contains the implicit assumption that the environment of the system is beyond control on any economically justifiable basis. In other words, a rough and ready criterion of economic justification is a matter of external or internal origin. Such usage may appear to be entirely empirical, but a study of actual system troubles on a large scale will show that this procedure is logical and adequate.
2. A relay operation is correct and legitimate if it assisted in isolating a maintained fault with less interruption and damage than any other economically justifiable installation. It is incorrect and illegitimate if it occurred unnecessarily or did not occur when necessary.
3. An interruption is legitimate if it originated outside of the system, that is, due to weather conditions, other companies, customers, public, etc. It is illegitimate if it originated within the company, that is, due to defective equipment, mistake by employee, or other inadequacy of routine or facilities. This definition contains the same assumption stated above. However, it is more quantitative, since, if the extent of the interruption is more than the economically justifiable minimum, the additional amount resulting from internal causes is charged up as illegitimate.

Some companies analyze electrical operation only as it concerns the high tension system, because it is difficult to get as complete information on distribution and utilization trouble as can be obtained on generation and transmission trouble. Accordingly, a space has been left in the heading of each report for indicating whether it refers to all divisions or merely to the transmission division of the company.

The summary is brief enough for transmittal to executives who desire a concise tabulation of results.

TABLE I

TROUBLE REPORT—ALL DIVISIONS
January, 1929
Summary

	Legitimate	Illegitimate	Per Cent Legitimate
Cases of trouble	72	44	62
Relay operations	181	11	94
System minutes	6	4	60

Following the summary in the Monthly Trouble Report are more or less detailed analyses of trouble, relaying and interruptions. These analyses are distributed to all department heads in the technical departments as well as to certain ones in the commercial departments.

There are many variables in connection with trouble, relaying and interruptions. Distributions by cause, damage, remedy, location, duration, date, time, justification, voltage, correctness, nature of trouble, type of equipment, class of service, etc., are all of interest and value. Cause is probably the most valuable classification and has been used in the typical forms herewith. The daily records are so arranged that it is practicable to go back at any time and make up special reports, using any of the above factors as a basis of classifications.

The practices of many power companies have been studied in arriving at the suggested classification for causes of trouble. The A. T. & T. Company schedule has also been consulted.

Every case of trouble is the result of a combination of conditions of the system and its environment. Three combinations are possible, viz:

1. Environment abnormal—system normal.
2. Environment normal—system abnormal.
3. Environment abnormal—system abnormal.

In Case 1 it is clear that the cause lies in the abnormality of the environment, and in Case 2 in that of the system. In these cases it is usually easy to decide the cause once the facts are known.

In Case 3 it is sometimes difficult to determine whether the abnormality of the environment or of the system is primarily responsible.

In some cases also several abnormalities may come into the picture, and the choice then is not always obvious. One rule is not to regard as abnormal any condition against which the system is normally protected, and to record as the cause or origin of the disturbance the *most* abnormal condition or occurrence observed. The decision as to which *is* the most abnormal must be a matter of judgment, and in doubtful cases it is natural to give the system the benefit of the doubt. Some companies provide space in their records for two

TABLE II

TROUBLE REPORT—ALL DIVISIONS
January, 1929
ANALYSIS OF TROUBLE
Causes

Origin of Legitimate Trouble:	Cases
Lightning	2
Other weather conditions	36
Interconnected utilities	3
Other utilities	1
Other customers	8
Public	2
Animals	0
Insufficient information to classify	20
Total	72
Origin of Illegitimate Trouble:	
Defective equipment	25
Personnel failures	4
System inadequacy	14
Insufficient information to classify	1
Total	44

TABLE III

TROUBLE REPORT—ALL DIVISIONS
January, 1929
ANALYSIS OF TROUBLE
Detailed Causes of Illegitimate Trouble

Causes:	Cases
Defective equipment—steam	1
Defective equipment—hydro	5
Defective equipment—electrical power	8
Defective equipment—electrical control	6
Defective equipment—transmission	0
Defective equipment—distribution	5
Defective equipment—miscellaneous	0
Personnel failure—planning	0
Personnel failure—design	0
Personnel failure—construction	0
Personnel failure—maintenance	1
Personnel failure—operation	1
Personnel failure—protection	2
Personnel failure—miscellaneous	0
System inadequacy—design	7
System inadequacy—planning	3
System inadequacy—construction	1
System inadequacy—maintenance	0
System inadequacy—operation	0
System inadequacy—protection	3
System inadequacy—miscellaneous	0
Insufficient information to classify	1
Total	44

causes, a primary or originating cause usually arising out of the environment, and a secondary or contributing cause usually residing in the system or equipment. This scheme is of advantage in subsequent analysis and tabulation of disturbances. In some cases the abnormality of the environment may be the primary cause of the trouble, and the abnormality or inadequacy of the system the primary cause of the interruption.

In doubtful cases a predetermined schedule of preference as between various causes is most helpful, as will be noted from the definitions given later.

The Monthly Analysis of Relay Operation is set up in such a manner as to focus attention on the causes of incorrect operation. Correct operations are tabulated by circuits for reference in regard to breaker maintenance, etc. Incorrect operations are classified by causes, and are also described individually with regard to cause, responsibility, effect and remedy, including a history of the changes made to prevent a recurrence of the incorrect operation. Incorrect operations are a sufficiently small percentage of the total that they can be studied better if the correct operations are not included therewith.

The classification used for incorrect operation of relays or other protective equipment includes all causes which result in incorrect operation of protective equipment.

The first and third classes of incorrect protective equipment operation refer to the relay and its accessories, and the second and fourth classes refer to system planning and system operation. In the past, some companies have considered only the former. Other companies have considered the latter under the heading of "system operation" but independent of "relay operation." The fundamental objection to considering system planning and system operation separately from protective equipment is the now well recognized fact that protection is cheaply obtained if included originally, but in general is costly and incompletely adequate if added to existing major facilities and existing operating practices.

The Analysis of Interruptions is usually set up by stations or by high tension customers or by a combination of the two. The form herewith includes all

TABLE IV

TROUBLE REPORT—ALL DIVISIONS
January, 1929
ANALYSIS OF RELAY OPERATION
Performance

Station	Voltage	Circuit	Correct	Incorrect
Arlington	110,000	Lenoir City	1	0
Arlington	66,000	Newport	1	0
Athens	66,000	Bus	0	1
Athens	22,000	Tellico	5	0
Blue Ridge	2,300	Blue Ridge	1	0
Carter Street	11,000	Ridgedale No. 1	1	0
Carter Street	11,000	Ridgedale No. 2	7	0
Carter Street	11,000	River Street	1	0
Carter Street	6,600	River Street	1	0
Carter Street	6,600	Southern Ferro	1	0
Carter Street	2,300	Transformer No. 3	0	1
Carter Street	2,300	Transformer No. 4	0	1
Carter Street	2,300	W-23	1	0
Carthage	11,000	Gainesboro	8	0
Carthage	11,000	Gordonsville	11	0
Carthage	11,000	Hartsville	13	0
Central Nashville	13,200	Gallatin Interurban	1	0
Central Nashville	13,200	Generator-20,000 kw	1	0
Central Nashville	13,200	N. C. & St. L.	10	0
Central Nashville	13,200	Warioto	1	0
Central Nashville	13,200	West Nashville	2	0
Central Nashville	2,300	Rotary No. 2	2	0
Coal Creek	66,000	Westbourne	1	0
Coal Creek	66,000	Petros	2	0
Great Falls	110,000	East	2	0
Great Falls	11,000	McMinnville	11	0
Hales Bar Hydro	110,000	Sequatchie	2	0
Knoxville	110,000	Lenoir City	1	0
Lebanon	6,600	Watertown	17	0
Lenoir City	110,000	Cleveland	2	0
McMinnville	2,300	Transformer 375 kv-a.	1	6
Murfreesboro	110,000	Bus	0	1
Murfreesboro	44,000	Columbia	13	0
Murfreesboro	11,000	Woodbury	1	0
Murfreesboro	2,300	Distribution No. 1	3	0
Ocoee No. 1	110,000	Maryville	0	1
Ocoee No. 1	110,000	Nashville	2	0
Ocoee No. 1	110,000	Ocoee No. 2	2	0
Ocoee No. 1	66,000	North	3	0
Ocoee No. 1	66,000	Ocoee No. 2	1	0
Ocoee No. 1	2,300	Benton	6	0
Ocoee No. 2	66,000	Ocoee No. 1	1	0
Petros	11,000	Windrock	14	0
Ridgedale	11,000	East Ridge	3	0
South Nashville	13,200	Asylum	5	0
South Nashville	13,200	Franklin	9	0
South Nashville	13,200	Radnor	1	0
South Nashville	2,300	Lebanon Road	1	0
South Nashville	2,300	South Nashville	1	0
Sweetwater	6,600	Main	2	0
Valdeau	11,000	Sig. Mtn. Lighting	5	0
Total			181	11

TABLE V

TROUBLE REPORT—ALL DIVISIONS
January, 1929
ANALYSIS OF RELAY OPERATION
Causes of Incorrect Operation

General Classification	Detailed Classification	Symbol	Cases
Defective equipment	Defective relay	DR	0
Defective equipment	Defective oil circuit breaker	DB	0
Defective equipment	Defective control wiring	DW	0
Defective equipment	Defective current transformer	DC	0
Defective equipment	Defective potential transformer	DP	0
Defective equipment	Other defective equipment	DX	0
Personnel failure	Mistake by employe—relay	MR	3
Personnel failure	Mistake by employe—maintenance	MM	0
Personnel failure	Mistake by employe—construction	MC	0
Personnel failure	Mistake by employe—operation	MO	0
Personnel failure	Mistake by employe—planning	MP	0
Personnel failure	Mistake by employe—design	MD	0
Personnel failure	Mistake by employe—other depts.	MX	0
Relay engineering	Poor relay setting	RS	2
Relay engineering	Poor type of relay	RT	0
Relay engineering	Wrong relay connection	RC	0
Relay engineering	Wrong relay rating	RR	0
Relay engineering	Relay engineering trouble	RX	0
System inadequacy	Poor system planning	SP	0
System inadequacy	Poor detail design	SD	0
System inadequacy	Poor construction methods	SC	0
System inadequacy	Poor maintenance practices	SM	0
System inadequacy	Poor operating practices	SO	0
System inadequacy	Other system inadequacy	SX	6
Total			11

TABLE VI

TROUBLE REPORT—ALL DIVISIONS
January, 1929
ANALYSIS OF RELAY OPERATION
Details of Incorrect Operation

The six incorrect operations of the generator switch at McMinnville on Jan. 5 were due to this machine being overloaded in carrying the town of McMinnville while the 11 kv. Great Falls line was out. The load at McMinnville has been increasing to such an extent that it is very difficult to get selective action between the McMinnville generator and the Great Falls supply. Higher settings on the generator switch would reduce the protection to the generator which is non-attended. The problem is being studied further, and a complete revision of settings will be made on an experimental basis.

The incorrect operations on the 2300 volt side of No. 3 transformer and No. 4 transformer at Carter Street on Jan. 5 were due to a mistake by a relay man. When the switchboard was moved and the new 2300 volt bus installed, settings were revised and the relay man apparently got the settings for some of the circuits confused. The transformer switches had been set with the same time as the feeder switches.

The operation of the Maryville line during trouble on the Ocoee No. 2 110 kv. line at 10:33 a.m. on Jan. 5 was due to the trip circuits on the locking relays having been connected in parallel instead of series. Instructions on this point were clear, but were probably overlooked by the relay man in wiring the panel.

The incorrect operation of the Columbia line during trouble on the Southern Cities system on Jan. 5 was apparently due to an unbalance in the 110 kv. ground relay circuit during 44 kv. trouble. This has been eliminated by higher relay settings.

On Jan. 18 the 66 kv. ground relay at Athens operated on 22 kv. trouble, evidently due to unbalance. This has been eliminated by a higher relay setting. Apparently this trouble is a complication of variations in bushing current transformer ratio during single-phase and ground short circuits. This trouble was discovered several years ago and is corrected by raising relay settings whenever it recurs. In some cases this involves some sacrifice of the sensitivity of ground protection.

the high tension substations, whether supplying large customers or supplying distribution. Interconnections are also included.

On account of the fact that the entire load supplied to certain stations or customers may not be interrupted completely it is necessary, when using the kilowatt-minute method, to multiply the kilowatts interrupted by the duration of the interruption and divide the result by the total kilowatts of the station in order to get the number of minutes of interruption to the average customer from that station. This makes the use of kilowatt-minutes in the daily reports practically necessary. Typical daily reports will be described later.

In addition to the minutes of interruption to each station, the monthly analysis shows the number of times interrupted.

Clearances may be tabulated in the above manner, but the monthly report is usually concerned only with interruptions due to disturbances rather than by appointment.

There is very little difference in procedure among the various companies with regard to the authorship of the Monthly Trouble Report. It is made up by someone connected with the electrical operation of the system, usually in the Relay Department. In many companies the Monthly Trouble Report or its equivalent has been entitled "Monthly Relay Report" or "Monthly Protection Report" because it has been set up by protective relay installations and has been prepared by the relay engineer. In most companies, however, the report has been expanded during the last two years to cover all items affecting protection, because performance of the protective equipment has been found to be less important intrinsically than its coordination with the design and operation of the system. The Monthly Trouble Report is logically made up by the relay engineer, since the clearing of faults by protective equipment occupies the center of the stage in most cases of trouble.

To be of a maximum value in making important decisions with regard to company policy, etc., the Monthly Trouble Report must have a sound statistical basis. It is recommended that in those companies where the report has not been originated by someone with adequate training along this line, that the general procedure in compiling the report be critically examined by a statistician, with reference to the methods used in arriving at averages, etc.

Further important requirements of the Monthly Trouble Report are that it shall be sound technically, prepared with absolute fidelity to all available evidence, open minded on all possibilities in connection with the improvement of service, and vigilant in looking for such opportunities.

It is thus not accidental that someone of engineering training in one of the departments responsible for service to customers is usually sufficiently interested to initiate some kind of a report on the performance of the system during abnormal electrical conditions.

Auxiliary Records

In addition to the above fundamental report there are given herewith detailed instructions covering a typical set of daily operating records, coordinated with the above report. One of the most definite things brought out in connection with the investigation of this subject is that in revising records the next thing to do, after setting up a desired form for the results, is to coordinate the forms for the initial tabulation or description of operating events as reported by operators, load dispatchers, maintenance men, etc. Unless this is done, the derivation of the results in the form desired involves so many work

TABLE VII

TROUBLE REPORT—ALL DIVISIONS

January, 1929

ANALYSIS OF INTERRUPTIONS

Station	Kw. Annual Average	High Tension			Distribution		
		Average Minutes	Times Partial	Times Complete	Average Minutes	Times Partial	Times Complete
Adams	1,000	....	....	....	....	....	....
Aluminum Company	......	....	....	....	....	....	....
Athens	200	8	....	3	....	....	....
Blue Ridge	15	....	....	....	121	1	....
Carter Street	14,800	....	....	....	10	5	....
Carthage	125	....	....	....	205	24	....
Charleston	20	5	....	2	....	....	....
Cleveland	1,000	5	....	2	....	....	....
Coal Creek	700	....	....	....	1	2	....
Columbia	1,000	....	....	....	29	....	8
Copperhill	1,400	....	....	....	....	....	....
Daisy	330	....	....	....	....	....	....
Englewood	100	59	....	3	....	....	....
Estill Springs	1,000	....	....	....	....	....	....
Etowah	150	8	....	3	....	....	....
Georgia 66,000	......	....	....	....	....	....	....
Georgia 110,000	......	....	....	....	....	....	....
Great Falls	400	....	....	....	4	6	....
Harriman	220	4	....	2	....	....	....
Holston Quarry	100	1	....	1	....	....	....
Isabella	1,300	....	....	....	....	....	....
Kentucky Utilities	......	....	....	....	....	....	....
Knoxville	10,500	....	....	....	....	....	....
LaFollette	250	1	....	1	....	....	....
Lebanon	275	....	....	....	5	13	....
Lenoir City	820	4	....	2	....	....	....
Long Street	2,500	....	....	....	....	....	....
Loudon	200	5	....	2	....	....	....
Mary Mine	700	....	....	....	....	....	....
Maryville	240	....	....	....	....	....	....
Mascot No. 1	1,700	1	....	1	....	....	....
Mascot No. 2	900	1	....	1	....	....	....
McPherson	1,200	....	....	....	....	....	....
Murfreesboro	400	2	....	1	*	3	....
Niota	10	5	....	2	....	....	....
Ocoee No. 1	15	....	....	....	570	2	....
Petros	250	513	1	2	241	13	....
Prendergast	240	8	....	3	....	....	....
Riceville	2	5	....	2	....	....	....
Richard City	2,200	....	....	....	....	....	....
Ridgedale	3,100	....	....	....	4	1	....
South Nashville	15,400	4	....	1	11	13	....
Sweetwater	220	5	....	2	7	3	....
Tellico Plains	10	933	....	3	....	....	....
Tenn. Pub. Service	2,500	1	....	1	....	....	....
Valdeau	4,600	....	....	....	7	3	....
Westbourne	600	1	....	1	1	1	....
Isolated stations	230	....	....	....	....	....	....
System Total	75,000	....	1	41	....	90	8
System average	......	3	....	....	7	....	....

*Less than ½ minute.

TABLE VIII

TROUBLE REPORT—ALL DIVISIONS
January, 1929
ANALYSIS OF INTERRUPTIONS
Causes

Origin of Legitimate Trouble:	Kw. Minutes
Lightning	0
Other weather conditions	141,349
Interconnected utilities	5,200
Other utilities	3,300
Other customers	71,590
Public	90
Animals	0
Insufficient information to classify	199,595
Total	421,124
Origin of Illegitimate Trouble:	
Defective equipment	89,460
Personnel failures	62,400
System inadequacy	148,200
Insufficient information to classify	0
Total	300,060

sheets and transcriptions of records as to involve much expense, delay and confusion. For this reason it is suggested that considerable attention be given to adapting daily records to their ultimate purpose.

On the assumption that most current operating events are reported by telephone, the daily log kept by the system load dispatcher (and by the division dispatchers, if any), is the initial tabulation of relaying, interruptions and miscellaneous trouble. If, however, such items are entered at random on a large log sheet, considerable delay is involved in sorting out and retabulating the various items. A better method is to divide the log sheet into sections—one section for relay operations, one for interruptions, one for miscellaneous troubles, etc. A still more promising procedure developed recently is to use separate letter size sheets for each of these records and cut down the size of the general log, as it will then contain only miscellaneous station readings, weather conditions, and other data required for permanent record but not for daily transmittal to other departments. This procedure saves copying data from the log to the relay, interruption, miscellaneous trouble and power reports. Furthermore, one day's record of relaying or interruptions may require more than one sheet of that particular form, which is easily available without using another general log sheet.

To investigate trouble efficiently, the department heads responsible should be promptly advised of its occurrence. To this end, the load dispatching office must get its daily reports out promptly. Such procedure conflicts with the requirement that certain reports customarily issued by the load dispatching office shall contain all the important evidence after a thorough investigation. These two ideas have resulted in many more or less efficient compromises as to the nature and time limit of issuing daily operating reports. Recent practice seems to favor the following procedure:

A. The load dispatcher on duty should report very important troubles immediately by telephone to the department heads interested.

B. The load dispatching office should issue a daily news bulletin to department heads and local managers covering important happenings of the day at the beginning of office hours on the following day. The information in this bulletin may be all description, or it may be preliminary tabulation on the same forms used for the official daily reports.

C. The essential results of the investigations by the department heads should be telephoned to the load dispatching office promptly.

D. Official daily reports should be issued by the load dispatching office within one to three days after their date. These will include the results of departmental investigations if essential to the reports.

To assist the dispatcher in getting all the data desired, a check list may be used. This lists the cases of trouble with a space for checking off the records affected, and also for checking their completion. One line is used for each case of trouble, thus facilitating the preparation of the analysis of trouble in the monthly trouble report, as each case may be classified as to cause.

The Load Dispatchers Daily Check List of Cases of Trouble is the only cross reference between the various daily operating reports. Many events are sufficiently well described in one report. For instance, a relay operation due to lightning may be noted only on the relay report if it results in no miscellaneous trouble and no interruptions to customers. The cases of trouble which do not cause relay operation, interruptions to customers, or damage to equipment, are very few. Such a case might

TABLE IX

TROUBLE REPORT—ALL DIVISIONS
January, 1929
ANALYSIS OF INTERRUPTIONS
Detailed Causes of Illegitimate Trouble

Causes:	Kw. Minutes
Defective equipment—steam	0
Defective equipment—hydro	0
Defective equipment—electrical power	22,980
Defective equipment—electrical control	3,500
Defective equipment—transmission	0
Defective equipment—distribution	62,980
Defective equipment—miscellaneous	0
Personnel failure—planning	0
Personnel failure—design	0
Personnel failure—construction	0
Personnel failure—operation	61,000
Personnel failure—maintenance	0
Personnel failure—protection	1,400
Personnel failure—miscellaneous	0
System inadequacy—planning	0
System inadequacy—design	148,200
System inadequacy—construction	0
System inadequacy—maintenance	0
System inadequacy—operation	0
System inadequacy—protection	0
System inadequacy—miscellaneous	0
Insufficient information to classify	0
Total	300,060

be the de-energizing of one of two parallel feeders at the request of a fire department. Such operation is abnormal and is a hazard to service supplied over the remaining feeder. The fact that such an abnormal condition could be handled without harm is important evidence as to the adequacy of the power system.

One company has been able to eliminate the use of the load dispatcher's daily check list by having a notation made on the margin of the daily news bulletin as to the cause of each case of trouble described therein.

The Load Dispatcher's Report of Miscellaneous Trouble is used only to cover occurrences which are not recorded elsewhere or are recorded elsewhere incorrectly. No form is shown for this report as it is chiefly description and not tabulation.

Some of the load dispatchers' daily reports are used only by one department or for making up monthly reports. Such daily reports would be made up by the load dispatcher on duty, inspected by the chief load dispatcher or his assistant and sent out without copying or typing.

The Load Dispatcher's Daily Report of Relay Operation is set up on a switch basis. The time the switch is closed back is shown as well as the time at which it relayed out so that it is easier to check the correctness of succeeding operations of other switches. Space is also provided for showing which target operated and the amount of ground current shown on the quick trip ammeters.

The column headed "Performance" is left blank by the load dispatcher and is filled in by the relay engineer, who makes an "OK" after each correct operation, an "X" after each incorrect operation, and a "?" after each operation which is doubtful in the light of present available information. Each questionable operation is investigated further and later is marked in accordance with the findings.

After checking over the Load Dispatcher's Daily Report of Relay Operations, the relay engineer enters the incorrect operations on a departmental record known as the Log of Incorrect Relay Operation.

The Log of Incorrect Relay Operation provides a running record of the performance of each switch, making it easy to follow the effects of changes in protection. This record uses the classification shown in connection with the Monthly Analysis of Relay Operation. A detailed explanation of the classification of incorrect relay operation is given in the next section headed "Definitions."

The Daily Report of Interruptions Affecting Customers is intended for distribution to the Commercial Departments interested in service to customers as well as to the Technical Departments.

In the typical form herewith, the Daily Report of Interruptions Affecting Customers is set up in two sections. The first is a tabulation which shows at a glance the important interruptions. The second is a brief general description of the reason for the interruption, stated in such language that it is clear to the commercial men and others responsible for explaining the interruption to the customers.

The Load Dispatcher's Daily Report of Kilowatt-Minutes Lost is a tabulation of kilowatt-minutes of interruption allocated against primary substations and high tension customers. It is computed by the load dispatcher on duty (so that sufficient information will be obtained immediately), checked the next day and sent to the relay engineer who notes in each column the cause of the interruption. Only one column is used for each interruption regardless of the number of stations affected and of the number of separate interruptions as long as they were due to one original cause. This report is filed until it is time to make up the Monthly Trouble Report. At this time the sheets are summarized horizontally by stations and classified as to Division and Cause. The classification as to Division is used chiefly for segregating generation and transmission interruptions from distribution and utilization interruptions.

This kilowatt-minute report takes the place of several reports otherwise desirable as it provides a tabulation of all interruptions to customers classified by substation, time, origin and cause, with a weighted measure of each interruption. The horizontal summary gives results directly in kilowatt-minutes. These are divided by the respective substation loads in kilowatts to get the total minutes of interruption to the average customer supplied from each station. The number of complete interruptions and of partial interruptions is best summarized from the Daily Report of Interruptions Affecting Customers.

Definitions

In classifying and tabulating operating events, questions often arise which are difficult to answer logically, but it is not so important to adopt a logical classification as it is to adopt one that will be accepted and followed uniformly. As a matter of interest in this connection, the interpretations and decisions of several operating companies are given below. These definitions apply chiefly to the Relay Analysis section of the Monthly Trouble Report. While these may not be satisfactory for general adoption, they are suggested as subjects for discussion in arriving at standard practices.

"Defective Equipment" includes defects in protective equipment, including relays, auxiliary relays, battery supply, control wiring, auxiliary switches, trip coils, instrument transformers, fuses, tripping reactors, etc. It is intended to cover defects in an individual piece of equipment rather than undesirable characteristics common to a class of equipment which should be known and considered in system planning and system design.

"Personnel Failure" is intended to cover mistakes by field relay men, construction men, operators, etc., which prevent the proper operation of protective equipment, or which cause the operation of protective equipment when there is no fault to be cleared by its operation. This classification includes only those mistakes which are a liability of the protective equipment. Mistakes in connection with other equipment which require breaker operation to clear the resulting trouble are not considered as involving incorrect protective equipment operation. "Personnel

TABLE X

LOAD DISPATCHER'S DAILY CHECK LIST OF CASES OF TROUBLE

Day: Friday. Date: December 21, 1928.

Number	Time	Station	Voltage	Circuit	Relay	Interr.	Misc.	Cause
1	12:48 A.M.	S. Nashville	13,200	Franklin	*	*	0	Other weather conditions
2	3:06 P.M.	Ocoee No. 2	......	Water Wheel	0	0	*	Def. equipment-hydro
3	7:40 P.M.	Ocoee No. 2	110,000	Ocoee No. 1	*	0	0	Lightning
4	9:09 P.M.	Carter Street	2,300	Transf. No. 1	*	*	*	Def. equipment-distribution
5	9:09 P.M.	Carter Street	2,300	Transf. No. 1	0	0	*	Personnel failure
6	9:55 P.M.	Carthage	11,000	Hartsville	*	*	0	Public

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*Complete information has been obtained and entered on corresponding report.

TABLE XI

LOAD DISPATCHER'S DAILY REPORT OF RELAY OPERATION

Day: Friday. Date: December 14, 1928.

Station	Kilo-volts	Name of Circuit	Time Out	Time In	Relay	Q.T.A.	Remarks	Performance
Carthage	11	Gordonsville	9:46 A.M.	9:47 A.M.	GR	....	High Wind	O.K.
Carthage	11	Gordonsville	9:47 A.M.	10:30 A.M.	OL	....	Tested Bad	O.K.
Carthage	11	Gordonsville	Failed to rel	ay on 2nd test	at 9:48 A.	M.	Latch stuck	×
Valdeau	44	Ridgedale	11:00 A.M.	11:02 A.M.	CZ	6.2	Lightning	O.K.
Ridgedale	44	Valdeau	11:00 A.M.	11:01 A.M.	CZ	2.5	Lightning	O.K.

TABLE XII

LOG OF INCORRECT RELAY OPERATION

Station: Arlington. Voltage: 110,000. Circuit: Lenoir City.

Date	Time	Defective Equipment	Personnel Failure	Relay Engineering	System Inadequacy	Remarks
3-26-28	7:03 P.M.	......	......	RS	......	Relayed ahead of Knoxville on trouble on Maryville line.
3-29-28	10:14 P.M.	......	......	......	SP	Off on Lenoir City station trouble—raised to 40 cycles.
6-13-28	6:15 P.M.	DB	......	......	......	Latch stuck on breaker.
6-13-28	6:18 P.M.	DB	......	......	......	Latch stuck on breaker.

TABLE XIII

DAILY REPORT OF INTERRUPTIONS AFFECTING CUSTOMERS

Day: Wednesday. Date: January 9, 1929.

Weather: Cloudy with wind and rain.

Customers Affected	Average Kw.	Total Minutes	Times Interrupted	Origin (Division)
Disturbances				
Hartsville Line..................	45	1	1	S.W.
Carter St.-Ridgedale No. 2 feeder..	2700	1	1	Chatt.
Clearances				
Warioto Cotton Mill feeder.......	2200	17	1	Nash.
Niota Substation................	10	38	1	P. & T.

At 9:55 a.m. service to the Hartsville line was interrupted for one-fourth minute when the oil switch controlling this line at Carthage Substation opened by overload relay due to a highway crew blasting near this line.

At 12:02 a.m. service to the Warioto cotton mill feeder was interrupted for 17 minutes by appointment when this line was cleared in order to replace a pin in a crossarm between Second and Third Avenues on Jefferson Street.

At 11:55 a.m. service to the Carter Street-Ridgedale No. 2 tie line was interrupted for one minute when the oil switch controlling this feeder at Carter Street Substation opened by ground relay due to trouble at the Cotton Compress Company.

At 12:00 noon service to Niota Substation was interrupted by appointment for 38 minutes when the Athens-Sweetwater section of 66 kv. line was cleared in order to tighten lugs on the west air-break switch at Sweetwater.

Failure" does not cover poor engineering judgment. It does include careless or intentional violation of instructions, misreading of data, typographical errors, poor manipulation of tools or material, mistakes in wiring and other such mistakes as are clearly assignable to a particular person and not to a defective piece of equipment or to poor engineering judgment in the application and operation of equipment.

"Relay Engineering" includes incorrect operations due to causes within the control of the relay engineer, on the assumption that the relay engineer has a free hand in specifying type, rating, connection, setting, testing, etc., of relays.

"System Inadequacy" includes incorrect operations due to causes beyond the control of the relay engineer, not due to a particular person, or to a defective piece of equipment, but due to a lack of, or misapplication of, equipment or methods. It covers all cases of incorrect operation not due to defective equipment, personnel failure, or relay engineering, considering as incorrect each case where there is proved economic justification for improved facilities to reduce interruption or damage. "System Inadequacy" includes incorrect operations due to poor system planning, poor detail designing, poor operating methods, lack of equipment, defects common to a class of equipment, misapplication of equipment, poor coordination of the various elements in an installation, etc.

One of the most difficult things to arrive at is an adequate definition of "Correct" system operation. This report is based on the following definition:

> To perform correctly, the system, including equipment, personnel and routine, must clear up an abnormal condition

TABLE XIV

LOAD DISPATCHER'S DAILY REPORT OF KILOWATT MINUTES LOST

Date		8-11-29	8-11-29	8-11-29				
	Kw. Average	7:06 A.M.	8:30 A.M.	10:00 P.M.				
Adams	1,000	......	......	......	......	......	......	......
Aluminum Company	......	......	......	......	......	......	......	......
Athens	200	......	......	......	......	......	......	......
Blue Ridge	15	......	......	......	......	......	......	......
Carter Street	14,800	......	......	500	......	......	......	......
Carthage	125	......	......	......	......	......	......	......
Charleston	20	......	......	......	......	......	......	......
Cleveland	1,000	......	......	......	......	......	......	......
Coal Creek	700	......	......	......	......	......	......	......
Columbia	1,000	......	......	......	......	......	......	......
Copperhill	1,400	......	......	......	......	......	......	......
Daisy	330	......	......	......	......	......	......	......
Englewood	100	100	......	......	......	......	......	......
Estill Springs	1,000	......	......	......	......	......	......	......
Etowah	150	150	......	......	......	......	......	......
Georgia 66,000	......	......	......	......	......	......	......	......
Georgia 110,000	......	......	......	......	......	......	......	......
Great Falls	400	......	......	......	......	......	......	......
Harriman	220	......	......	......	......	......	......	......
Holston Quarry	100	......	1400	......	......	......	......	......
Isabella	1,300	......	......	......	......	......	......	......
Kentucky Utilities	......	......	......	......	......	......	......	......
Knoxville	10,500	......	......	......	......	......	......	......
LaFollette	250	......	......	......	......	......	......	......
Lebanon	275	......	......	......	......	......	......	......
Lenoir City	820	......	......	......	......	......	......	......
Long Street	2,500	......	......	......	......	......	......	......
Loudon	200	......	......	......	......	......	......	......
Mary Mine	700	......	......	......	......	......	......	......
Maryville	240	......	......	......	......	......	......	......
Mascot No. 1	1,700	......	......	......	......	......	......	......
Mascot No. 2	900	......	......	......	......	......	......	......
McPherson	1,200	......	......	......	......	......	......	......
Murfreesboro	400	......	......	......	......	......	......	......
Niota	10	......	......	......	......	......	......	......
Ocoee No. 1	15	......	......	......	......	......	......	......
Petros	250	......	......	......	......	......	......	......
Prendergast	240	480	......	......	......	......	......	......
Riceville	2	......	......	......	......	......	......	......
Richard City	2,200	......	......	......	......	......	......	......
Ridgedale	3,100	......	......	4,000	......	......	......	......
South Nashville	15,400	......	......	......	......	......	......	......
Sweetwater	220	......	......	......	......	......	......	......
Tellico Plains	10	370	......	......	......	......	......	......
Tenn. Public Service	2,500	......	......	......	......	......	......	......
Valdeau	4,600	......	......	......	......	......	......	......
Westbourne	600	......	......	......	......	......	......	......
Isolated stations	......	......	......	......	......	......	......	......
Total	75,000	1,100	1,400	4,500	......	......	......	......
Division	......	H.T.	L.T.	L.T.				
Cause	......	Lightn.	Customer	Public				

with less damage and interruption than any other economically justifiable system.

The procedure required to "prove" economic justification for improved facilities may vary with different companies. In balancing the cost against the value of the improved facilities, the relay engineer usually is the person best acquainted with the extent of the interruption and amount of the damage, as well as with the changes in facilities or methods required to reduce interruption and damage, but he may not be able alone to estimate the cost of such changes. However, in all companies some qualified individual analyzes certain trouble and suggests remedies. This report recommends that in such a technical field as electrical operation the relay engineer be the party authorized to recommend such changes as he may consider economically justifiable, and to consider as incorrect such operations as presumably would not have occurred if the recommended changes had been in effect. It is further recommended that the relay engineer attempt economic justification of improved facilities only after a thorough investigation of the operation in question and after consultation with the other department heads familiar with the proposed improved facilities. He should obtain their advice but not necessarily their consent, as the responsibility for reducing interruptions and protecting equipment is logically his.

Many other definitions of correct relay operation have been used at various times. Most of these are listed below, each followed by a statement of its shortcomings as they are seen from the standpoint of this report:

"Relay Operation is correct if the equipment acts as the relay engineer expects it to act." Then it would always be correct if the relay engineer knew enough about his equipment and the laws of nature to predict its performance under any condition.

"Relay Operation is correct if it makes the best possible use of existing equipment." It is the duty of the relay engineer not only to make the best use of what he has, but also to get what he needs. To consider "whatever is, is right," is to stand in the way of advances in the art, as well as to prevent accepting the best standards of present practice.

"Relay Operation is designed for certain frequent operating set-ups. Unusual set-ups will unavoidably interfere with relay operation, which should, nevertheless, be considered as correct, if operation is correct under the designed conditions." There ought to be some way of measuring the adequacy of the design of a relay system in meeting unusual as well as normal conditions. Otherwise we place a premium on ignorance of the requirements of profitable operation. To consider unsatisfactory operations as correct if they occurred under conditions not anticipated does not tend to develop more adequate relay systems or to discourage operating set-ups which are difficult to relay. To consider such relay operation as incorrect does direct attention to an unsatisfactory condition and tend toward its betterment if an economically justifiable solution can be found—and it usually can.

"Relay Operation is correct if the best present day protective equipment and relay schemes are properly applied, even if in the present stage of the art insufficient protection is provided under certain operating conditions." Even if the art of relaying has reached a high state, it is likely that economically justifiable changes in operating methods may be made or that proper system planning could have eliminated those conditions that overtax the best relay schemes. Experience shows that present relay equipment and relay schemes are adequate to give 100 per cent protection under all justifiable operating conditions if protection is adequately considered in system planning.

"Relay Operation is incorrect if undesired." Correct operation must be attainable in the present state of the art, otherwise incorrect operation is a justifiable condition. If there is no known way of improving relay operation, it is correct.

"Relay Operation is correct if it makes the best use of such breakers as are automatic and of sufficient capacity to clear the trouble." If there were an established practice of periodically reporting the deficiencies in major equipment applications and performance, protective equipment reports might be confined to relays and their accessories. However, relay operation reports are customarily depended upon for their story of the performance of the system during abnormal conditions. In the absence of any particular objections to this practice and in view of its established position, we see no reason for limiting the scope of relay operation to minor or control equipment.

Special definitions with regard to relay operation are shown below:

1. Operation of relays by hand or electrically for test are included in the Daily Report of Relay Operations, but are not counted in the monthly summary, whether correct or not.
2. Do not count fuse failures in the monthly relay analysis. They may be included in the daily report if desired.
3. Classify incorrect operation of relays due to poor adjustments as due to incorrect settings.
4. In the relay report do not count auxiliary relay operations which do not interrupt fault current. For instance, an auxiliary relay may trip the low side of a transformer whenever the high side opens, to facilitate paralleling, but the low side operation should not be counted unless there is a source of power on the low side.
5. Interruptions to tie lines may be considered as by appointment after communication with the other company's dispatcher and securing permission to leave the tie line open.
6. If one breaker fails to open and a second breaker has to open to clear the trouble, consider the first operation as incorrect and the second as correct.
7. When a line supplied from an ungrounded system gets down on the ground or other non-insulating material, charge up an incorrect operation due to lack of grounding transformers.
8. Consider the incorrect operation of a potential operated relay due to potential fuse failure as a liability of this type of relay, and classify it as a miscellaneous relay trouble on the assumption that the type of relay is correct.
9. Count one relay operation for each switch operation regardless of the number of relays which tripped the switch.
10. Consider failures to relay on out-of-step conditions within a plant or between plants as incorrect under the head of Poor System Planning, since there are at present no adequate relays for out-of-step conditions, and the only apparent remedy lies in improving the excitation system.
11. If a flashover burns the current transformer or trip circuit open, do not charge up an incorrect operation, whether the breaker opens or not.
12. If lightning trips out a switch by grounding the control cable, consider the relay operation as incorrect unless there is no economically justifiable means available for preventing a repetition of the trouble.
13. If a load dispatcher tests a bad line in series with a good line when he could have tested the line direct from a generating plant with a reduced interruption, consider the relay operation on the good line as incorrect and due to poor operating practices. If there are specific instructions against this practice,

however, consider the operation as incorrect and due to personnel failure on the part of the load dispatcher.

14. If the system is operating with one of two parallel lines out of service unnecessarily and additional switches open due to a back-up protection for single line operation, this operation should be classified as incorrect and due to poor operating practices.

15. If circuits trip out due to additional load being added without notice, charge this up as incorrect and due to poor construction practices.

16. Charge up incorrect operations in connection with the experimental setting of relays under the classification "RX."

17. Do not count as a relay operation a switch opening due to control wiring trouble if trip current does not pass through the relay.

18. In general, any urgent hand operation of a breaker to clear trouble is incorrect.

19. In general, any relay operation is correct if there is no known justifiable way of improving its performance.

20. If a station does not have bus protection, the clearing during station trouble, at either or both ends of lines which supply the station is considered as correct.

21. In classifying interruptions by divisions of a company, the operating jurisdiction of the Division is used.

22. Do not use the classification "Unknown" or "Miscellaneous" unless absolutely necessary. The entire classification is a matter of judgment, and it is better for the man responsible for the report to make a guess at the time of the trouble as to the classification than to accumulate a large number of "Miscellaneous" and "Unknown" items which cannot be analyzed even approximately at a later date by someone less familiar with the details.

23. Do not count cases where a customer closes a relay accidentally.

24. Do not count customer's relay trouble in the relay report unless the customer's relay engineering is done by the power company.

25. Consider switch operation by hand on account of overload as incorrect if the overload is such as could have been carried for a few minutes or until the operator could call the dispatcher, providing also that there were no relays which should have operated at this overload.

26. If a generator winding breaks down between turns but does not take sufficient current to operate properly set differential relays, do not count any relay operation, since there is at present no known way of clearing minor coil failures between turns.

27. In general, all switching done under the jurisdiction of the dispatcher to reduce overload is correct, as it is not intended that all system switching should be performed by relays. The relays are intended to take care of things which cannot wait for the dispatcher.

28. Do not charge an incorrect operation due to obsolete relays as due to the wrong type of relay. Charge up an incorrect operation due to poor detail engineering design.

29. Charge up insufficient grounding capacity at stations to system planning, the same as a lack of any grounding transformers.

30. Consider loss of load due to clearances during stormy weather as incorrect and due to poor operating practices.

31. In case a switch comes out by differential relay and the operator forgets to reset the auxiliary relay, causing the switch to relay again when he attempts to close it, do not count this last operation as a relay operation, as it is not concerned with the clearing of trouble.

32. Whenever there is any question as to whether an interruption was due to weather conditions or some other cause, charge it to weather conditions.

33. Whenever there is any question as to whether an interruption was due to defective equipment or system inadequacy, use the classification "System Inadequacy."

34. Momentary interruptions to lines are not classified as equipment failures, but permanent interruptions are so considered unless there are extenuating weather conditions.

35. A lighting flashover on a transmission line should be considered as legitimate, but a bus flashover should be considered as illegitimate and probably due to system inadequacy in connection with lightning arresters.

36. Normal replacements and adjustments should not be counted as cases of trouble if the work is prearranged and if there is no interruption or only an interruption by appointment.

37. To operate correctly, protective equipment must isolate a maintained fault with less interruption and damage than any other economically justifiable installation.

THE USE OF HYDRO-ELECTRIC UNITS AS SYNCHRONOUS CONDENSERS[1]

Foreword

The use of hydro-electric units as synchronous condensers is coming to be an accepted practice in the field of hydro-electric development. This practice, like so many other electrical problems, is the direct result of the ever-increasing demand for better voltage, better power factor, and for better service conditions. All public utility concerns now recognize the necessity of operating their systems in such a way as to meet this ever-increasing demand.

This paper records the general experimental results and economic conclusions of a number of operating companies who have equipped their hydro-plants so the units can be used as synchronous condensers.

In this report, hydro plants have been classified as either run of river or storage plants. By run of river plant is meant a plant whose operation is governed entirely by river flow conditions and which at the most can store only a limited amount of water during the week-end light-load period. Storage plants have enough storage capacity for seasonal river flow regulation with only one major fill-up and draw-down per year.

The kilowatt-hour storage figures given are based on the economical draw-down, and represents the generation from the passage of the stored water not only through the storage plant but also through all plants on the same stream below the storage plant.

Typical Installations

One company has recently equipped six of its small hydro plants to be used in this way as synchronous condensers. As the efforts of this company are typical they will be described in detail. These plants are all on streams that have a low water season each fall. Most of these plants were recently acquired in the taking over of three small power systems serving a very promising lighting and factory territory. They all feed into a comparatively low voltage network. Constantly increasing load, lagging power factor and the urgent need of voltage boosting (under the low water conditions of no kilowatt-hour output) resulted in trying out the synchronous condenser idea.

Preliminary consideration brought out three essential problems:

1. To maintain an unfailing water supply to all lignum vitæ bearings.
2. To eliminate water from wheel chambers to minimize power losses.
3. To determine the operating characteristics of the water wheel unit used as a synchronous condenser and determine if satisfactory operation could be expected if the necessary changes were made in the hydraulic end.

The time and expense of equipping any one of these plants for use as a synchronous condenser was relatively small, but it was not always known just what the behavior of an ordinary generator would be if the water was cut off, and the generator allowed to motor continuously.

Let us consider the first and second problems together. Five of a group of six plants converted were of the open-flume type, which entirely sealed the draft chest and prevented the draft tube from emptying. In the vertical type units there were no lignum vitæ bearings to become unwatered when the draft chest and runner space were empty. In this case it was only necessary to provide an effective means of allowing the water to pass out of the water-wheel when the turbine gates were entirely closed and the unit still on the line. The first scheme tried was that of putting a two-inch pipe opening through the cover-plate, just over the runner, this pipe being controlled by a suitably placed valve on the operating floor. It was found that when the gates were closed and the valve opened the water-wheel would not always evacuate. As all the vertical type plants had been so built that it was possible to insert a 3-inch pipe through the concrete into the draft tube, just beneath the runner, this was tried out. In all cases where the runner had been placed so that the pipe was never below high tail water the water-wheel would always evacuate.

In the case of the horizontal units there were saddle bearings in the middle of the draft chest that had to have an auxiliary water supply when the unit was used as a synchronous condenser. A screened supply of water from the open flume was piped through the draft chest manhole cover directly into this lignum vitæ saddle bearing. A 3-inch pipe directly into the draft chest brought up to the top of the pit with a throttle on the pipe successfully controlled the air inlet. A cone-shaped valve and seat placed inside the screen on the manhole cover just above the saddle bearing was interlocked by a system of inclosed rods and levers to the main air throttle in such a way that when the unit was being used as a synchronous condenser, the opening of the air throttle opened the water supply and vice versa.

The third problem referred to, or the behavior of the generators under such conditions, was the most vital. All of the eleven generators experimented with were made by reputable manufacturers. It was found that in eight instances the generators of one make would operate with entire satisfaction at a plant located near the center of distribution, while in three instances a generator of the same make, size, and with practically the same speed would not work satisfactorily at the end of a relatively long line when carrying either partial or full boost kilovolt amperes. Pulsations would invariably set up, and no adjustment of voltage on either exciter or generator field would damp out the oscillations. The use of these three generators as synchronous condensers was temporarily abandoned.

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[1] A report by Frank M. Nash, Carolina Power & Light Co.
Publication No. 289-66, Serial Report, Hydraulic Power Committee.

Horizontal Units More Satisfactory

Of the group of six plants converted, four have vertical and two horizontal units. It is interesting to note in this connection that all of the plants that did not operate satisfactorily were of the vertical type, while plants of the horizontal type have given no trouble at all.

In testing out units, operated as synchronous condensers, without evacuation of wheel chambers, it was found that with gates closed each unit would draw about 20 to 30 per cent of its rating from the line. When the water-wheel was allowed to evacuate, the unit would draw from 4 to 7 per cent of its rating. One low head unit drew 9 per cent. The tests showed that in the cases cited it took from four to six times as much power to operate the units as condensers with wheel chambers full of water as it did when wheel chambers are empty. It was also noted that as long as the water was allowed to remain in the wheel chambers of the three unstable machines used as synchronous condensers, discussed above, no difficulties due to pulsations of voltage and current ever occurred. Unwatering the wheels made the resulting synchronous condenser unstable.

Turbines equipped with automatic vacuum breakers will, of course, automatically empty their draft tubes whenever the machine is operated with gates closed, as would be the case when used as synchronous condensers.

Attention has recently been called to the fact that the admission of air through openings in the head cover results in a distinct improvement in efficiency of turbines at low gate openings. Such openings are controlled automatically by the governor and, of course, operate to break the vacuum when the gates are closed. These devices, therefore, serve a double purpose when the machine is also used as a synchronous condenser.

Proper lubrication of the main turbine bearing is essential. Where runner clearances are small, as in high head practice, a small quantity of water may also have to be supplied for the purpose of minimizing the possibility of heating in case of slight rubbing contact.

If possible, it is desirable to provide some means of determining and checking runner clearances, when it is planned to motor the unit as a synchronous condenser, so that injurious rubbing contact may be avoided or corrected. Clearances or wobbling can be measured or checked by means of a stationary bracket, or pointer, attached to the turbine head cover or guide bearing. The distance between it and the shaft can be measured with a pair of inside calipers, and the amount of wobble measured or checked. By using two brackets, having adjustable cap screws and lock nuts, each set and locked at a given distance from the shaft, when the clearance is uniform, any variations may be detected, measured and adjusted for.

Turbine runners are often set very nearly down to tail-water level. Under such conditions large runners are apt to lift the tail-water level to such an extent as to cause a large amount of undesirable frictional resistance between the runners and the water. In such cases, forcing compressed air into the tailrace may have to be resorted to in order to force the water in the draft tube to a proper distance below the runner.

It is not the intent here to go into a discussion of the theoretical phases of this subject. That would furnish ample material for a separate paper. However, it seems that the following points should be mentioned: Two of these machines that would not operate satisfactorily at the end of a small conductor, low voltage line are duplicates of two other machines which do operate satisfactorily at a center of distribution. This indicates that the characteristics of these machines when combined with the characteristics of the small conductor, low voltage line, produce an unstable condition. Again, a part of this trouble may be due, not so much to the line conditions as it is to the reactance of the group of generating stations against the reactance of the unit being operated as a condenser. Knowing the characteristics of the generator to be operated as a synchronous condenser, and calculating the characteristics of the line to which it is connected, the probable results could be quite accurately forecast. Again this brings up the stability limit of a system composed of generators or condensers or both, and it is probably true that under certain load conditions on these high resistance lines there is not enough synchronizing power left to hold the units in step when being operated as synchronous condensers.

This company, in taking up the matter with the manufacturers, found that the cost of new field poles for these three machines (which would include amortisseur windings) was not at all prohibitive. The cost of building new lines for higher voltage or larger conductor was prohibitive.

However, as the eight generators which are operating satisfactorily as synchronous condensers are at present taking care of voltages and power factor requirements under low water conditions without the use of the three unstable machines, there is no need at present of making alterations. It is believed that these three units could be utilized if the proper additions are made.

As to the cost of equipping old plants to be operated as synchronous condensers, it seems that there are very few instances in which this could not be done economically.

If satisfactory regulation, under low water conditions, is an essential, then the expense of installing new field coils, including amortisseur windings, is certainly permissible. In the cases cited, and in many similar cases, the use of the generators as synchronous condensers brings about the desired results at only a fraction of the cost of separate synchronous condenser outfits, and utilizes equipment which would otherwise be idle.

New Plants Installed

As a result of the experiments with these small generators, the company referred to has equipped each of its three units in a new 63,000 kw. hydro-electric station with vacuum break pipes. This consists of a six-inch pipe entering the draft tube just beneath the lowest point of the vertical runner. This pipe is brought around the scroll case, and up some twenty feet to a valve on the operating floor. Provision is also made for letting compressed air into this vacuum pipe to hold elevation of tail-water below water-wheels if desirable during high tail-water.

One of the 21,000-kw. machines in the new plant is equipped with amortisseur windings at an additional cost of $1,400. The governor is set so that when operating as a synchronous condenser it will quickly pick up the load that might be suddenly thrown on, and take up the regulation of the speed. Thus, with a water storage of 3,000,000 kw-hr. back of it, this 21,000-kw. machine serves at one and the same time as a synchronous condenser to boost voltage during low water periods; to buck voltage during light load periods and as an emergency energy stand-by unit within the limits of the water storage. The increased generation can be added automatically when needed by the operation of the governor.

The superintendent of power control of a large interconnected system calls attention to the fact that the use of hydro-electric units as synchronous condensers greatly improves the operation of the system relaying, inasmuch as it provides synchronous capacity at hydro stations during off-peak and low water periods.

When hydro units are being run as condensers, with head gates open and guide vanes held closed by proper governor setting, the units are available for use as standby capacity, if the frequency falls below a predetermined value.

Geographic location of hydro plants, with relation to load centers is also a factor which should be considered in connection with a plan to use them for this purpose. Unless financial or other special conditions forbid, it may be found more economical to install synchronous condensers in locations near the large load centers.

Questionnaire Basis of Study

As a basis of this study, the following questionnaire was sent to all southern hydro-electric companies, who indicated that they were using their generators as synchronous condensers:

1. Number of generators—horizontal or vertical —reaction or impulse.
2. Full load kw-hr. rating each.
3. Generator voltage.
4. R.p.m.
5. How are generators excited?
6. Transmission line voltage.
7. How many generators used as synchronous condensers and approximate cost of equipping them for use as such?
8. Kw. required to operate as synchronous condensers.
9. How do you secure evacuation of water from wheel and draft chambers?
10. How are exposed water-wheel bearings, if any, cared for?
11. Relative location of plant as to load (end of long line, center of distribution, etc.).
12. Does generator have amortisseur or damper field windings? If no damper windings now, do you contemplate installing them in the near future? Give proposed cost of such installation.
13. Does generator have greater tendency to go out of phase when used as synchronous condenser?
14. Approximate change in voltage and power factor when using full effect of condenser.
15. State your opinion as to the merits of this method of voltage and power factor regulation.

Replies were received from about 25 stations. The tabulation of the replies (see Tables I to V inclusive) show that at least 80 per cent of the southern hydro-electric companies (and many companies in other parts of the country as well) use their generators in some form as synchronous condensers.

A few of the replies show that some operators may not be aware of the excessive loss of water which occurs when floating a generator on the line, or the excessive loss of energy which occurs with gates closed and unit operated with wheel chamber full of water as compared with the small percentage of energy required from the system to operate the generators as synchronous condensers with water-wheels running in free air. The reduction in running losses by removal of the water from the wheel chambers can be directly evaluated in dollars and represents a saving of considerable magnitude.

Another point brought out is the fact that these water-wheel synchronous condensers fall out of step much more easily when bucking voltage than they do when boosting. This agrees with the operation of a regular synchronous condenser, as would be expected.

One plant reported that the idea of evacuating the wheel chamber was investigated, but was not found practicable because of the fact that the fore bay was almost entirely filled with silt, and at practically any time of the year the water will begin spilling over the dam if it is shut off at the turbines for 20 or 30 minutes; consequently there was nothing gained in shutting the water off the wheel.

Two plants reported that such alterations were not advisable in view of the fact that the plants would soon be rebuilt. One plant reported that they would soon change from manual to automatic operation.

One company reports the use of a double-decked generator. It has a 60-cycle, 25,000-kw. generator mounted on top of a 36-cycle, 17,000-kw. generator, both connected to one 27,000-h.p. water-wheel. By this means they deliver power to either of two large power consumers, one a local 36-cycle system and the other a 110,000-volt, 60-cycle transmission line. The 60-cycle machine is equipped with amortisseur windings, and provision is made to empty the wheel chamber when operated as a frequency changer to take power from the 60-cycle system for use on the 36-cycle side, when water is scarce.

Two units report 100 per cent variation in power taken from system, depending on kv-a. loading. A check on this estimate would no doubt reveal a fairly constant kw. taken from system practically independent of kv-a. loading.

There was no opportunity to discuss the replies to the questionnaire with each contributor. They are tabulated just as sent in. It would be very interesting and instructive to have a record of actual test runs on all the apparatus referred to in the five charts shown. There can be no doubt but that such a record would show up much more information favorable to the use of hydro-electric units as synchronous condensers. A regular synchronous condenser of 1000 kv-a. capacity would probably cost around $14,000, including shelter. This would represent an annual charge of about $2,000.

In many cases the use of generating units as synchronous condensers, steam as well as hydro, entirely avoids this heavy annual charge at practically no additional expense and utilizes machinery that would otherwise be standing idle.

A large system in the Northwest reports a saving of between 2 and 3 per cent in efficiency by motoring one unit in a large plant, as a synchronous condenser, and running the other units at their points of greatest efficiency.

Another large hydro power company reports that the venting of draft tubes reduced the power required to motor a 21,000-kw. unit, from 5000 kw. to 500 kw., and for a 9000-kw. unit, from 1500 kw. to 200 kw.

A study of the charts will reveal other interesting and helpful information.

THE USE OF PRESENT DAY HYDRO-ELECTRIC UNITS AS SYNCHRONOUS CONDENSERS
TABULATION OF REPLIES TO QUESTIONNAIRES

TABLE I		UNIT A	UNIT B	UNIT C	UNIT D
1	GENERATORS	THREE VERTICAL REACTION	SIX HORIZONTAL REACTION FOUR RUNNERS ON EACH SHAFT	THREE HORIZONTAL REACTION FOUR RUNNERS ON EACH SHAFT	ONE HORIZONTAL REACTION TWO RUNNERS ON EACH SHAFT
2	RATING K.W.	2-22 000 1-18 000	3-3500 3-4500	2-850 1-1200	1-600
3	VOLTAGE	13800	4000	2300	2300
4	R.P.M.	2-90 1-75	164	150	400
5	HOW EXCITED	MOTOR GENERATOR	WATER WHEEL DRIVEN EXCITERS	WATER WHEEL DRIVEN EXCITERS	BELT DRIVEN EXCITERS
6	TRANSMISSION VOLTAGE	110 000	110 000	60 000	11 000
7	USED AS CONDENSERS AND COST OF EQUIPPING	ALL MAY BE USED AS SYNCHRONOUS CONDENSERS	THREE EQUIPPED AT A COST OF $25 EACH	ALL EQUIPPED AT A COST. OF $208 EACH	YES, AT NO COST
8	KW TO OPERATE AS SYN. CONDENSER	ESTIMATED 650 KW EACH	100 KW EACH	60 KW EACH	45 KW EACH
9	HOW EMPTY WHEEL CHAMBERS	SIX INCH PIPE JUST BELOW EACH RUNNER UP TO OPERATING FLOOR	AIR FOLLOWS ALONG SHAFT AND INTO WHEEL CHAMBER	AIR PIPE TO DRAFT CHEST	AIR FOLLOWS ALONG SHAFT AND INTO WHEEL CHAMBER
10	HOW CARE FOR EXPOSED BEARINGS	NONE EXPOSED	WATER PIPED THROUGH DRAFT CHEST	WATER PIPED THROUGH DRAFT CHEST	NONE EXPOSED
11	RELATIVE LOCATION OF PLANT	AT END OF 100 MILE LINE	FAIRLY CENTRAL	CENTER OF DISTRIBUTION	CENTER OF DISTRIBUTION
12	DAMPER WINDINGS INSTALLED OR CONTEMPLATED	1-22000 KW GENERATOR HAS AMORTISSEUR WINDINGS ON FIELD POLES	NONE	NONE	NONE
13	SEE BELOW *	NOT TRIED OUT YET	NO	VERY LITTLE	SLIGHTLY
14	EFFECT ON VOLTAGE AND POWER FACTOR	NOT TRIED OUT YET	VOLTAGE VARIES FROM 3 TO 4% ABOUT 1¼% PER UNIT	VOLTAGE VARIES FROM 4 TO 3% ABOUT 1¼% PER UNIT	VOLTAGE VARIES FROM 4 TO 3%
15	MERITS OF THIS METHOD		SOME WHAT LIMITED BUT SATISFACTORY AND INEXPENSIVE	VERY EFFECTUAL AND INEXPENSIVE	VERY GOOD WITHIN LIMIT AT NO EXPENSE

* DOES GENERATOR HAVE GREATER TENDENCY TO GO OUT OF PHASE WHEN USED AS SYNCHRONOUS CONDENSER

THE USE OF PRESENT DAY HYDRO-ELECTRIC UNITS AS SYNCHRONOUS CONDENSERS
TABULATION OF REPLIES TO QUESTIONNAIRES

TABLE II

		UNIT E	UNIT F	UNIT G	UNIT H
1	GENERATORS	TWO VERTICAL REACTION	TWO VERTICAL REACTION	ONE VERTICAL REACTION	TWO VERTICAL REACTION
2	RATING KW	500 EACH	500 EACH	500 EACH	350 EACH
3	VOLTAGE	2300	2300	2300	2300
4	R.P.M.	164	112	164	225
5	HOW EXCITED	BELT DRIVEN EXCITER	BELT DRIVEN EXCITER	BELT DRIVEN EXCITER	BELT DRIVEN EXCITER
6	TRANSMISSION VOLTAGE	22 000	22 000	11 000	11 000
7	USED AS CONDENSER AND COST OF EQUIPPING	BOTH EQUIPPED WITH VACUUM BREAK PIPE AT COST OF $40 EACH	BOTH USED AS CONDENSER AT COST OF $75 EACH	NOT SUCCESSFUL YET COST $25	BOTH EQUIPPED AT COST OF $30 EACH
8	KW TO OPERATE AS SYN. CONDENSER	30 KW EACH	35 KW EACH	32 KW	30 KW
9	HOW EMPTY WHEEL CHAMBER	VACUUM BREAK AIR PIPE INSTALLED JUST BENEATH RUNNER	VACUUM BREAK AIR PIPE INSTALLED JUST BENEATH RUNNER	VACUUM BREAK AIR PIPE INSTALLED JUST BENEATH RUNNER	VACUUM BREAK AIR PIPE INSTALLED. JUST BENEATH RUNNER
10	HOW CARE FOR EXPOSED BEARINGS	NONE EXPOSED	NONE EXPOSED	NONE EXPOSED	NONE EXPOSED
11	RELATIVE LOCATION OF PLANT	END OF LONG LINE	CENTER OF DISTRIBUTION	NEAR ONE END OF SMALL CONDUCTOR LINE	END OF LOW VOLTAGE SMALL CONDUCTOR LINE
12	DAMPER WINDINGS INSTALLED OR CONTEMPLATED	NONE NOW BUT CONTEMPLATED	NONE NOT CONTEMPLATED	NONE NOW BUT CONTEMPLATED	NONE NOT CONTEMPLATED
13	SEE BELOW *	WILL NOT ALWAYS HOLD IN STEP NOW	NO	WILL NOT HOLD IN STEP AS A CONDENSER	SLIGHTLY
14	EFFECT ON VOLTAGE AND POWER FACTOR	WILL BOOST VOLTAGE 5% BUT CAUSES PULSATION	WILL BOOST VOLTAGE FROM 2 TO 4%	WILL GO OUT OF STEP	WILL BOOST VOLTAGE 6%
15	MERITS OF THIS METHOD	NOT SATISFACTORY YET	GIVES GOOD RESULTS WITH PRESENT EQUIPMENT AT LITTLE COST	CHARACTERISTICS OF MACHINE WHEN COMBINED WITH THE CHARACTERISTICS OF LONG LINE, SMALL CONDUCTOR, AND LOW VOLTAGE, ARE NOT STABLE	GOOD RESULTS WITH ONE UNIT. OTHER UNIT SET TOO LOW FOR WHEEL CHAMBER TO EVACUATE.

* DOES GENERATOR HAVE GREATER TENDENCY TO GO OUT OF PHASE WHEN USED AS A SYNCHRONOUS CONDENSER

THE USE OF PRESENT DAY HYDRO-ELECTRIC UNITS AS SYNCHRONOUS CONDENSERS
TABULATION OF REPLIES TO QUESTIONNAIRES

TABLE III

		UNIT I	UNIT J	UNIT K	UNIT L
1	GENERATORS	SIX HORIZONTAL REACTION	FOUR VERTICAL REACTION	THREE VERTICAL REACTION	SEVEN HORIZONTAL REACTION
2	RATING KW	2400 EACH	11250 EACH	7500 EACH	2400 EACH
3	VOLTAGE	2300	6600	6600	4000
4	R.P.M.	300	171.4	128.6	200
5	HOW EXCITED	WATER WHEEL DRIVEN EXCITERS	WATER WHEEL DRIVEN D.C. GENERATOR ALSO DIRECT CONNECTED EXCITER	DIRECT CONNECTED EXCITER AND M.G. SET	DIRECT CONNECTED EXCITER AND M.G. SET
6	TRANSMISSION VOLTAGE	66 000	110 000	110 000	19 000
7	USED AS CONDENSER AND COST OF EQUIPPING	SIX USED AS CONDENSERS NEGLIGIBLE COST	ALL USED AS CONDENSERS NO CHANGE MADE MINIMUM GATE OPENING 0.1	ALL USED AS CONDENSERS NO CHANGE MADE GATE OPEN AT NO LOAD	ALL USED AS CONDENSERS NO CHANGE MADE GATE OPEN AT NO LOAD
8	KW TO OPERATE AS SYN. CONDENSER	105 KW EACH	WATER TAKES CARE OF LOSSES	WATER TAKES CARE OF LOSSES	WATER TAKES CARE OF LOSSES
9	HOW EMPTY WHEEL CHAMBER	VACUUM BREAK PIPE	NO MEANS PROVIDED	NO MEANS PROVIDED	NO MEANS PROVIDED
10	HOW CARE FOR EXPOSED BEARINGS	NO EXTRA PRECAUTIONS	NO EXTRA PRECAUTIONS	NO EXTRA PRECAUTIONS	NO EXTRA PRECAUTIONS
11	RELATIVE LOCATION OF PLANT	END OF LINE 50 MILES FROM LOAD CENTER	80 MILES FROM LOAD CENTER	80 MILES FROM LOAD CENTER	20 MILES FROM LOAD CENTER
12	DAMPER WINDINGS INSTALLED OR CONTEMPLATED	NONE NONE CONTEMPLATED	NONE NONE CONTEMPLATED	NONE NONE CONTEMPLATED	NONE NONE CONTEMPLATED
13	SEE BELOW *	YES	YES	YES	YES
14	EFFECT ON VOLTAGE AND POWER FACTOR	LIMITS NOT KNOWN	1½ % PER UNIT APPROXIMATELY MAXIMUM OF 6 %	1½ % PER UNIT MAXIMUM OF 6 %	UNDETERMINED
15	MERITS OF THIS METHOD	GOOD	SATISFACTORY	SATISFACTORY	SATISFACTORY

* DOES GENERATOR HAVE GREATER TENDENCY TO GO OUT OF PHASE WHEN USED AS A SYNCHRONOUS CONDENSER

THE USE OF PRESENT DAY HYDRO-ELECTRIC UNITS AS SYNCHRONOUS CONDENSERS
TABULATION OF REPLIES TO QUESTIONNAIRES

TABLE IV

		UNIT M	UNIT N	UNIT O	UNIT P
1	GENERATORS	SIX VERTICAL REACTION	THREE VERTICAL REACTION	TWO VERTICAL REACTION	FIVE HORIZONTAL REACTION
2	RATING KW	13500 EACH	16 500 EACH	1-11500 1-15000	4500 EACH
3	VOLTAGE	6600	6600	6600	2300
4	R.P.M.	100	100	150	360
5	HOW EXCITED	DIRECT CONNECTED EXCITERS	DIRECT CONNECTED EXCITERS	DIRECT CONNECTED EXCITERS - 220 V	WATER WHEEL DRIVEN EXCITERS
6	TRANSMISSION VOLTAGE	110 000	110 000	120 000	120 000 AND 60 000
7	USED AS CONDENSER AND COST OF EQUIPPING	ALL USED. WHEELS INSTALLED WITH VACUUM BREAKERS	ALL USED. WHEELS INSTALLED WITH VACUUM BREAKERS	1-11500 KW MACHINE NO ADDITIONAL COST	ALL USED. NO ADDED COST OF EQUIPMENT
8	KW TO OPERATE AS SYN. CONDENSER	500 KW	NO TEST MADE	300 TO 600 DEPENDING ON KVA LOADING (?)	300 OR LESS DEPENDING ON KVA LOADING (?)
9	HOW EMPTY WHEEL CHAMBER	TWO 2 INCH HAND OPERATED VALVES IN TOP OF SCROLL CASE	2-5 IN. VALVES IN TOP OF SCROLL CASE OPERATED AUTOMATICALLY FROM SPEED RING	2-SECOND FEET LEAKAGE THROUGH BROOME TYPE HEAD GATE	AIR PASSES ALONG SHAFT LINE INTO WHEEL CHAMBER
10	HOW CARE FOR EXPOSED BEARING	WATER PIPED TO BEARING FROM PENSTOCK	WATER PIPED TO BEARING FROM PENSTOCK	2 INCH WATER LINE TO LIGNUM VITAE STEADY BEARING	WATER PIPED THROUGH STRAINS TO BEARINGS
11	RELATIVE LOCATION OF PLANT	40 MILES FROM LOAD CENTER	50 MILES FROM LOAD CENTER	80 MILES FROM LOAD CENTER	30 TO 80 MILES FROM LOAD CENTER
12	DAMPER WINDINGS INSTALLED OR CONTEMPLATED	YES. INSTALLED WHEN PLANT WAS BUILT	YES. INSTALLED WHEN PLANT WAS BUILT	NONE NONE CONTEMPLATED	NONE NONE CONTEMPLATED
13	SEE BELOW *	YES, ESPECIALLY WHEN BUCKING VOLTAGE	YES, ESPECIALLY WHEN BUCKING VOLTAGE	YES	YES
14	EFFECT ON VOLTAGE AND POWER FACTOR	ABSORBS SYSTEM WATTLESS CURRENT	ABSORBS SYSTEM WATTLESS CURRENT	MAXIMUM INCREASE OF 250 V OR 4% - 125 V PER UNIT	MAXIMUM INCREASE OF 140 V OR ABOUT 6% - 30 V PER UNIT
15	MERITS OF THIS METHOD	CHIEF MERIT IS UTILIZES EQUIPMENT WHICH WOULD OTHERWISE BE IDLE IN DRY SEASON	CHIEF MERIT IS UTILIZES EQUIPMENT WHICH WOULD OTHERWISE BE IDLE IN DRY SEASON	RESULTS SATISFACTORY	RESULTS SATISFACTORY

* DOES GENERATOR HAVE GREATER TENDENCY TO GO OUT OF PHASE WHEN USED AS A SYNCHRONOUS CONDENSER

THE USE OF PRESENT DAY HYDRO-ELECTRIC UNITS AS SYNCHRONOUS CONDENSERS
TABULATION OF REPLIES TO QUESTIONNAIRES

TABLE V

		UNIT Q	UNIT R	UNIT S	UNIT T
1	GENERATORS	TWO VERTICAL REACTION TWO RUNNERS EACH	THREE HORIZONTAL REACTION	2-VERTICAL GENERATORS ON ONE VERTICAL REACTION WATER WHEEL	FOUR HORIZONTAL
2	RATING KW	2- 1875	3-650	1-25000·60~ 1-17100·36~	2-3000 2-5000
3	VOLTAGE	6600	6600	13200	12000
4	R.P.M.	133		156	200
5	HOW EXCITED	DIRECT CONNECTED EXCITER	WATER WHEEL DRIVEN EXCITER	DIRECT CONNECTED EXCITER AND M.G. SET	WATER WHEEL DRIVEN EXCITER
6	TRANSMISSION VOLTAGE	66000	66 000	11000 AND 110 000	110 000
7	USED AS CONDENSER AND COST OF EQUIPPING	USED AS CONDENSER AT SMALL GATE OPENING	USED AT ABOUT 12% GATE OPENING	USED AS FREQUENCY CHANGER IN EXCHANGE OF POWER	ALL USED AS CONDENSERS DURING AN EXTREMELY LOW WATER PERIOD
8	KW TO OPERATE AS SYN. CONDENSER	NOT TRIED OUT	NOT TRIED OUT	10% AT 3/4 LOAD	NO TEST MADE
9	HOW EMPTY WHEEL CHAMBER	NOT EMPTIED	NOT EMPTIED	PIPE IN COVER PLATE	USED A DRAIN FROM BOTTOM OF WHEEL CASE TO TOP OF DRAFT TUBE
10	HOW CARE FOR EXPOSED BEARINGS	NONE EXPOSED	NONE EXPOSED	NONE EXPOSED	NONE EXPOSED
11	RELATIVE LOCATION OF PLANT	NEAR END OF LINE	NEAR LOAD CENTER	CENTER OF 11000 V SYSTEM END OF 120 MI. 110,000 V. LINE	MIDDLE OF TRANSMISSION LINE
12	DAMPER WINDINGS INSTALLED OR CONTEMPLATED	NONE NONE CONTEMPLATED	NONE NONE CONTEMPLATED	AMORTISSEUR WINDING ON ONE UNIT	NONE NONE CONTEMPLATED
13	SEE BELOW *	NO	NO	IT DOES NOT	NO TROUBLE EXPIENCED
14	EFFECT ON VOLTAGE AND POWER FACTOR	NOT DETERMINED	NOT DETERMINED	HELPS VERY MUCH	NOT DETERMINED
15	MERITS OF THIS METHOD	GOOD. NO STORAGE. RIVER SILTED UP ALMOST TO TOP OF DAM. WATER WILL WASTE IN 30 MIN. AFTER CLOSING GATES	GOOD. WILL PROBABLY REBUILD PLANT	SEE TEXT. AN EXTRA LOSS OF 900 KW OCCURS WHEN WHEEL CHAMBER IS NOT EVACUATED	O.K. FOR EMERGENCY USE P.F. REGULATION SHOULD BE HANDLED AT LOAD END INSTEAD OF GEN. STATION
*	DOES GENERATOR HAVE GREATER TENDENCY TO GO OUT OF PHASE WHEN USED AS A SYNCHRONOUS CONDENSER.				

MECHANICAL RELIABILITY OF HYDRO-ELECTRIC UNITS—1927

The present report embodies the results of the fourth year's study of this subject by the Hydraulic Power Committee. The same restrictions upon age and size of units were continued from the earlier years, namely, installation in 1920 or later and a capacity of 5000 kw. or greater.

The fact that for 1927 records were contributed for 134 units, as compared with 95 in the 1926 report, indicates the very encouraging increase in cooperation which has been noted of member companies operating eligible units from year to year. The units reported upon this year include 91 of the 95 in the 1926 report, 14 of which were installed during 1927 and 29 of earlier date than 1927, but for which no data had been previously contributed.

In the collection, tabulation and analysis of the data, no change has been made from the previous year's procedure. Also a complete definition and description of all the terms used having been made a part of the first report in 1924, it is believed unnecessary to repeat these. The 1927 records were contributed by 31 operating companies.

Of the 134 turbines, 106 were of the vertical reaction type (non-propeller) with a total rating of 2,572,780 h.p.; 9 of the horizontal reaction type (total rating 142,400 h.p.); 11 of the impulse type (total rating 274,000 h.p.); and 8 of the propeller type (232,000 h.p.), making a grand total of 3,221,180 h.p. and an average rating of 24,039 h.p. Combined with these turbines were 114 vertical generators, having a total rating of 2,031,260 kw., and 20 horizontal generators, with a total rating of 288,450 kw.—grand total, 2,319,710 kw.

The range of the generator ratings is from 5000 to 52,000 kw., with an average of 17,311 kw.; that of the speeds from 90 to 600 r.p.m.; and that of the heads from 45 to 2381 ft. The range of head of reaction type units is from 40 to 909 ft.; while the impulse type units extend from 1108 to 2381 ft.

Table I lists the principal characteristics, by reference groups, of all of the units whose analysis has been included in this report. The operating records for the year 1927 are tabulated by reference groups in Table II. In Table III the records of the units of each type are summarized and compared with the corresponding summaries for 1924, 1925 and 1926 and with a summary of steam unit reliability records for the year 1925, taken from a Serial Report of the Prime Movers Committee on Turbines, N. E. L. A. Pub. No. 267-78.

The range of outage time percentages for 1927, as noted in Table II, except for one unit which is far out of line, are quite comparable with those of previous years, namely, from 14.77 per cent to 0 for the total outage time; and for the outage time in demand, 14.59 per cent to 0. The extremely high outage time percentages of the one unit mentioned are due principally to the reduced base upon which they are computed, this unit having been installed late in 1927. Of the 80 reference groups, 31 are noted as having 0 outage time in demand.

Fig. 1 shows the outage time, both total and in demand, of all the reference groups arranged by type of unit, and also in the order of decreasing magnitude of total outage time.

The outage time percentages, both total and in demand, have been plotted for each individual unit in Fig. 2 against the year of installation. Neither installation nor least squares analysis of the data indicated any relation between age and outage time of magnitude comparable with the division of the individual units from the average. This result provides further confirmation of the conclusions reached from study of the earlier data on this relation.

Table IV contains the outage time percentages averaged according to year of installation for the years 1924, 1925, 1926 and 1927.

Fig. 3 is derived by entering the outage time percentages of each reference group against the generator rating. Again, no definite relation is observable between outage time, either total or in demand, and the size of the unit.

Table V presents an analysis in total by reference groups and causes of outage of the total outage hours; these details being summarized into classes according to turbine type with the per cent of the total outage time resulting from each case in Table VI.

For all of the classes of units in Table VI, the most important principal group of causes of outage time is Waterwheels and Auxiliaries. The next in order is Generators and Appurtenances, and the last, General Hydraulic Causes.

Of the individual causes affecting the outage of the entire number of units, Headgates or Intake is the largest item of General Hydraulic Causes, with Other General Hydraulic Causes following. In the Water Wheels and Auxiliaries group the leading place goes to the Runner, with General Overhauling and Replacements second. Cleaning and Other Causes respectively hold first and second places in the group of Generators and Appurtenances.

Publication No. 289-68, Serial Report, Hydraulic Power Committee.

TABLE I

PRINCIPAL CHARACTERISTICS OF HYDRO-ELECTRIC UNITS, 1927 DATA

Group Reference No.	H.P. of Each Turbine	Turbine Type	Vertical or Horizontal	Number of Runners	Rated Head, Ft.	R.P.M.	Year Installed	Rating of Each Generator Kw.	Number of Units in Group
1	15,000	Reaction	Vertical	1	216.8	225	1921	10,000	1
2	15,000	Reaction	Vertical	1	197.9	225	1921	10,000	1
3	40,000	Reaction	Vertical	1	454	257	1922	31,500	2
4	33,000	Reaction	Vertical	1	315	225	1925	24,300	3
5	18,000	Impulse	Horizontal	2	1375	360	1922	12,000	1
6	9,500	Impulse	Horizontal	1	1865	514	1921	6,000	1
7	17,690	Reaction	Vertical	1	225	277	1927	12,150	2
8	35,000	Reaction	Vertical	1	740	428	1923	25,000	3
9	30,000	Reaction	Vertical	1	680	428	1921	22,500	1
10	25,000	Reaction	Vertical	1	820	500-600	1921	15,750	2
11	22,500	Impulse	Horizontal	2	1900	375	1923	15,750	1
12	35,000	Impulse	Horizontal	2	1900	300	1925	25,000	1
13	22,500	Impulse	Horizontal	2	1680	375	1923-25	15,750	2
14	15,000	Reaction	Vertical	1	350	360	1920	11,360	3
15	12,000	Reaction	Vertical	1	272	257	1921	8,480	1
16	40,000	Impulse	Horizontal	2	2381	360	1927	31,000	1
17	20,000	Reaction	Vertical	1	157	171.4	1925	13,500	2
18	18,600	Reaction	Horizontal	2	125	200	1922	10,000	1
19	7,500	Reaction	Horizontal	1	245.4	400	1924	6,250	1
20	14,000	Impulse	Horizontal	1	1673	360	1924	12,500	1
21	30,000	Impulse	Horizontal	2	1108	171	1921(2)–24	20,000	3
22	70,000	Reaction	Vertical	1	213.5	107	1924	52,000	2
23	70,000	Reaction	Vertical	1	213.5	107	1924	52,000	1
24	8,200	Reaction	Horizontal	1	325	514	1921	5,250	1
25	35,000	Reaction	Vertical	1	909	514	1924	25,500	1
26	11,000	Reaction	Vertical	1	265	341	1922	8,000	1
27	8,700	Reaction	Vertical	1	180	300	1920	6,000	1
28	14,500	Reaction	Vertical	1	204	240	1921	10,000	1
29	9,000	Reaction	Vertical	1	47	120	1924	6,000	2
30	9,000	Reaction	Vertical	1	47	120	1927	6,000	2
31	10,000	Reaction	Vertical	1	96	185	1921	7,200	1
32	14,000	Reaction	Vertical	1	96	150	1924	10,000	1
33	9,000	Reaction	Vertical	1	81	164	1923	6,800	1
34	10,900	Reaction	Vertical	1	157	300	1924	10,000	2
35	11,500	Reaction	Vertical	1	268	360	1922	7,500	2
36	10,500	Reaction	Vertical	1	126	225	1925	7,500	2
37	15,500*	Reaction	Vertical	1	83(max.)	120	1924	12,000	1
38	9,000	Reaction	Vertical	1	45	100	1925	6,000	2
39	20,000	Reaction	Vertical	1	62	94.7	1924	12,000	2
40	20,000	Reaction	Vertical	1	70	100	1925	15,000	2
41	20,000	Reaction	Vertical	1	70	100	1924	15,000	1
42	40,200	Reaction	Vertical	1	145	140	1922	30,000	1
43	30,000	Propeller	Vertical	1	60	120	1924	24,750	4
44	11,100	Reaction	Vertical	1	160	180	1926	7,500	2
45	11,000	Reaction	Vertical	1	75	133.3	1924	9,600	2
46	12,000	Reaction	Vertical	1	400	514	1925	9,600	2
47	25,000	Reaction	Vertical	1	70	100	1923	17,500	3
48	45,000	Reaction	Vertical	1	85–145	120	1926	33,000	3
49	14,000	Reaction	Vertical	1	75	128	1926	7,500	3
50	22,000	Reaction	Vertical	1	150	174.4	1924	11,250	4
51	15,200	Reaction	Vertical	1	189	200	1925	8,000	2
52	22,200	Reaction	Vertical	1	149	164	1925	15,000	1
53	8,700	Reaction	Vertical	1	180	360	1923	6,000	1
54	16,500	Reaction	Vertical	1	525	514	1923	11,000	1
55	10,000	Reaction	Vertical	1	79	150	1924	7,000	2
56	21,500	Reaction	Vertical	1	127	150	1927	15,000	2
57	34,000	Reaction	Vertical	1	93	100	1927	28,800	3
58	24,000	Reaction	Vertical	1	66	90	1927	20,000	3
59	8,000	Reaction	Horizontal	2	68	200	1922	5,000	1
60	22,000	Reaction	Vertical	2	112	150	1926	15,000	2
61	23,000	Reaction	Horizontal	1	460	360	1924	16,000	1
62	24,300†	Reaction	Horizontal	2	180–255	300	1926	15,600	2
63	28,000	Propeller	Vertical	1	56	138.5	1922	18,900	2
64	28,000	Propeller	Vertical	1	56	138.5	1926	18,900	1
65	28,000	Propeller	Vertical	1	56	138.5	1927	18,900	1
66	52,500	Reaction	Vertical	1	305	187.5	1921	38,000	2
67	55,000	Reaction	Vertical	1	305	187.5	1922	38,000	1
68	55,000	Reaction	Vertical	1	305	187.5	1922–23	38,000	2
69	58,000	Reaction	Vertical	1	294	187.5	1924	47,000	1
70	58,000	Reaction	Vertical	1	294	187.5	1925	46,000	3
71	25,700	Reaction	Vertical	1	60	120	1924	18,000	1
72	7,500	Reaction	Vertical	1	190	360	1923	5,200	2
73	10,000	Reaction	Vertical	1	70	187	1924	8,000	2
74	18,000	Reaction	Vertical	1	88	133.3	1926	12,800	1
75	18,000	Reaction	Vertical	1	88	133.3	1926	12,800	1
76	18,000	Reaction	Vertical	1	88	133.3	1926	12,800	1
77	18,000	Reaction	Vertical	1	88	133.3	1926	12,800	1
78	28,500	Reaction	Vertical	1	350	300	1926	20,000	2
79	13,500	Reaction	Horizontal	2	130	225	1922	10,500	1
80	15,000	Reaction	Horizontal	2	130	225	1925	10,500	1

*At 78 ft. †At 230 ft.

TABLE II

1927 OPERATING RECORDS

Group Reference No.	Average Service Time %	Average Idle Time %	Average Outage Time %	Average Outage Time When in Demand %	Average Outage Time When Not in Demand %	Average Reserve Time %	Average Demand Time %	Average Capacity Factor %	Average Output Factor %	Average Service Demand Availability Factor %	Average Output, Million Kw-hr.
1	96.99	3.01	3.01	0.00	3.01	0.00	96.99	30.30	31.20	100.00	26.55
2	95.57	4.43	4.43	0.00	4.43	0.00	95.57	51.20	53.60	100.00	44.82
3	73.11	26.89	0.00	0.00	0.00	26.89	73.11	55.20	75.50	100.00	152.22
4	79.91	20.09	2.94	0.00	2.94	17.15	79.91	60.20	75.30	100.00	128.28
5	86.70	13.30	8.52	0.00	8.52	4.78	86.70	27.00	31.20	100.00	28.40
6	43.84	56.16	1.47	0.00	1.47	54.69	43.84	34.20	78.00	100.00	17.98
7	48.00	52.00	11.17	0.00	11.17	40.83	48.00	31.00	64.50	100.00	16.62
8	80.79	19.21	1.54	0.02	1.52	17.67	80.81	79.20	98.00	100.00	173.52
9	91.33	8.67	1.72	0.13	1.59	6.95	91.46	92.30	101.10	99.80	177.00
10	76.91	23.09	2.35	0.16	2.19	20.74	77.07	67.60	87.80	99.80	93.22
11	92.13	7.87	2.25	0.00	2.25	5.62	92.13	72.30	78.50	100.00	99.81
12	82.85	17.15	3.00	0.00	3.00	14.15	82.85	71.00	85.70	100.00	155.59
13	96.50	3.50	1.63	0.08	1.55	1.87	96.58	84.60	87.70	99.90	116.79
14	98.44	1.56	0.23	0.23	0.00	1.33	98.67	69.20	70.30	98.70	69.71
15	97.86	2.14	1.50	1.48	0.02	0.64	99.34	80.00	81.80	98.60	59.49
16	87.50	12.50	11.55	6.30	5.25	0.95	93.80	43.90	50.20	93.30	102.48
17	80.90	19.10	0.41	0.06	0.35	18.69	80.96	62.40	77.20	99.90	73.81
18	81.34	18.66	0.54	0.24	0.30	18.12	81.58	73.80	90.70	99.70	64.62
19	97.52	2.48	1.95	1.95	0.00	0.53	99.47	43.60	44.70	98.00	23.88
20	84.38	15.62	0.79	0.00	0.79	14.83	84.38	26.20	31.10	98.50	28.64
21	85.42	14.58	3.92	0.06	3.86	10.66	85.48	43.10	50.40	99.90	75.52
22	97.52	2.48	2.06	2.06	0.00	0.42	99.58	90.18	92.47	97.94	410.78
23	96.65	3.35	3.12	3.12	0.00	0.23	99.77	101.56	105.07	96.88	462.62
24	93.70	6.30	4.61	4.61	0.00	1.69	98.31	36.30	38.76	95.31	16.70
25	99.65	0.35	0.35	0.35	0.00	0.00	100.00	64.48	64.71	99.65	144.03
26	85.97	14.03	2.83	1.92	0.91	11.20	87.89	59.52	69.24	97.82	41.71
27	94.73	5.27	5.27	0.19	5.08	0.00	94.92	76.76	84.20	99.80	41.92
28	98.37	1.63	1.63	0.00	1.63	0.00	98.37	64.10	65.16	100.00	56.15
29	91.38	8.62	2.09	2.09	0.00	6.53	93.47	73.13	80.03	97.76	38.43
30	75.99	24.01	3.36	3.36	0.00	20.65	79.35	61.81	81.34	95.78	18.33
31	90.24	9.76	0.96	0.11	0.85	8.80	90.35	55.66	61.68	99.87	35.10
32	69.01	30.99	0.86	0.57	0.29	30.13	69.58	52.02	75.38	99.18	45.56
33	99.31	0.69	0.68	0.10	0.58	0.01	99.41	59.55	59.96	99.90	35.47
34	91.69	8.31	0.35	0.00	0.35	7.96	91.69	49.94	54.46	100.00	43.74
35	50.80	49.20	0.57	0.46	0.11	48.63	51.26	58.43	115.04	99.11	38.30
36	33.39	66.61	0.11	0.11	0.00	66.50	33.50	43.16	129.26	99.66	28.35
37	71.42	28.58	3.67	0.00	3.67	24.91	71.42	43.72	61.22	100.00	45.96
38	70.91	29.09	4.61	0.00	4.61	24.48	70.91	51.85	73.12	100.00	27.25
39	85.91	14.09	2.39	0.12	2.27	11.70	86.03	67.23	78.26	99.85	70.67
40	99.72	0.28	0.28	0.28	0.00	0.00	100.00	77.36	77.58	99.72	101.60
41	99.97	0.03	0.03	0.03	0.00	0.00	100.00	73.48	73.51	99.97	96.55
42	91.03	8.97	1.08	0.35	0.73	7.89	91.38	68.03	74.73	99.62	178.76
43	86.94	13.06	6.32	2.71	3.61	6.74	89.65	68.70	79.14	96.98	148.56
44	93.35	6.65	1.24	0.71	0.53	5.41	94.06	95.33	102.12	99.30	62.63
45	51.24	48.76	0.03	0.03	0.00	48.73	51.27	43.60	85.08	99.95	36.67
46	21.02	78.98	5.20	0.00	5.20	73.78	21.02	16.19	77.03	100.00	13.61
47	84.71	15.29	9.25	0.00	9.25	6.04	84.71	63.47	74.92	100.00	97.29
48	41.56	58.44	3.56	0.04	3.52	54.88	41.60	24.05	57.86	99.92	69.51
49	26.39	73.61	1.21	0.00	1.21	72.40	26.39	16.30	61.77	100.00	10.71
50	40.97	59.03	5.44	0.00	5.44	53.59	40.97	16.74	40.85	100.00	16.49
51	29.12	70.88	11.63	0.00	11.63	59.25	29.12	25.70	88.24	100.00	18.01
52	69.77	30.23	8.94	0.15	8.79	21.29	69.92	58.89	84.40	99.79	77.37
53	97.13	2.87	2.87	2.87	0.00	0.00	100.00	75.85	78.07	97.13	39.86
54	85.22	14.78	3.46	1.86	1.60	11.32	87.08	*	*	97.86	*
55	51.28	48.72	3.42	0.04	3.38	45.30	51.32	25.34	49.42	100.00	15.54
56	68.92	31.08	1.55	0.16	1.39	29.53	69.08	34.60	50.35	99.76	38.35
57	100.00	0.00	0.00	0.00	0.00	0.00	100.00	47.71	47.71	100.00	83.44
58	99.98	0.02	0.02	0.02	0.00	0.00	100.00	51.41	51.41	99.98	41.95
59	55.22	44.78	0.92	0.00	0.92	43.86	55.22	55.60	100.80	100.00	24.39
60	57.78	42.22	0.48	0.02	0.46	41.74	57.80	40.32	69.76	99.96	52.99
61	70.64	29.36	1.32	0.04	1.28	28.04	70.68	34.96	49.46	99.96	49.00
62	90.30	9.70	0.73	0.04	0.69	8.97	90.34	84.15	93.19	99.95	114.99
63	92.48	7.52	2.84	0.02	2.82	4.68	92.50	58.43	63.19	99.98	193.50
64	93.54	6.46	2.55	0.00	2.55	3.91	93.54	70.81	75.70	100.00	127.19
65	17.76	82.24	81.62	72.13	9.49	0.62	89.89	14.30	80.53	19.76	3.96
66	70.89	29.11	6.44	0.00	6.44	22.67	70.89	75.56	106.46	100.00	251.16
67	80.25	19.75	2.69	0.00	2.69	17.06	80.25	88.66	110.48	100.00	295.12
68	71.46	28.54	4.93	0.07	4.86	23.61	71.53	82.85	115.81	99.90	275.47
69	74.66	25.34	1.67	0.07	1.60	23.67	74.73	74.53	99.84	99.91	306.87
70	75.00	25.00	2.28	0.00	2.28	22.72	75.00	74.89	99.85	100.00	301.78
71	94.20	5.80	2.60	0.68	1.92	3.20	94.88	63.63	67.55	99.28	100.34
72	85.23	14.77	14.77	14.59	0.18	0.00	99.82	36.49	42.81	85.38	16.62
73	97.87	2.13	2.13	1.71	0.42	0.00	99.58	55.72	56.93	98.28	39.04
74	42.26	57.74	0.00	0.00	0.00	57.74	42.26	33.08	78.27	100.00	37.09
75	56.86	43.14	0.00	0.00	0.00	43.14	56.86	44.87	78.91	100.00	50.31
76	30.59	69.41	0.00	0.00	0.00	69.41	30.59	23.90	78.13	100.00	26.80
77	61.61	38.39	0.00	0.00	0.00	38.39	61.61	48.61	78.90	100.00	54.50
78	50.31	49.69	2.36	0.98	1.38	47.33	51.29	31.34	62.32	98.09	54.90
79	78.25	21.75	2.18	0.00	2.18	19.57	78.25	44.73	57.45	100.00	41.35
80	51.06	48.94	3.03	0.00	3.03	45.91	51.06	26.95	52.77	100.00	24.78
Av. of 134 Units ..	74.80	25.20	3.58	1.23	2.35	21.62	76.03	54.53†	73.38†	98.60	89.71†

*Data not available. †Average of 133 units.

TABLE III

SUMMARY OF OPERATING RECORDS, HYDRO-ELECTRIC UNITS

	1924			1925			1926						1927						Steam Units, 1925
									Reaction Wheels						Reaction Wheels				
	Impulse Wheels	Reaction Wheels	Total	Impulse Wheels	Reaction Wheels	Total	Propeller Wheels	Impulse Wheels	Vertical	Horizontal	Total	Total	Propeller Wheels	Impulse Wheels	Vertical	Horizontal	Total	Total	
1. Number of units included	1	20	21	7	36	43	4	12	73	6	79	95	8	11	106	9	115	134	191
2. Average generator rating, kw	17,500	16,210	16,270	16,786	16,614	16,642	24,750	15,229	14,800	10,000	14,435	14,970	21,825	17,614	17,523	10,522	16,975	17,311	29,460
3. Service time, %	61.2	77.06	76.30	78.05	81.32	80.79	82.18	80.50	69.51	81.98	70.46	72.22	80.50	84.24	73.06	78.70	73.50	74.80	65.08
4. Idle time, %	38.8	22.94	23.70	21.95	18.68	19.21	17.82	19.50	30.49	18.02	29.54	27.78	19.50	15.76	26.94	21.30	26.50	25.20	34.92
5. Outage time, %	6.5	7.37	7.32	1.84	4.42	3.99	11.28	2.30	3.05	4.43	3.15	3.45	14.84	3.87	2.89	1.78	2.80	3.58	13.36
6. Outage time when in demand, %	0.0	1.03	0.98	0.79	1.92	1.73	2.02	0.80	1.01	0.91	1.01	1.08	10.38	0.60	0.65	0.77	0.66	1.23	3.34
7. Outage time when not in demand, %	6.5	6.34	6.34	1.05	2.54	2.29	9.26	1.50	2.04	3.52	2.15	2.37	4.46	3.27	2.24	1.01	2.14	2.35	10.02
8. Reserve time, %	32.3	15.57	16.38	20.11	14.26	15.22	6.54	17.20	27.44	13.59	26.39	24.33	4.66	11.89	24.05	19.52	23.70	21.62	21.56
9. Demand time, %	61.2	78.09	77.28	78.84	83.26	82.62	84.21	81.29	70.53	82.89	71.47	73.31	90.88	84.84	73.71	79.47	74.16	76.03	68.42
10. Maximum possible service time, %	93.5	92.63	92.68	98.16	95.58	95.01	88.72	97.70	96.87	95.57	96.77	96.55	85.16	96.13	97.11	98.22	97.20	96.38	86.64
11. Capacity factor, %	14.4	46.14	44.43	24.61	51.49	47.44	68.25	50.52	50.37	46.19	49.74	50.62	59.60	52.10	54.46	53.80	54.41	54.53	44.35
12. Output factor, %	23.5	59.88	58.24	31.53	63.32	58.51	83.05	62.64	75.10	56.55	73.38	72.43	74.90	61.94	74.83	69.00	74.37	73.38	68.14
13. Service demand availability factor, %	100.0	98.21	98.30	99.04	97.84	98.04	97.60	99.11	98.12	99.17	98.19	98.28	88.46	99.21	99.26	99.21	99.25	98.60	95.16

TABLE IV

AVERAGE OUTAGE TIME CLASSIFIED BY YEAR OF INSTALLATION

Year Installed	1927 Data			1926 Data			1925 Data			1924 Data		
	Number of Units	Average Outage Time, %		Number of Units	Average Outage Time, %		Number of Units	Average Outage Time, %		Number of Units	Average Outage Time, %	
		Total	In Demand		Total	In Demand		Total	In Demand		Total	In Demand
1920	4	1.49	0.22	4	3.04	0.19	3	3.19	0.20	4	3.63	0.55
1921	14	3.20	0.48	11	1.99	0.95	7	2.74	1.37	5	12.39	2.27
1922	14	2.18	0.25	9	1.15	0.20	9	3.98	2.07	5	1.88	0.64
1923	14	5.55	2.44	15	4.28	1.33	7	5.46	0.73	6	10.33	0.65
1924	33	2.80	0.90	25	4.20	1.42	13	2.36	0.08	1	0.80	0.80
1925	22	3.49	0.05	22	2.72	0.55	4	9.63	9.43	....	....	....
1926	19	1.39	0.19	9	5.24	1.82	....	....	....	....	....	....
1927	14	8.96	6.11	....	....	....	....	....	....	....	....	....
Total..	134	3.58	1.23	95	3.45	1.08	43	3.99	1.73	21	7.08	1.02

TABLE V

ANALYSIS OF OUTAGE HOURS, 1927 DATA

Group Reference No.	General Hydraulic Causes						Generators and Appurtenances									
	Ice or Trash	Floods	Penstock or Canal	Head-gates or Intake	Other General Hydraulic	Total General Hydraulic	Vibration	Lubrication or Oil Leakage	Rotor or Field	Armature Iron or Windings	Exciter and Rheostats	Ventilation System	Cleaning	Inspection	Other Causes	Total Generators and Appurtenances
1	......	......	24.00	......	......	24.00	......	230.00	......	......	1.00	......	3.00	......	......	234.00
2	......	......	150.00	......	......	150.00	......	238.00	......	......	......	......	......	......	......	238.00
3	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
4	......	......	......	......	......	......	......	......	40.00	......	......	......	......	......	......	40.00
5	......	......	17.00	......	......	17.00	......	......	......	......	......	......	......	......	......	......
6	......	......	117.00	......	......	117.00	......	......	......	......	......	......	......	......	......	......
7	......	......	......	65.00	......	65.00	......	......	......	......	......	32.00	......	......	......	32.00
8	......	......	29.00	......	......	29.00	......	34.00	......	......	......	......	65.00	25.00	......	124.00
9	30.00	......	......	......	......	30.00	......	4.00	......	......	......	......	30.00	......	......	34.00
10	......	......	23.00	......	......	23.00	......	......	......	......	......	......	94.00	......	......	94.00
11	......	......	32.00	......	......	32.00	......	......	......	......	......	......	......	......	......	......
12	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
13	31.00	......	......	......	15.00	46.00	......	......	......	......	......	......	......	......	......	......
14	19.00	......	......	......	......	19.00	......	......	......	......	......	......	......	......	7.00	7.00
15	......	......	......	......	......	......	......	......	......	......	......	......	......	......	2.00	2.00
16	......	......	......	......	......	......	......	......	9.00	440.00	......	......	......	......	396.00	845.00
17	......	......	......	......	......	......	......	......	......	......	8.05	......	......	......	......	8.05
18	......	......	2.20	......	......	2.20	......	......	......	......	0.19	37.16	......	......	......	37.35
19	6.25	......	40.50	7.75	8.28	62.78	......	......	6.00	......	......	......	......	......	6.57	12.57
20	......	......	......	67.23	......	67.23	......	......	......	......	......	......	......	......	......	......
21	......	......	......	......	......	......	......	......	73.43	......	0.17	......	44.85	11.80	......	130.25
22	45.00	......	......	......	......	45.00	......	......	4.00	......	27.00	9.00	......	......	......	40.00
23	28.00	......	......	......	......	28.00	......	......	6.00	......	2.00	......	......	......	......	8.00
24	......	......	9.00	......	39.00	48.00	......	......	......	......	1.00	......	8.00	1.00	5.00	15.00
25	......	......	......	......	10.00	10.00	......	......	......	......	......	......	......	......	2.00	2.00
26	12.00	......	......	......	......	12.00	......	......	......	168.00	......	......	......	......	......	168.00
27	......	......	......	......	......	......	......	......	......	......	......	......	96.00	......	34.00	130.00
28	......	......	......	......	......	......	......	......	......	......	......	......	15.00	......	60.00	75.00
29	11.00	......	......	......	6.00	17.00	......	......	......	......	14.00	......	......	1.00	286.00	301.00
30	3.00	......	......	......	......	3.00	......	......	7.00	......	5.00	......	......	......	300.00	312.00

TABLE V—(*Continued*)

ANALYSIS OF OUTAGE HOURS, 1927 DATA

Group Reference No.	General Hydraulic Causes						Generators and Appurtenances									
	Ice or Trash	Floods	Penstock or Canal	Head-gates or Intake	Other General Hydraulic	Total General Hydraulic	Vibration	Lubrication or Oil Leakage	Rotor or Field	Armature Iron or Windings	Exciter and Rheostats	Ventilation System	Cleaning	Inspection	Other Causes	Total Generators and Appurtenances
31	......	......	......	31.00	......	31.00	......	2.00	......	......	......	......	15.00	10.00	......	27.00
32	......	......	......	31.00	......	31.00	......	3.00	......	......	......	......	5.00	9.00	......	17.00
33	2.50	......	......	......	......	2.50	......	......	2.10	......	......	......	......	16.70	14.70	33.50
34	......	......	8.60	......	......	8.60	......	4.00	......	......	15.20	......	......	10.20	......	29.40
35	......	......	......	......	......	......	......	80.00	......	......	......	......	10.00	......	......	90.00
36	......	......	......	......	......	......	......	......	......	......	......	......	10.00	......	......	10.00
37	......	......	......	......	......	......	......	......	......	......	......	......	......	......	2.75	2.75
38	......	......	......	......	......	......	......	......	......	6.82	......	......	......	......	17.96	24.78
39	38.81	......	......	......	......	38.81	......	......	......	......	14.50	......	73.50	......	28.53	116.53
40	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
41	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
42	......	......	......	......	......	......	......	......	......	......	18.25	......	......	4.00	......	22.25
43	79.00	......	......	6.00	......	85.00	......	1.00	......	......	14.00	......	10.00	......	38.00	63.00
44	121.00	......	......	......	......	121.00	......	......	1.00	......	10.50	......	......	3.00	7.50	22.00
45	......	......	......	2.90	......	2.90	......	......	......	......	0.60	......	......	......	0.25	0.85
46	......	......	......	......	......	......	......	......	......	......	......	......	768.00*	......	......	768.00
47	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
48	......	......	......	......	......	......	......	......	......	......	......	......	96.00	......	......	96.00
49	......	......	......	......	......	......	......	......	......	......	......	......	200.00	......	18.60	218.60
50	......	......	......	......	2.40	2.40	......	......	......	......	23.20	......	102.40	6.40	72.16	204.16
51	......	......	......	......	......	......	......	46.70	......	......	......	......	32.90	16.80	......	96.40
52	......	......	......	12.00	......	12.00	......	......	......	......	1.00	......	10.00	10.00	......	21.00
53	1.20	......	......	......	......	1.20	......	......	......	0.80	19.10	......	......	......	0.40	20.30
54	......	......	......	......	63.00	63.00	......	130.00	30.00	......	......	......	......	......	34.00	194.00
55	......	......	......	......	......	......	......	......	......	......	......	......	......	11.00	22.00	33.00
56	......	......	......	......	......	......	......	......	......	4.00	......	141.00	......	......	54.00	199.00
57	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
58	......	......	......	......	......	......	......	......	......	......	2.77	......	......	......	......	2.77
59	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
60	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......

TABLE V—(*Continued*)

ANALYSIS OF OUTAGE HOURS, 1927 DATA

Group Reference No.	General Hydraulic Causes						Generators and Appurtenances									
	Ice or Trash	Floods	Penstock or Canal	Head-gates or Intake	Other General Hy-draulic	Total General Hy-draulic	Vibra-tion	Lubri-cation or Oil Leakage	Rotor or Field	Arma-ture Iron or Wind-ings	Exciter and Rheo-stats	Venti-lation System	Cleaning	In-spection	Other Causes	Total Genera-tors and Appur-tenances
61	......	......	......	......	......	......	......	8.00	24.00	......	......	2.00	......	6.00	8.00	48.00
62	......	......	......	......	......	......	......	......	......	......	......	......	29.00	......	16.00	45.00
63	8.00	......	......	46.00	......	54.00	......	45.00	111.00	......	2.00	93.00	312.00	63.00	......	626.00
64	......	......	......	1.00	......	1.00	......	......	6.00	......	......	......	78.00	23.00	......	107.00
65	......	......	......	......	......	......	......	......	......	......	......	......	4.00	14.00	86.00	104.00
66	......	......	......	......	......	......	......	4.00	......	48.00	14.00	......	......	8.00	......	74.00
67	......	......	......	......	......	......	......	......	......	120.00	......	......	12.00	6.00	2.00	140.00
68	......	......	......	......	......	......	......	......	......	6.00	16.00	......	5.00	5.00	......	32.00
69	......	......	......	......	......	......	......	......	......	......	16.00	......	10.00	8.00	......	34.00
70	......	......	......	......	......	......	......	......	......	40.00	12.00	......	150.00	......	......	202.00
71	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
72	375.00†	800.00‡	......	1380.00§	......	2555.00	......	......	......	......	......	......	......	......	......	......
73	......	......	......	......	......	......	......	......	......	......	......	......	30.00	......	......	30.00
74	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
75	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
76	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
77	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
78	......	......	79.20	......	7.92	87.12	......	115.45	......	31.30	4.00	14.00	2.00	......	......	166.75
79	......	......	......	......	......	......	......	......	......	......	0.25	......	......	13.98	......	14.23
80	......	......	......	......	......	......	......	......	......	......	8.75	......	......	38.83	6.42	54.00
Total 134 units....	810.76	800.00	531.50	1649.88	151.60	3943.74	0.00	945.15	319.53	864.92	250.53	328.16	2320.65	321.71	1527.84	6878.49
Aver. per each unit	6.05	5.97	3.97	12.31	1.13	29.43	0.00	7.05	2.38	6.46	1.87	2.45	17.32	2.40	11.40	51.33

Notes: *Cleaning and inspection. †Ice blocking intake and breaking racks. ‡Flood floated out a section of wood stave penstock. §Replacement of pipe line and construction of new intake, gate-house and racks.

TABLE V—(*Continued*)

ANALYSIS OF OUTAGE HOURS, 1927 DATA

Group Reference No.	Waterwheels and Auxiliaries														Total All Causes
	Runner	Turbine Shut-off Valve	Turbine Gates or Needle Nozzle	Guide Bearings	Thrust Bearings	Governor and Governor System	Pressure Regulators or By-pass Nozzle	Draft Tubes	Lubrication System	Vibration	Seal Rings	Inspection	General Overhauling	Other Causes	Total Waterwheel and Auxiliaries	
1	......	......	......	6.00	......	......	......	......	......	......	......	......	......	......	6.00	264.00
2	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	388.00
3	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
4	......	5.00	......	8.00	......	3.00	118.00	......	......	......	600.00	......	......	......	734.00	774.00
5	387.00	......	5.00	......	......	......	......	......	......	......	......	6.00	331.00	......	729.00	746.00
6	......	......	12.00	......	......	......	......	......	......	......	......	......	......	......	12.00	129.00
7	......	......	......	......	......	......	889.00	......	......	......	......	......	......	......	889.00	986.00
8	97.00	40.00	......	12.00	......	15.00	......	16.00	......	......	......	72.00	......	......	252.00	405.00
9	......	......	......	45.00	25.00	......	......	......	......	......	......	2.00	......	15.00	87.00	151.00
10	93.00	......	......	25.00	65.00	21.00	......	90.00	......	......	......	......	......	......	294.00	411.00
11	......	150.00	5.00	......	......	10.00	......	......	......	......	......	......	......	......	165.00	197.00
12	58.00	170.00	18.00	......	......	10.00	7.00	......	......	......	......	......	......	......	263.00	263.00
13	......	......	10.00	......	......	14.00	2.00	......	......	......	......	3.00	63.00	5.00	97.00	143.00
14	......	......	......	1.00	......	......	4.00	......	13.00	......	......	8.00	8.00	......	34.00	60.00
15	......	......	......	23.00	24.00	2.00	1.00	20.00	2.00	......	58.00	......	......	......	130.00	132.00
16	......	......	11.00	......	......	......	15.00	......	......	......	......	......	......	......	26.00	871.00
17	......	......	......	......	......	57.95	......	......	......	......	......	7.00	......	......	64.95	73.00
18	......	......	......	3.68	......	......	......	......	0.75	......	2.74	......	......	......	7.17	46.72
19	......	1.89	......	......	......	5.90	......	......	......	......	......	......	......	87.73	95.52	170.87
20	......	......	......	......	......	2.18	......	......	......	......	......	......	......	......	2.18	69.41
21	0.42	......	......	......	......	28.53	19.70	27.15	......	......	......	140.95	677.88	......	894.63	1024.88
22	154.00	......	6.00	62.00	......	44.00	......	......	......	......	......	9.00	......	......	275.00	360.00
23	230.00	......	4.00	......	......	......	......	......	......	......	......	3.00	......	......	237.00	273.00
24	......	......	......	......	......	59.00	......	......	......	......	......	......	218.00	64.00	341.00	404.00
25	......	......	......	3.00	......	7.00	......	......	......	......	......	......	......	9.00	19.00	31.00
26	......	......	......	......	......	......	......	......	......	......	......	68.00	......	......	68.00	248.00
27	......	......	......	......	......	......	......	......	......	......	......	24.00	300.00	8.00	332.00	462.00
28	......	......	......	......	......	8.00	......	......	7.00	......	......	......	......	53.00	68.00	143.00
29	......	......	......	......	......	......	......	......	......	......	......	48.00	......	......	48.00	366.00
30	......	......	......	......	......	......	......	......	......	......	......	......	......	17.00	17.00	332.00

TABLE V—(*Continued*)

ANALYSIS OF OUTAGE HOURS, 1927 DATA

Group Reference No.	Waterwheels and Auxiliaries															Total All Causes
	Runner	Turbine Shut-off Valve	Turbine Gates or Needle Nozzle	Guide Bearings	Thrust Bearings	Governor and Governor System	Pressure Regulators or By-pass Nozzle	Draft Tubes	Lubrication System	Vibration	Seal Rings	Inspection	General Overhauling	Other Causes	Total Waterwheel and Auxiliaries	
31	......	......	......	......	......	3.00	......	......	......	......	......	13.00	10.00	......	26.00	84.00
32	......	......	......	2.00	......	2.00	......	......	......	......	......	12.00	11.00	......	27.00	75.00
33	......	......	......	......	......	5.90	......	......	......	......	......	2.00	15.10	......	23.00	59.00
34	......	......	6.40	......	......	0.40	......	......	......	......	......	15.60	......	......	22.40	60.40
35	......	......	......	......	......	......	......	......	......	......	......	......	10.00	......	10.00	100.00
36	......	......	......	......	......	......	......	......	......	......	......	......	10.00	......	10.00	20.00
37	......	......	......	3.78	......	......	......	......	2.45	......	......	312.83	......	......	319.06	321.81
38	......	......	......	704.03	......	36.35	......	......	41.92	......	......	......	......	......	782.30	807.08
39	......	......	......	162.16	......	13.48	......	14.68	......	......	......	73.80	......	......	264.12	419.46
40	......	......	......	48.17	......	......	......	......	......	......	......	1.00	......	......	49.17	49.17
41	......	......	......	......	......	......	......	......	......	......	......	2.66	......	......	2.66	2.66
42	......	......	......	71.00	......	1.25	......	......	......	......	......	......	......	......	72.25	94.50
43	44.00	......	15.00	180.00	......	65.00	......	......	......	......	......	144.00	......	......	2069.00	2217.00
44	21.00	......	......	51.00	......	......	......	......	......	......	......	......	......	1.66	73.66	216.66
45	......	......	......	......	......	1.05	......	......	......	......	......	......	......	......	1.05	4.80
46	......	144.00	......	......	......	......	......	......	......	......	......	......	......	......	144.00	912.00
47	2430.00*	......	......	......	......	......	......	......	......	......	......	......	......	......	2430.00	2430.00
48	......	......	......	......	......	......	......	......	......	......	......	379.00	......	459.00†	838.00	934.00
49	......	......	......	......	......	......	......	......	......	......	......	100.00	......	......	100.00	318.60
50	......	......	......	7.00	......	......	......	51.60	1642.40	......	......	......	......	......	1701.00	1907.56
51	......	......	......	5.80	......	7.80	......	......	......	......	......	26.10	1902.20	......	1941.90	2039.30
52	744.00	......	......	......	......	......	......	......	......	......	......	6.00	......	......	750.00	783.00
53	229.60	......	......	......	......	......	......	......	......	......	......	......	......	......	229.60	251.10
54	......	......	......	......	......	......	......	......	......	8.00	......	......	38.00	......	46.00	303.00
55	400.00‡	......	......	148.00	......	......	......	13.00	......	5.00	......	......	1.00	......	567.00	600.00
56	......	......	......	......	26.00	......	......	......	......	4.00	......	......	......	......	30.00	229.00
57	......	......	......	......	......	......	......	......	......	......	......	......	......	......	....	....
58	......	......	......	......	......	......	......	......	......	......	......	......	......	......	....	2.77
59	......	......	......	......	......	......	......	......	......	......	......	80.00	......	......	80.00	80.00
60	......	......	......	......	......	......	......	......	4.50	......	......	80.00	......	......	84.50	84.50

TABLE V—(*Concluded*)

ANALYSIS OF OUTAGE HOURS, 1927 DATA

Group Reference No.	Waterwheels and Auxiliaries															Total All Causes
	Runner	Turbine Shut-off Valve	Turbine Gates or Needle Nozzle	Guide Bearings	Thrust Bearings	Governor and Governor System	Pressure Regulators or By-pass Nozzle	Draft Tubes	Lubrication System	Vibration	Seal Rings	Inspection	General Overhauling	Other Causes	Total Waterwheel and Auxiliaries	
61	......	8.00	13.00	......	......	4.00	8.00	12.00	3.00	......	8.00	12.00	......	......	68.00	116.00
62	......	......	......	......	......	5.00	......	......	......	......	......	42.00	36.00	......	83.00	128.00
63	......	......	10.00	......	......	147.00	......	......	3.00	......	......	108.00	10.00	36.00	314.00	994.00
64	......	......	6.00	......	......	50.00	......	......	......	......	......	30.00	......	48.00	134.00	242.00
65	......	......	......	......	......	......	......	......	......	......	......	8.00	......	1083.00§	1091.00	1195.00
66	600.00	......	372.00	......	......	......	......	82.00	......	......	......	......	......	......	1054.00	1128.00
67	......	......	6.00	72.00	......	......	......	......	......	......	......	6.00	12.00	......	96.00	236.00
68	300.00	......	......	60.00	......	......	......	15.00	......	......	......	10.00	15.00	432.00#	832.00	864.00
69	......	......	......	100.00	......	......	......	......	......	......	......	12.00	......	......	112.00	146.00
70	48.00	......	......	300.00	......	......	......	......	......	......	......	......	50.00	......	398.00	600.00
71	168.00	......	......	......	......	......	......	......	60.00	......	......	......	......	......	228.00	228.00
72	......	......	......	32.00	......	......	......	......	......	......	......	......	......	......	32.00	2587.00
73	......	......	......	......	......	......	......	......	......	336.00‖	......	8.00	......	......	344.00	374.00
74	......	......	......	......	......	......	......	......	......	......	......	......	......	......	....	....
75	......	......	......	......	......	......	......	......	......	......	......	......	......	......	....	....
76	......	......	......	......	......	......	......	......	......	......	......	......	......	......	....	....
77	......	......	......	......	......	......	......	......	......	......	......	......	......	......	....	....
78	......	5.00	2.00	24.18	10.00	3.00	......	9.25	......	......	......	106.00	......	......	159.43	413.30
79	......	......	......	......	......	1.83	......	......	22.38	......	......	14.92	134.67	2.97	176.77	191.00
80	......	......	......	......	1.77	4.42	......	......	1.08	......	......	15.83	182.68	5.22	211.00	265.00
Total 134 units..	6004.02	523.89	501.40	2159.80	151.77	639.04	1063.70	1971.68	1803.48	353.00	668.74	2011.69	4035.53	2326.58	24214.32	35036.55
Average per unit	44.81	3.91	3.74	16.12	1.13	4.77	7.94	14.72	13.46	2.63	4.99	15.01	30.12	17.36	180.71	261.47

Notes: *Welding pitted areas in runners. †Efficiency test. ‡Measuring clearances and painting runners with wear-resistant paint. §1056 hours—runner struck side when governor belt*came off. #New sleeve on shaft. ‖Spring thrust not bolted down.

TABLE VI

ANALYSES OF CAUSES OF OUTAGE IN PER CENT OF TOTAL OUTAGE TIME

	Propeller Type	Impulse Type	Horizontal Reaction Type	Vertical Reaction Type	All Reaction Type	All Units
Number of units included	8	11	9	106	115	134
General Hydraulic Causes:						
Ice or trash	1.87	0.90	0.45	2.69	2.57	2.32
Floods	....	....	....	3.13	2.97	2.29
Penstock or canal	....	4.82	3.84	1.22	1.36	1.52
Headgates or intake	1.14	1.95	0.40	5.97	5.68	4.70
Other general hydraulic	....	0.44	3.37	0.35	0.50	0.43
Total general hydraulic	3.01	8.11	8.06	13.36	13.08	11.26
Water Wheels and Auxiliaries:						
Runner	0.95	12.94	....	21.59	20.47	17.14
Shut-off valve	....	9.29	0.70	0.76	0.76	1.50
Turbine gates or needle nozzle	0.67	1.77	0.93	1.55	1.52	1.43
Guide bearings or main bearings	3.87	....	0.26	7.74	7.35	6.16
Thrust bearing	....	....	0.13	0.59	0.56	0.43
Governor and governor system	5.64	1.88	5.72	0.91	1.16	1.82
Pressure regulator or deflectors	....	1.27	0.57	3.96	3.79	3.04
Draft tube	34.88	0.79	0.86	1.22	1.20	5.63
Lubrication system	0.06	....	1.94	6.94	6.68	5.15
Vibration	....	....	....	1.38	1.31	1.01
Seal rings	....	....	0.77	2.57	2.48	1.91
Inspection	6.24	4.35	11.75	5.51	5.83	5.74
General overhauling and replacements	0.21	31.13	40.76	9.33	10.96	11.52
Other causes	25.11	0.15	11.41	3.89	4.28	6.63
Total water wheel	77.63	63.57	75.80	67.94	68.35	69.11
Generator and Appurtenances:						
Vibration	....	....	....	....	....	....
Lubrication or oil leakage	0.99	....	0.57	3.49	3.34	2.70
Rotor or field	2.52	2.39	2.14	0.35	0.44	0.91
Armature iron or windings	....	12.78	....	1.66	1.58	2.47
Exciter and rheostats	0.34	0.01	0.73	0.88	0.87	0.71
Ventilation system	2.00	....	2.79	0.77	0.87	0.94
Cleaning	8.69	1.30	2.64	7.18	6.95	6.62
Inspection	2.15	0.34	4.27	0.59	0.78	0.92
Other causes	2.67	11.50	3.00	3.78	3.74	4.36
Total generator	19.36	28.32	16.14	18.70	18.57	19.63
Total—all causes	100.00	100.00	100.00	100.00	100.00	100.00
Total outage time in per cent of total time	5.73	3.62	1.78	2.88	2.79	3.07

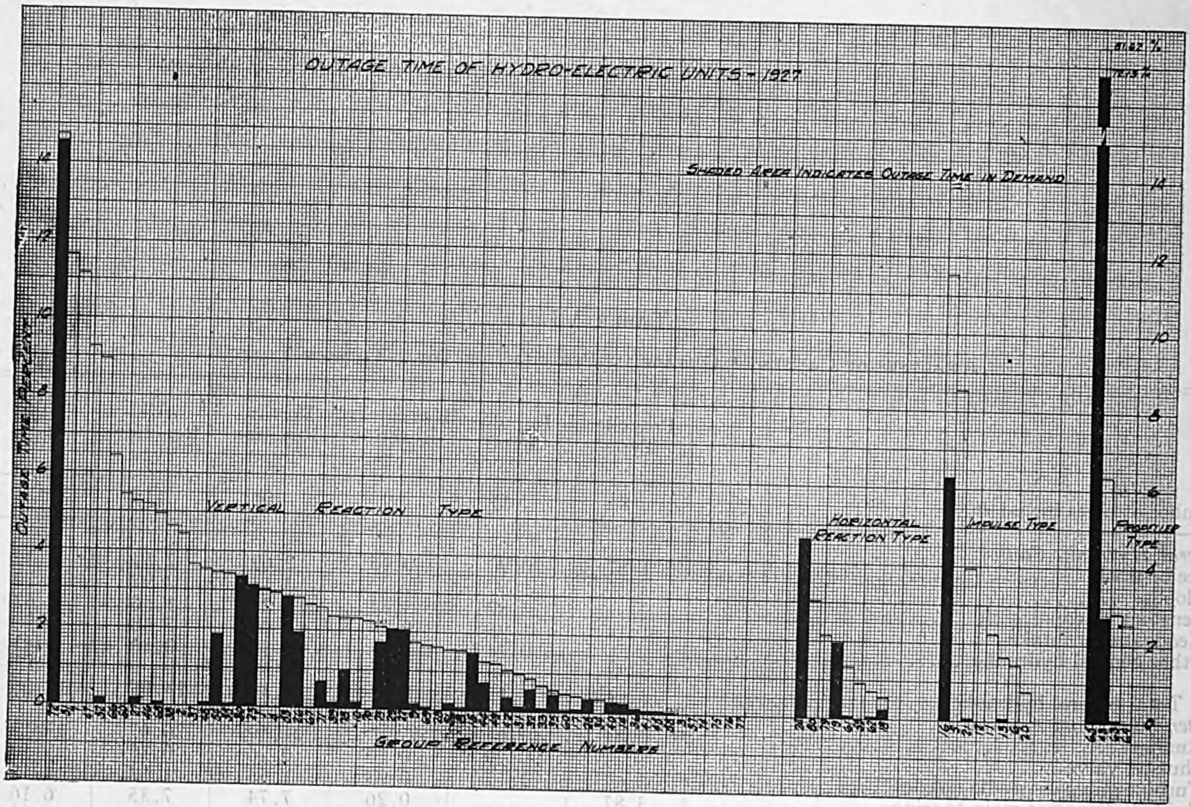


FIG. 1—OUTAGE TIME OF HYDRO-ELECTRIC UNITS, 1927, BY GROUPS.

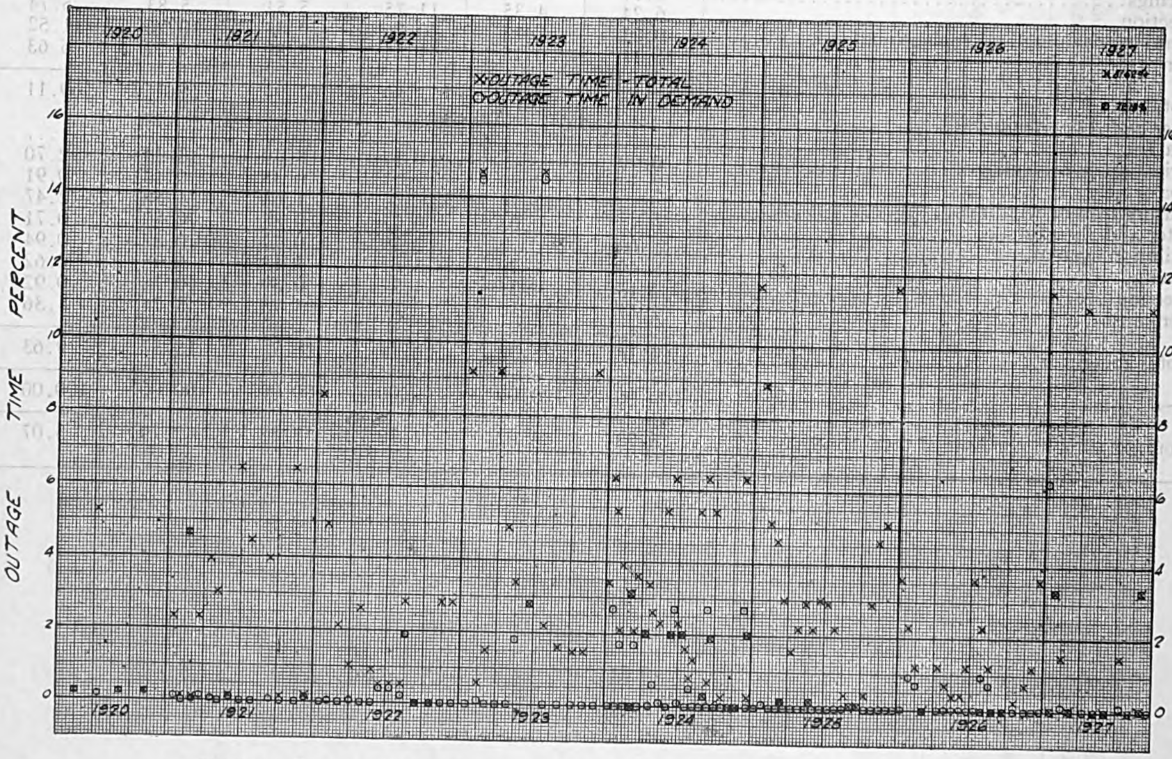


FIG. 2—OUTAGE TIME, TOTAL AND IN DEMAND REFERRED TO CALENDAR DATES.

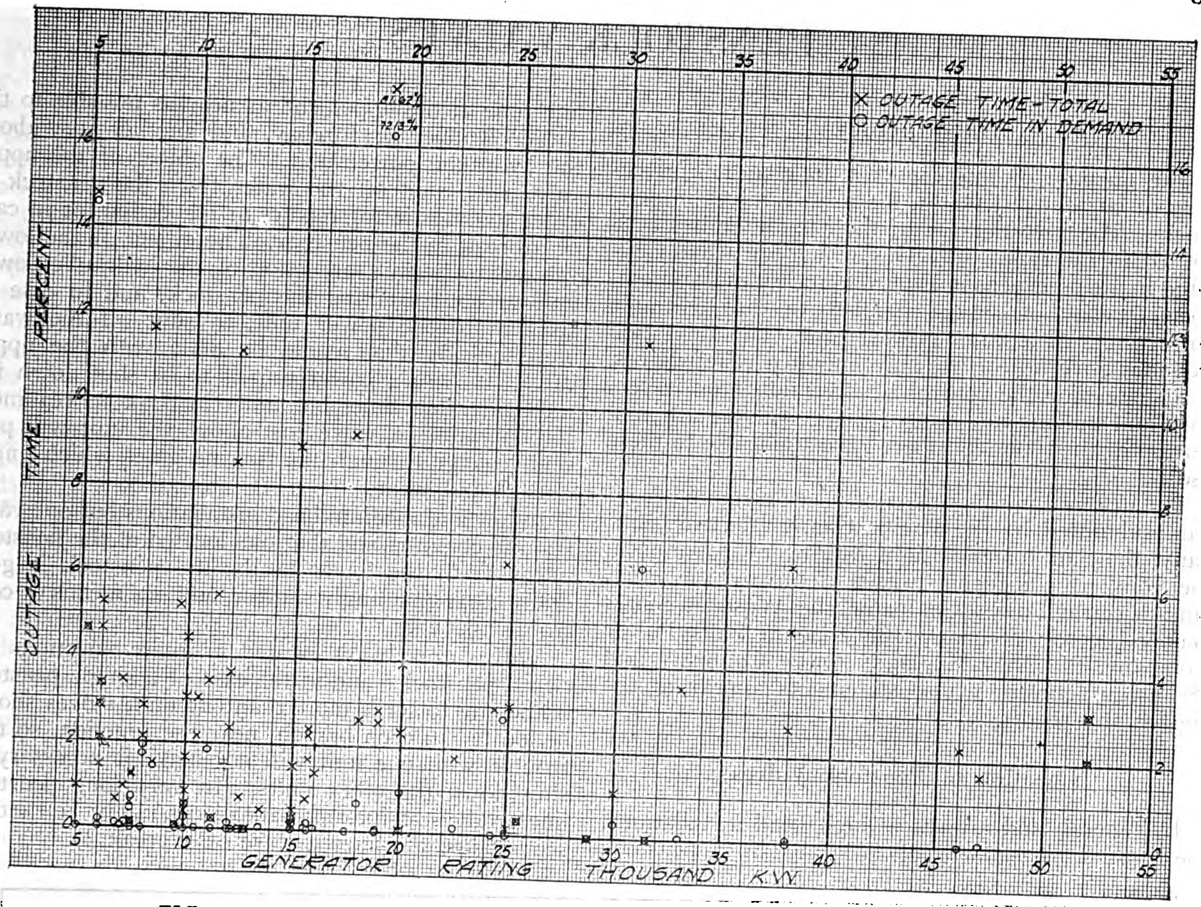


FIG. 3—OUTAGE TIME, TOTAL AND IN DEMAND, REFERRED TO GENERATOR RATING.

PENSTOCK VALVES

Introductory

The purpose of this report is to give a brief review of current practice in the use of valves in penstocks. The investigation of the committee has been limited to the types of valves which are usually located in a closed penstock or conduit leading from an open forebay or surge chamber to the hydraulic power units of a water power plant. This definition excludes governor or pressure operated relief valves, head gates for the control of diversion from reservoirs and streams, and free discharge valves, although certain of the types considered are applicable to these uses.

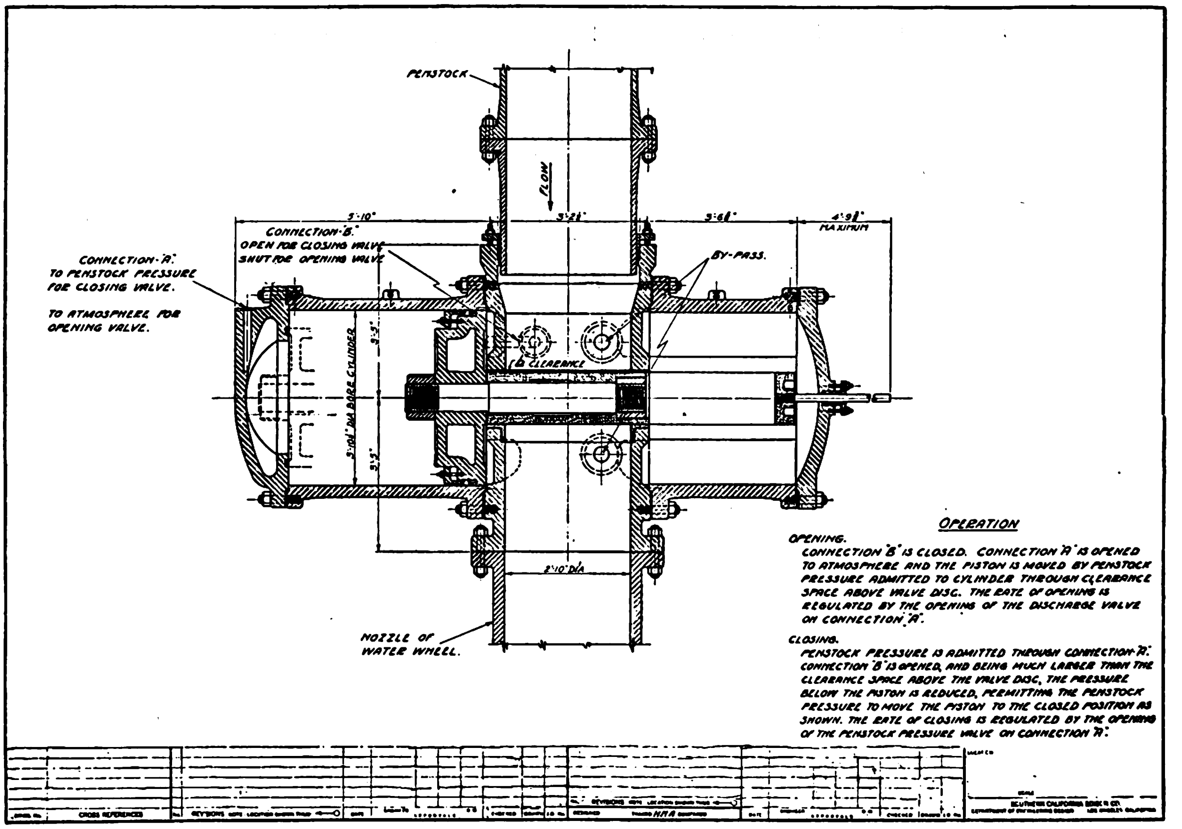
The material in this report has been compiled from data submitted by the Pacific Gas & Electric Company, the San Joaquin Light & Power Corporation, the Southern California Edison Company, the Portland Electric Power Company, the Western States Gas & Electric Company, the Niagara Falls Power Company, the New England Power Company and the manufacturers whose statements appear at the end of the report.

Location of Penstock Valves

In general, and always in high head installations, there are at least two valves located in a penstock line; one at the upper end as near as possible to the surge chamber or forebay, and another just above the hydraulic power unit. The object of the upper valve is to shut off the water from the penstock in order to drain it for repairs or inspection, or in case of a break in the penstock. The object of the lower valve is to permit inspection of the hydraulic power unit without draining the penstock, and in case of accident to the power unit, to shut off the water more quickly than could be done with the upper valve. In case a power unit is to be shut down for a considerable time, but must be kept in readiness for operation, a valve just above the unit will prevent leakage through the turbine gates which might cause rapid wear.

In low and medium head installations but one valve is quite common and that one located at the penstock inlet. With the lower heads, the penstock is generally correspondingly shorter, and one means of control is adequate.

Valves are always located in interconnections between penstocks, and in the case of a single penstock branching to serve more than one unit, valves should be located in each branch, near the junction, so that trouble with one unit will not make it necessary to shut down the other units. In very long penstock lines, valves at intermediate points might be used to sectionalize the lines in case of a break.



OPERATION

OPENING.
CONNECTION "B" IS CLOSED. CONNECTION "A" IS OPENED TO ATMOSPHERE AND THE PISTON IS MOVED BY PENSTOCK PRESSURE ADMITTED TO CYLINDER THROUGH CLEARANCE SPACE ABOVE VALVE DISC. THE RATE OF OPENING IS REGULATED BY THE OPENING OF THE DISCHARGE VALVE ON CONNECTION "A".

CLOSING.
PENSTOCK PRESSURE IS ADMITTED THROUGH CONNECTION "A". CONNECTION "B" IS OPENED, AND BEING MUCH LARGER THAN THE CLEARANCE SPACE ABOVE THE VALVE DISC, THE PRESSURE BELOW THE PISTON IS REDUCED, PERMITTING THE PENSTOCK PRESSURE TO MOVE THE PISTON TO THE CLOSED POSITION AS SHOWN. THE RATE OF CLOSING IS REGULATED BY THE OPENING OF THE PENSTOCK PRESSURE VALVE ON CONNECTION "A".

FIG. 1-A.

Publication No. 289-72, Serial Report, Hydraulic Power Committee.

Choice of Type of Valve

Penstock valves are never operated at part opening. They are always either fully open or shut. For this reason the hydraulic characteristics of the valve at part opening are of no importance, except for the effect that they may have on the smoothness of operation and on the wear of the valve parts during the period of closing or opening. Such valves are rarely operated under flow conditions. They should be designed to give good hydraulic condition at full opening and to be structurally strong enough not to be damaged in any way by the disturbances due to throttling when they are opened or closed with unequal pressures above and below.

The valves reported on cover a wide range of types, sizes and operating conditions.

Gate valves are in use at both the upper and lower ends of penstocks, and in the high head plants of California they are the predominant type. Gate valves 96 in. in diameter are used at the upper end of one plant and operate satisfactorily at a head of about 70 ft. One plant is using 32-in. gate valves of the follower ring type at the bottom of the penstock under a head of 2381 ft. Gate valves of the follower ring type 24 in. in diameter have been in successful use for more than ten years under a head of 2100 ft.

A recent design of hydraulically operated gate valve, for which a patent has been issued, is illustrated in Fig. 1A. Four of these valves have been installed for a head of 2400 ft., and are operating satisfactorily. Some of the advantages of this valve are: (1) A considerable saving in weight and cost over a comparable gate valve of the usual design; (2) a saving in space requirements; (3) elimination of stuffing boxes, except for the indicator rod.

Butterfly valves are also used quite extensively both at the upper and lower ends of penstocks.

Butterfly valves at the upper ends of penstocks have been installed with diameters of 11 ft. 6 in. for a head of 140 ft., and 7 ft. 6 in. for a head of 230 ft. These valves have cast steel disks and bodies. Structural steel valves 27 ft. in diameter have been installed in an Eastern plant for about 90 ft. head.

At the lower ends of penstocks, butterfly valves 9 ft. inside diameter are operating under a head of 455 ft., and a 72-in. valve has been operating for over three years under a head of 930 ft. This is the highest head for any butterfly valve ever used, as far as the committee can ascertain.

Manufacturers of butterfly valves state that there is no apparent reason why such valves cannot be built to operate successfully at heads of 1000 ft. or more.

Needle valves, unbalanced and externally controlled, have been used for many years for the highest heads at which water power has been developed. These valves are regulating valves directly controlling the jets of impulse wheels, and do not properly come within the scope of this report. Moreover, they are of comparatively small size, the largest being about 11 in. diameter, but the maximum operating velocity is very high, as high as 300 ft. per second or more. These valves are mentioned because there is no question as to their reliability, although they are subject to rather rapid wear, and consequent leakage, due to the high velocity and their constant operation at full and partial opening.

In one California plant, unbalanced needle valves with external hydraulic cylinder control are used as penstock valves just above the needle nozzles of the power unit.

Balanced plunger valves have been used as shut-off valves adjacent to the power units in a number of California plants. Johnson valves with internal hydraulic control 72 in. diameter, under 830 ft. head have been used. In these valves the pressure in the internal hydraulic operating chamber is controlled by a system of external needle valves. Johnson valves with a mechanical control of the internal pressure chambers are in use in sizes up to 24 in. diameter under 2100 ft. head.

Johnson valves 21 ft. in diameter, under 200 ft. head, are in operation in the plant of the Niagara Falls Power Company.

In general, insofar as the head under which the valve is to operate affects the choice of type, both gate valves and balanced plunger valves are in general use for heads over 600 ft. with gate valves predominating, with a tendency in the last two years to use gate valves of the follower ring type for the highest heads. For heads less than 600 ft., butterfly valves seem to be gaining favor, for both the upper and lower positions in penstocks, although there are a number of instances where gate valves without follower rings have been used at the upper ends of penstocks at heads of 200 ft. or less.

TABLE I

LOSSES IN LARGE DIAMETER VALVES

12 Ft Diameter Butterfly Intake Valve

Flow Cu. Ft per Second	Loss in Feet Head
1483	2.47
1236	1.65
1200	1.56
812	0.72
800	0.70

12 Ft. 6 In. Diameter Butterfly - Bellmouth Intake

Flow Cu. Ft per Second	Loss in Feet Head
1483	0.21
1236	0.147
1200	0.139
812	0.064
800	0.062

12 Ft. x 9 Ft Johnson-Boving Valve

Flow Cu. Ft. per Second	Loss in Feet Head
1483	1.38
1236	0.97
1200	0.915
812	0.422
800	0.41

Loss of Head in Valves

Reliable information on which to base comparisons of loss of head through the different types of penstock valves is very meager. In gate valves of the follower ring type, in which the follower ring is of the same diameter as the pipe and registers accurately with the pipe when the valve is open, the loss is unquestionably negligible. In gate valves without follower rings the cavities for the gate seat and guides must create considerable disturbance with consequent hydraulic losses, but there are no accurate data available on the amount of these losses.

In straightway plunger valves with carefully designed water passages the losses should be quite small.

In unbalanced needle valves with external control of the needle the losses are undoubtedly greater, due to the unavoidable bends in the valve body and to the disturbance caused by the needle stem projecting through the main water passage.

Messrs. Glenfield and Kennedy, Ltd., Engineers, Kilmarnock, Scotland, have published some tables giving estimated losses through large diameter-butterfly and plunger valves. They do not state how far these estimates are based on actual tests. Table I gives the published data as a matter of interest, and to invite comment on their probable degree of accuracy. The estimated losses in the 12 ft. x 9 ft. Johnson-Boving valve when plotted on log paper appear to lie on a line with a slope of 2, as shown in Fig. 1.

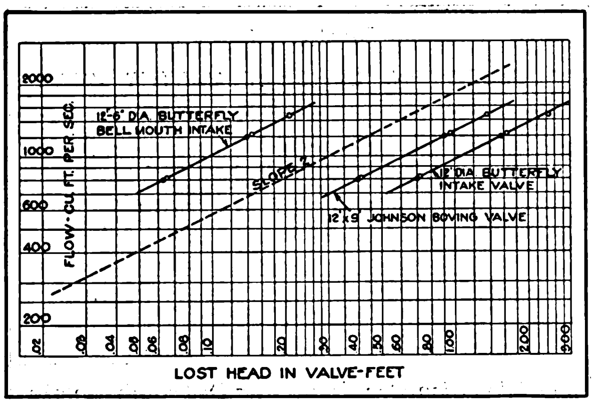


FIG. 1—LOSSES IN LARGE DIAMETER VALVES.

The following report on losses through butterfly valves has been furnished by E. A. Dow for the New England Power Company, and is the most comprehensive study of the subject that has come to the attention of the committee.

The data on head losses given in Table II are from tests in which pressures were observed at several points, as shown on the accompanying diagrams. An additional diagram (Fig. 2) is included showing friction head loss for 96 in. Dow valves which are located in the entrance to a pressure tunnel and, while not strictly penstock valves, they perform a similar duty, operating under a head of 110 ft.

TABLE II
NEW ENGLAND POWER COMPANY
TABULATION OF PENSTOCK VALVE DATA

	Station No. 5		Sherman	Davis Bridge		Searsburg
	Top	Bottom	Top	Top	Bottom	Bottom
Number of Valves	3	3	1	3	3	1
Nominal Size	84"	78"	168"	96"	84"	78"x56"
General Type	Butter-fly	Butter-fly	Butter-fly	Butter-fly	Butter-fly	Balance Plunger
Type Description	Shaft-Arm	Shaft-Arm	Disc-Arm	Disc-Arm	Shaft-Arm	-
Manufacturer	Allis-Chalmers	Allis-Chalmers	S.M. Smith	Coffin Valve	Allis-Chalmers	W.S.M.
Operating Head	30	230	25	155	390	230
Full Load C.F.S.	320	320	1025	600	600	320
Friction Loss	—	0.33	—	—	0.78	0.70
Velocity thru Nominal Area	8.3	9.6	6.7	12.0	15.6	18.7 Disch
Velocity head for Nominal Area	—	1.44	—	—	3.78	—
Fric. Hd.+Vel. Hd.	—	0.23	—	—	0.21	—
Operated by	Elec. Motor	Hyd. Cyl.	Elec. Motor	Elec. Motor	Hyd. Cyl.	Hyd. Cyl.
Emergency Closing	Local Control	Local Control	Remote Control	Remote Control	Local Control	Auto-matic
Hand Gear	Yes	No	Yes	Yes	No	No
Source of Hyd. Press.	—	Penstock	—	—	Penstock	Penstock

A feature of interest in connection with the determination of head loss through butterfly or other valves is brought out in Fig. 3, which shows an apparent head loss at piezometer connection No. 4 greater than that at connection No. 5 farther downstream. The real loss may be still less than that obtained at point No. 5, but no connection below this point was available.

All tests made demonstrate that the entire loss through the butterfly valve occurs downstream from the center line where the jet is expanding, no observable loss having been found above the center line.

Use of Valves as Meters

The calibration of valves to serve as Venturi meters has been advocated. From the data available on loss of head, it would appear that the differentials given by head loss alone would be too small to give accurate differential readings. In many installations, however, particularly of valves close to the turbine, the reduction in diameter from upstream to downstream of the valve will give sufficient velocity differential in addition to the head loss to be measured accurately with instruments commercially available.

This is well illustrated by Fig. 5. The loss of head alone is very small, and being the difference between nearly equal magnitudes, the errors of observation are greatly magnified. The curve of total differential against flow, however, is quite smooth, and could undoubtedly be recorded accurately.

Power Required to Operate Valves

The following data on butterfly valves also has been furnished by Mr. E. A. Dow:

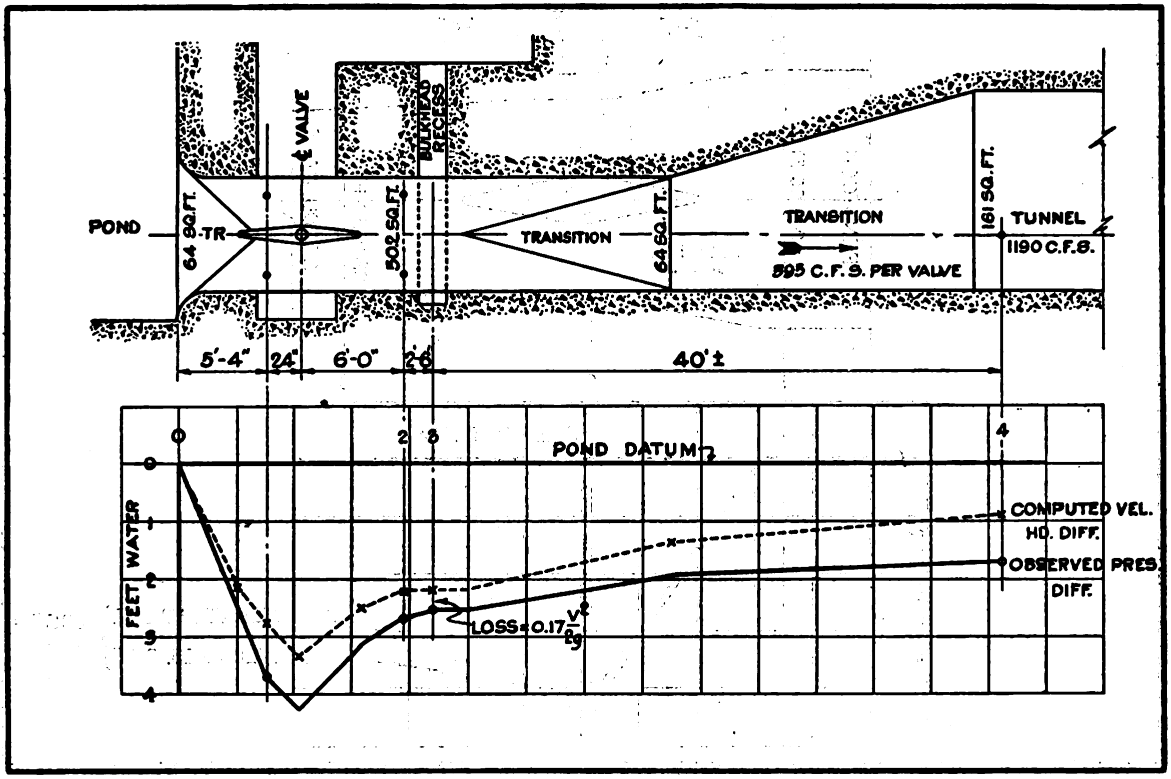

POND
64 SQ.FT.
TR
℄ VALVE
50.2 SQ.FT.
BULKHEAD RECESS
TRANSITION
64 SQ.FT.
TRANSITION
595 C.F.S. PER VALVE
161 SQ.FT.
TUNNEL
1190 C.F.S.
5'-4"
24"
6'-0"
2'6"
40'±
0
2
3
4
POND DATUM
COMPUTED VEL. HD. DIFF.
OBSERVED PRES. DIFF.
LOSS = 0.17 V²/2g
FEET WATER
0
1
2
3
4

FIG. 2—Friction Losses in 96-In. Dow Pivot Valve and Setting.

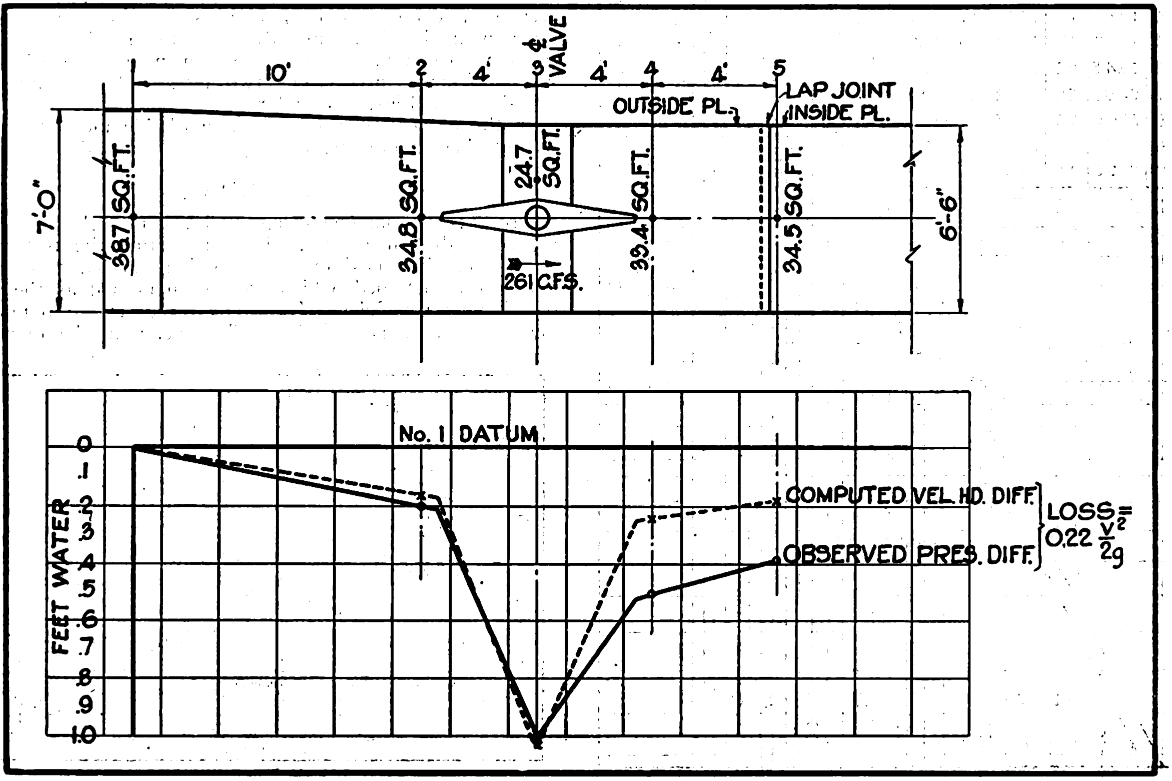

10'
2
4'
3
℄ VALVE
4'
4
4'
5
LAP JOINT
OUTSIDE PL.
INSIDE PL.
7'-0"
38.7 SQ.FT.
34.8 SQ.FT.
24.7 SQ.FT.
33.4 SQ.FT.
34.5 SQ.FT.
6'-6"
261 C.F.S.
No. 1 DATUM
COMPUTED VEL. HD. DIFF.
OBSERVED PRES. DIFF.
LOSS = 0.22 V²/2g
FEET WATER
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0

FIG. 3—Friction Losses in 78-In. Butterfly Valve and Setting.

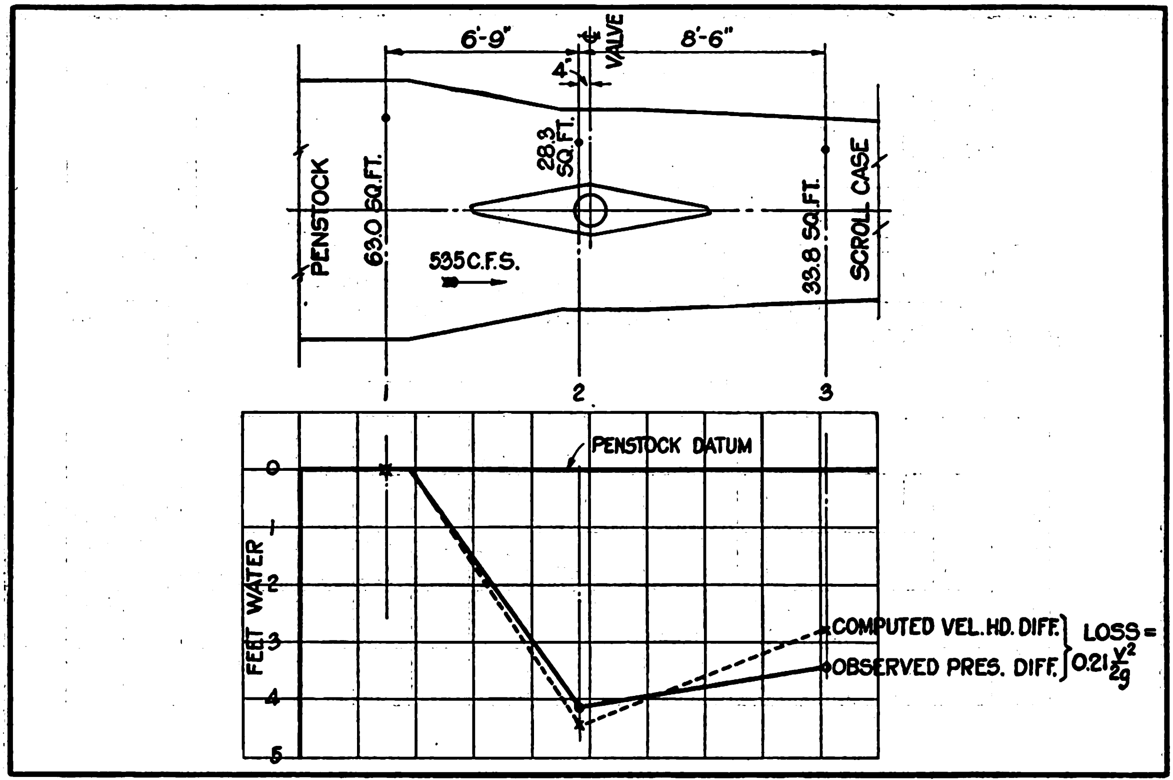
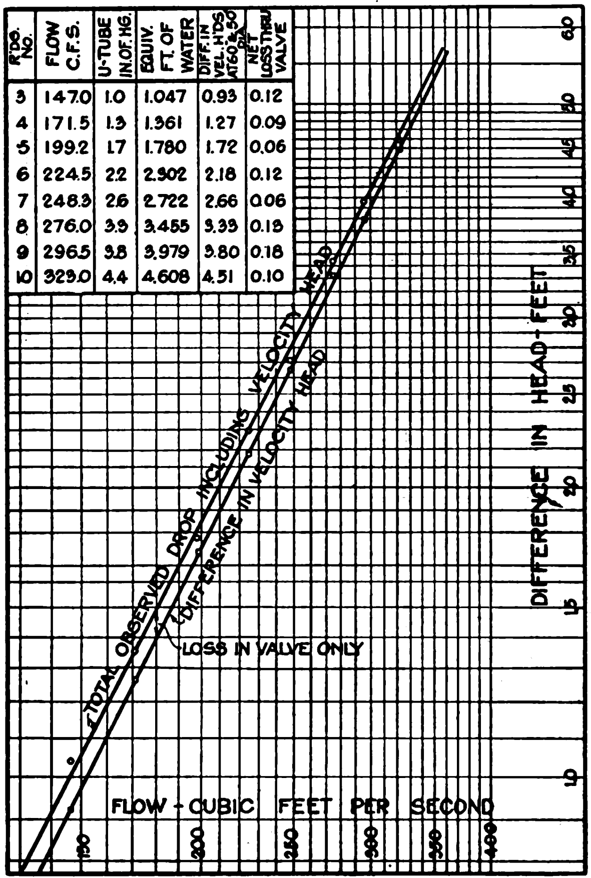


FIG. 4—FRICTION LOSSES IN 84-IN. BUTTERFLY VALVE AND SETTING.



R'DG. No.	FLOW C.F.S.	U-TUBE IN. OF HG.	EQUIV. FT. OF WATER	DIFF. IN VEL. H'DS AT 60 & 50 DIA.	NET LOSS THRU VALVE
3	147.0	1.0	1.047	0.93	0.12
4	171.5	1.3	1.361	1.27	0.09
5	199.2	1.7	1.780	1.72	0.06
6	224.5	2.2	2.302	2.18	0.12
7	248.3	2.6	2.722	2.66	0.06
8	276.0	3.3	3.455	3.33	0.13
9	296.5	3.8	3.979	3.80	0.18
10	323.0	4.4	4.608	4.51	0.10

FIG. 5—LOSSES IN 60 IN. x 50 IN. BALANCED PLUNGER VALVE.

In predicting the power necessary to provide for operating valves of the butterfly type, the magnitude and relative time of occurrence of the maximum moment is often the most difficult to obtain. With a view to obtaining definite methods of attacking this problem, a series of tests were carried out, first on a 78-in. shaft-arm valve, then on an 8-in. model disk-arm valve, and the results were compared with similar data on an 8¼-in. manufacturer's standard shaft-arm valve. The two tests and the comparison are shown in Figs. 6, 7 and 8.

In the process of producing a workable method of computing these moments, an expression was adopted of the form

$$M = KD^3V^2$$

where D is the diameter in feet and V is the velocity through projected discharge area. By substituting the test values at various disk positions and solving for K, a series of values was obtained, which have been plotted as the curve of Moment Coefficient "K." The three sets of data show very similar shapes of the "K" curve, with the maximum

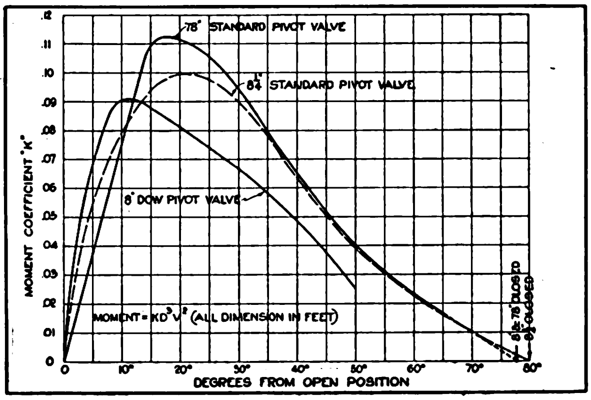


FIG. 6—COMPARISON OF MOMENT COEFFICIENTS FROM VARIOUS PIVOT VALVE TESTS.

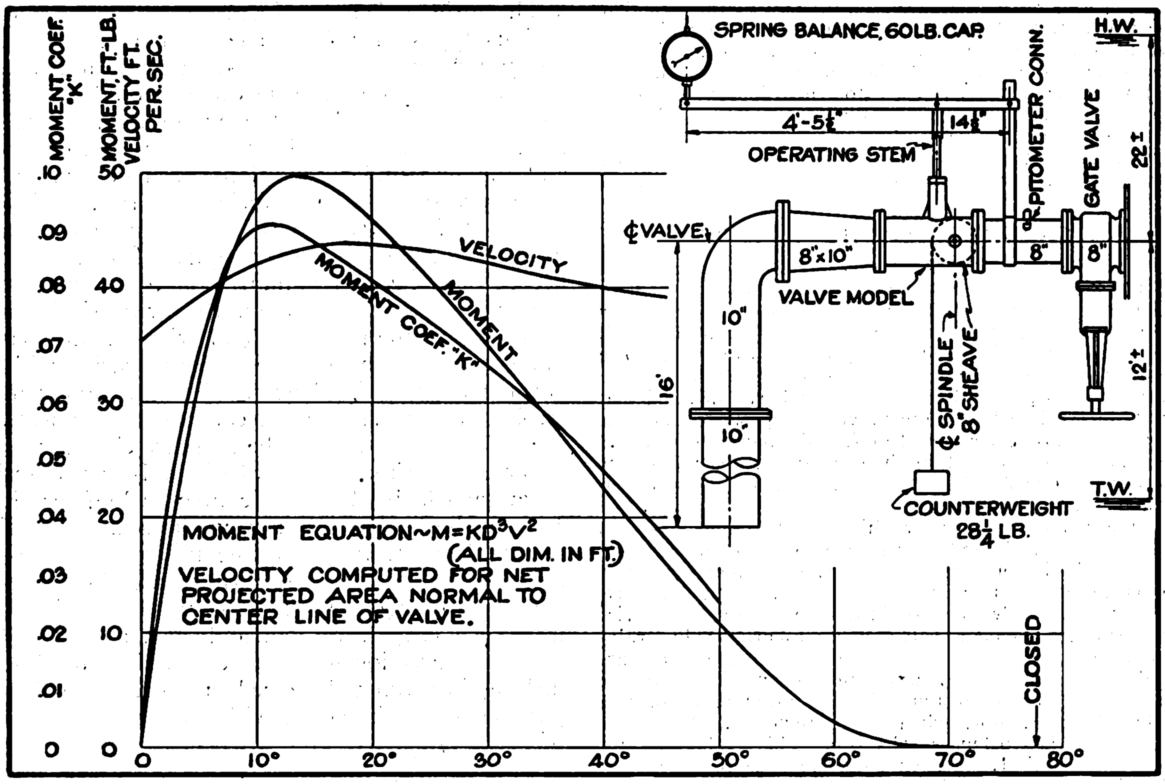
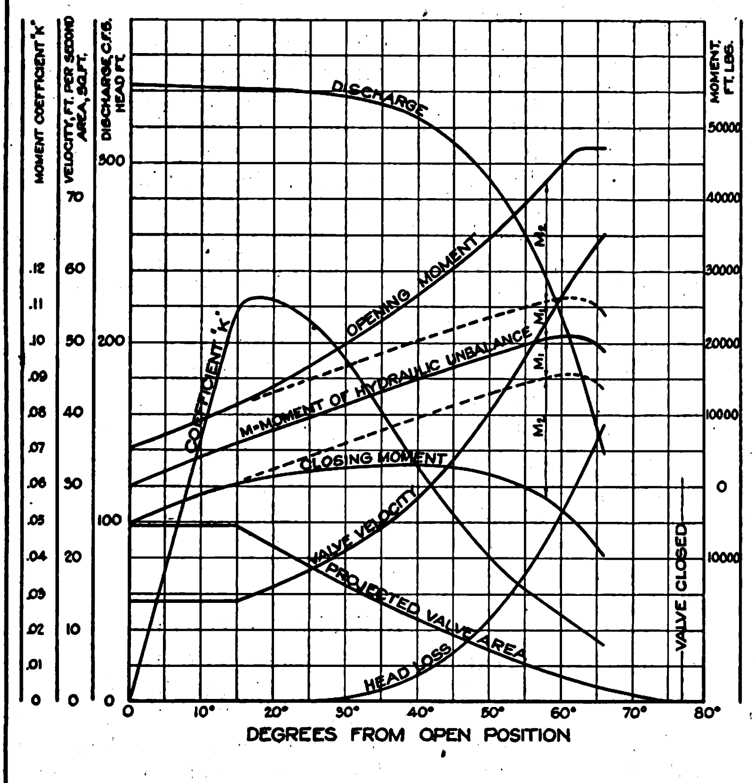


FIG. 7—Moment Characteristics of 8-In. Model Dow Pivot Valve.



VALVE DATA ~ Diameter 78"

Disc thickness 16"

Spindle diam. 10"

POWER ~ 20" Hydraulic cylinder using penstock water at 250 ft. head.

TEST ~ Valve was oscillated thru a small angle each side of each nominal angular position. The operating force required while moving thru nominal position was determined from the pressure gages connected to each end of the operating cylinder. The discharge was indicated by the venturi meter. Areas were taken from design drawings.

TEST DATA ~ M = Moment due solely to unbalance of hydraulic forces, friction having been deducted.

M_1 = Constant moment due to friction inherent in the mechanical construction and independent of applied forces.

M_2 = Variable moment due to friction of applied forces.

EQUATION ~ $M = KD^3V^2$
(all dimensions in feet)

FIG. 8—Moment Characteristics of 78-In. Butterfly Valve.

at nearly the same angular position, in spite of the fact that in the actual tests the velocity variation differed widely in the 78-in. valve and 8-in. model, the former rising sharply with closing motion, the latter holding relatively steady.

In this formula "M" is the Moment (foot pounds) of hydraulic unbalance always tending to produce closure. It is the moment which would exist if all mechanical friction were eliminated. Friction acts to increase the opening moment and decrease or even reverse the closing moment.

Rugged Control Mechanism Essential

"The results of the tests demonstrate the necessity of a very rugged control mechanism for a valve used to control free discharge service such as a synchronous by-pass, or high head reservoir outlet. The most severe condition which would ordinarily be imposed on a penstock valve is closure with the turbine gates open. This is a comparatively easy condition to design for, but it should be borne in mind that a break in the line below the valve may produce moments approaching those encountered in free discharge service and the design of the control mechanism would depend on the importance and probability of having to close the valve in such an emergency.

All the valves covered by this report complete a full stroke under normal conditions in two to five minutes.

In general, the operating mechanism of these valves is such as to maintain rigid control of valves at all parts of stroke. The only one provided with a restoring device is the balanced plunger valve at Searsburg. This valve is controlled by a piston valve of which the ports are shifted toward neutral by mechanical connection with the plunger. The control piston valve is moved at a constant rate by electric motor, which is in turn controlled automatically by the turbine mechanism. This is because the station is an entirely automatic one and the plunger valve is closed during all shutdown periods.

Demonstration of ability to close with turbine gates open has been made in tests on the 78-in. valves at No. 5, the 96-in. valves at Davis Bridge and the balanced plunger valve at Searsburg. The design of the others, especially the disk-arm pivot type, is such as to permit safe closure even under free spouting velocity such as would result from a rupture below the valve. Closure of a penstock butterfly valve with turbine gates open, as in the case of a gate valve under similar conditions, results in a loud roar as the control passes from the turbine to the valve. The valve housing may be felt to tremble, but no shocks are experienced and no damage results if the control mechanism is of a suitably rugged design.

The Sherman valve and the 96-in. upper valve at Davis Bridge are equipped with remote control apparatus to permit emergency closing from the power house, but require an operator on hand to open them.

No by-passes are provided for the disk-arm valves, but the plunger valve at Searsburg and the lower butterfly valves at Davis Bridge are provided with relatively small by-passes. The plunger valve by-pass is not used, but the Davis Bridge butterflies are provided with snap rings, which produce so much friction that it is necessary to fill the scrolls through the by-passes before the main valves can be opened. This is a serious disadvantage at this plant, as it is necessary to keep the scroll cases drained to minimize motoring losses and the time required to fill the scrolls through the by-passes prevents the units from picking up load as rapidly as would be desirable in an emergency.

It is hoped that any engineers or manufacturers having knowledge of reliable tests on head losses and power required by various types of penstock valves will bring them to the attention of the committee in order that the results may be published and made available to the industry.

The power required to operate penstock valves is not a deciding factor affecting the choice of type The total power is comparatively small, and the few times per year that the valve is operated the kilowatt-hour power consumption is negligible.

The estimated actual force needed to operate the various types of valve varies widely, according to the judgment of different designers, and further tests, especially on butterfly valves, would be of great value. For gate valves, the maximum force is that required to overcome the friction between the disk and the seat under conditions of maximum unbalanced pressure. The coefficient of friction is estimated at from 0.35 to 0.7, the more conservative designers using the larger figure. For unbalanced needle valves, the maximum force to be overcome is the hydrostatic pressure on the area of the valve opening plus the packing gland friction. In balanced plunger valves the operating force varies with the varying degree of balance at different points in the stroke; it is usually taken care of automatically by the leakage to and from the pressure chambers.

Some experiments on a 3⅞-in. valve are described in an article by C. B. McAulay, Chief Engineer, Joshua Hendy Iron Works, in the *Journal of Electricity,* Nov. 1, 1926. While the scale of this experiment is too small to permit extending the conclusions to large valves, the results show that there is a very large variation, and even a complete reversal of direction in the force required to close the disk against full unbalanced pressures. Further experiments of this nature with large valves would be of great value.

Space Required for Valves

The space required may be a factor in the selection of the type of valve, especially where the valves are to be located inside the power house close to the hydraulic units.

Gate valves with hydraulic cylinder operation or with outside screw and yoke and mechanically operated require a great deal of head room, amounting to at least four times the nominal diameter of the valve measured from the center line of the pipe.

Butterfly valves may be installed in a much smaller space than gate valves.

Needle and plunger valves have a maximum diameter of, roughly, twice their nominal size, and are four or five times as long as the same size gate or butterfly valves.

Relative Cost of Different Types

The cost of penstock valves varies greatly with the head, size and conditions of installation. In general, it may be said that within their respective limitations the relative costs of the different types, from the least to the most, are in the order of butterfly, gate valve, externally operated needle valve and straightway plunger or Johnson valve.

Reliability in Operation

Reliability in operation is of the utmost importance. In case of an accident to the hydraulic power unit or a break in the pipe line, the prompt closing of one of the penstock valves may be the only means of preventing loss of life and serious damage to the plant. For this reason valves of rugged design with a simple and direct control are preferable to valves with complicated automatic control which might not function properly in an emergency.

Gate valves have repeatedly been closed under full penstock flow and in a few cases under flows considerably in excess of the normal. Gate valves chatter and are very noisy in operation under these conditions, but no damage to the valves or pipe line has been detected due to such operation. In one case the cast iron leaf of a 42-in. gate valve under about 200 ft. head was completely broken due to vibration when closing under flow. This was replaced with a cast steel leaf which has since operated satisfactorily. An exactly similar valve under 200 ft. head operated satisfactorily when closed under the flow due to a ruptured penstock.

Butterfly valves have been subjected to spouting velocity while closing under emergency conditions without any apparent harm. The instances reported have been of valves at the upper end of penstocks under moderate head.

Externally controlled unbalanced needle valves have been used for many years under very severe conditions and are generally considered thoroughly reliable. The operating mechanism of such valves must, of course, be strong enough to stand full unbalanced pressure.

Balanced and partially balanced plunger valves operating under heads of 800 ft. or more have not proved as reliable under all conditions of operations as other types. However, for low and medium head installations they have proved satisfactory. In large balanced valves under high heads the balancing forces are enormous, often in the millions of pounds, and the pressure in the balance chambers is often maintained through a small clearance space around the plunger, or by a very slight cracking of the control valves. Variations in the hydraulic balance which are very slight relative to the forces involved bring very large forces to bear upon the plunger with a consequent tendency to irregular, jerky travel. In closing such valves under unbalanced conditions, there is a wide variation in the forces acting on the plunger during the stroke and a tendency for the plunger to accelerate in the last few inches of travel to its seat. In one instance, where a 60-in. balanced plunger valve was closed under a flow of about 300 second ft., the rapid closure in the last few inches caused a pressure rise of 80 per cent in the pipe line.

Tests have recently been made by the Western States Gas & Electric Company on 28-in. diameter gate valves and plunger valves under practically the same conditions of head and flow. The maximum static pressure above the valves was 820 lb. per sq. in. The maximum flow for the plunger valve tests was 90 second ft., and for the gate valve tests 114 second ft. In the tests on plunger valves the penstock was unwatered and the tests started with fairly low pressures, gradually increasing the pressure on successive tests until full static head was reached. The discharge of water was controlled by the pressure regulator at the turbine. In the tests on gate valves the penstock was not unwatered but the valves were tested for varying discharges with varying rates of closure, the pressure regulator again being used to control flow. The pressures during operation were recorded at various points in the penstock, as well as the time of closure.

Marked surges were set up in the penstock in the plunger valve tests, but not in the gate valve tests.

The following paragraphs are quoted from the company's report:

> These tests of plunger valves seemed to point out certain things that may be of interest:
>
> 1. That it is hard to balance a plunger-type valve under the varying conditions of action and reaction incident to the approach to final closure with water velocities such as are obtained in high head practice.
> 2. That the operating cylinder must have a wide margin of power and be provided with throttling ports independent of the control mechanism.
> 3. That the control mechanism must be very sensitive to any motion of the plunger, especially as the plunger approaches final closure.
> 4. That port valves in the control mechanism must be designed to be tight as regards leakage, and prevent wire drawing of water across final seats or ports.
> 5. That ample provision should be made for flushing silt out of all internal working parts.
> 6. That all flow passages should be made as nearly streamline and smooth as possible.
>
> In the tests on closing gate valves under discharge conditions there is a pronounced "chatter point." This seems to occur where the control of discharge shifts from the pressure regulator to the gate valve, although the "screaming" persists in continually lessening amount until final closure is made. This "chatter" is telegraphed through the water column to all gages. This phenomenon might be explained in this way. That, while the discharge orifice in the gate valve is being reduced at a uniform rate, yet this orifice is a very poor one from a hydraulic point of view. Water under high velocity past sharp edges with abrupt changes in areas and directions of flow undoubtedly set up swirling vacuum pockets and hydraulic impacts that might easily set up a mechanical vibration below the valve that would be carried by the penstock and water column, much as sound would be carried. While some pressure waves were undoubtedly set up, the charts taken did not have the characteristics of the plunger valve charts where true pressure waves were set up upon closure.

Leakage

Tightness is somewhat more important in valves at the lower ends of penstocks than at the upper end.

Gate valves and needle and plunger valves, properly designed, are absolutely tight, under the highest heads and in the largest sizes.

Butterfly valves are not absolutely tight, but if well designed the leakage is small, and the other advantages of this type for a particular location may offset the objection to slight leakage. Adjustable seat rings are used on butterfly valves by some manufacturers, and prevent much leakage around the rim of the disk. Most of the leakage occurs where the shaft enters the bearings.

The following report has been received from the Philadelphia Electric Company on the operation of the 27-ft. butterfly valves at Conowingo Station:

> These valves have been in service for approximately one year, and no trouble whatever has been experienced with the valve itself or the hydraulic operating mechanism. Some little difficulty was experienced initially with the rubber tube sealing device. This device consists of a rubber tube in which a spiral spring is inserted to hold the tube in the recess provided in the valve body during the closing operation. After the valve is fully closed, the tube is expanded by water pressure to form a seal between the

valve body and the casing. As a result of the early operations of the valve and sealing device, the spiral spring contracted lengthwise into the tube leaving several feet of the tube without support. This portion of the tube was thus allowed to come out of the recess and was crushed between the valve body and the casing during the closing operation. This trouble was remedied by fastening the ends of the spiral springs to the ends of the tubes.

One of these valves has been tested for leakage at the normal operating head. The leakage found was from .3 to .4 cu. ft. per second.

Table III gives the amount of leakage measured in tests of some butterfly valves.

TABLE III

LEAKAGE TESTS OF BUTTERFLY VALVES

Dia. of Valve Inches	Adjustable Seat	Test Pressure Lbs. per Sq. In.	Leakage Cu. Ft. per Min.
48	Yes	108	0.15
54	Yes	66	9.00
60	—	65	1.20
72	Yes	140	0.77
72	Yes	210	4.80
72	Yes	210	2.62
72	No	33	3.00
102	Yes	50	0.89
129	Yes	84	7.50
129	Yes	84	1.10
129	Yes	84	3.70

Emergency Operation

Operation at spouting velocity is frequently given as a specification requirement. This is a severe requirement and is rarely met with in practice, although in the event of an accident to the power unit or a break in the pipe line, the ability of the valve to meet this condition is important, and it is for just such emergencies that penstock valves should be designed.

Specifications should state exactly what is meant by "Operation at Spouting Velocity." One interpretation is operation under conditions equivalent to the total removal of the conduit below the valve, resulting in the maximum discharge of which the upper conduit is capable, such as would result from a rupture in the part below the valve. The other interpretation is operation under conditions of the maximum normal flow through the conduit which results in the development of full spouting velocity as the valve approaches the closed position.

The first interpretation should be applied to valves in the upper parts of penstocks, where bursts may occur below them. For valves at the bottom of penstocks, the requirement might be made less, if the designer has sufficient confidence in the reliability of the hydraulic unit. One company has specified for a 96-in. butterfly valve under 700 ft. head that it must be capable of closing safely with a velocity of 100 ft. per second through the open valve. This is about half the full spouting velocity, and it is reasonable to assume that a break in the hydraulic turbine might never be so serious as to cause a greater discharge.

Operating Mechanism

Gate valves under high heads are usually operated by hydraulic cylinders taking their pressure from the penstock. The control of the pressures to the opening and closing sides of the piston may be by means of a small four-way valve, hand operated. Some recent designs, however, have used sleeve valves of various types, some without packing and some using cup leathers, operated by a small electric motor. Power for the motor is taken from a storage battery, to insure its operation in case of failure of the alternating current supply. Hand control is also provided. Hydraulic operation is particularly applicable to valves of automatic plants which may be arranged to close on failure of the control power.

Mechanical operation of gate valves under moderate heads, through screw stems and gearing, with electric motor drive and auxiliary hand control is very common practice. For high head gate valves of large size, the forces to control are so large that mechanical operating gear is not practicable.

The design of operating gear for gate valves, whether hydraulic or mechanical, should be carefully examined to see that it is adequate for the most severe conditions of operation. Trouble has occurred from stems buckling, threads cutting, due to excessive bearing pressure, and motors stalling, all as a consequence of under-estimating the power required to operate the valve under full unbalanced pressure.

Hydraulic or electric control is almost essential with valves of any considerable size, on account of the great length of time required to operate if hand power applied through mechanical gearing is used.

Gasoline engine drive has been used for very large valves as an auxiliary to electric drive, where the length of time required for hand operation would be too great. It is not suited to remote control, and is only desirable under special conditions. Electric operation, with two or more independent sources of power is considered the most compact, cheapest and simplest control for butterfly valves under most conditions.

Needle valves of the angle type are in use with both hydraulic and electric operating gear. The forces acting on the plungers of this type of valves are very large for high heads, larger than the force required to move gate valve disks, and it was the desire to reduce the power required to operate, and the cost of the heavy operating gear that led to the development of balanced plunger valves.

Balanced plunger valves have been used in a number of plants at the lower end of the penstock. Their operation depends on very critical balances of pressure, and while their operation under equalized pressure above and below is satisfactory enough, their operation under unbalanced pressure conditions or under full flow is considered hazardous, at least by the operators of fairly high head installations.

For lower heads, in Eastern practice, balanced plunger valves of the Johnson type are considered more favorably.

Attention is directed to an article published in the *Electrical World,* July 24, 1926, on the Wallenpaupack hydro-electrical development of the Pennsylvania Power & Light Company:

> The Johnson Hydraulic Valves used in this installation are Type "B" and Type "T" hydraulic control, operated by means of hand wheel, motor or solenoid valve. These Johnson valves can be operated either in the valve chamber from the switchboard or automatically, as is usually provided in a Johnson valve installation. The new feature of the design, however, is the provision for quickly opening the Johnson valves by means of the solenoid-operated valve in the piping of the Johnson valve.
>
> The operation of this solenoid valve will cause the Johnson valve to open about half way in four seconds. The valve will continue to open at this rate until nearly fully opened. At the end of four seconds, however, enough water will pass to carry approximately the full load of the unit. One-half second after the Johnson valve begins to open a contact will be made that will cause the turbine to be put on governor control and will start opening the turbine gates, bringing the unit up to no load speed. The unit can, therefore, be made ready for synchronizing with the line and loading up in a very short time.
>
> With this installation, the unit is equipped with a very long conduit leading up to a surge tank, and from there the water is led through a steel penstock to the Johnson valve located at the entrance to the turbine casing. The head on the plant is about 360 ft. In this case the putting of a unit on the line and building up load in a few seconds starting with the Johnson valve closed is a big step forward toward automatic operation.

The pressure for hydraulic operating cylinders is commonly taken from the penstock. Pressure from another source is sometimes provided in addition so that the valve may be operated for inspection or repair with the penstock empty.

In case of a break below the valve, the operating pressure available from the penstock is greatly reduced due to increased friction loss and conversion of pressure head to velocity head, and the operating cylinder must be large enough to close the valve with this reduced pressure.

The opening and closing time of penstock valves is specified anywhere from 2 to 7 min. One company has specified a 2-min. time for all butterfly valves regardless of size. For valves so located that pressure rise can be ignored, the rate is determined largely by mechanical considerations and varies from about 1 min. for the smaller valves to 3 min. for the larger ones. The permissible rate for valves at the lower end of long penstocks is governed largely by considerations of pressure rise and safety. The rate of movement of the valve plunger or disk should be uniform throughout the time of stroke, or should be slower during the last part of the closing stroke. In the earlier design of balanced plunger valves, there was a decided tendency for the valve plunger to accelerate during the last part of the closing stroke. When a valve is closed under normal flow, but with unbalanced conditions, as might occur when the penstock valve is used to shut off the flow to a turbine without closing the turbine gates, the flow through the valve does not decrease uniformly. When the valve is 80 per cent closed, the flow may still be more than 80 per cent of the initial flow, depending on the discharge conditions below the valves. Therefore, an acceleration of plunger travel during the last 20 per cent of the stroke may cause an excessive pressure rise in the pipe line. This condition has occurred in practice, and it was this defect in operation which led to the development of restoring mechanisms to control the rate of valve travel.

Restoring mechanisms have been constructed in various ways, but the object is to apply a retarding force or a reversal of force to the moving element of the valve in case it accelerates beyond a predetermined rate. For free discharge regulating valves, restoring mechanisms have been applied to hold the valve at some intermediate position, but this condition does not hold for penstock valves, and for them the sole object of the restoring mechanism is to limit and control the rate of travel.

Restoring mechanisms may be applied to the hydraulic operating of any type of valve, but are rarely used with gate or butterfly valves.

Needle and plunger valves, however, are subject to great changes in the hydraulic forces on the moving element during the transition from normal unrestricted flow to throttling, and since the mechanical friction is small in comparison the forces must be almost completely sustained by the operating cylinders or chambers. This means that there will be a tendency for the rate of movement of the plunger to change with the pressure differences. In case an exterior operating cylinder is used, as with the various forms of angle and offset needle valves, it is possible to use watertight pistons, in which case orifices in both inlet and exhaust pipes will give a stroke of sufficient uniformity for applications where pressure rise conditions are favorable. However, where absolute uniformity of stroke is required, a restoring mechanism on the control valve is essential. Needle valves where the pistons permit some leakage, and straightway plunger valves where there must be a certain amount of clearance around the parts of the plungers that form the working pistons, require restoring mechanisms.

Automatic emergency closing devices are not yet in use in any of the plants reported on. One company, however, is just completing the installation of such devices just below the upper valves on all of its more important penstocks. In this device an increase in velocity in the penstock of, say, 50 per cent above the normal maximum will cause an increase in the differential pressure at a slightly contracted section of the pipe. The increase in differential pressure will operate a relay which, in turn, will close the electric circuit of the valve motors.

Remote control for operating the upper penstock valves from the power house switchboard is generally standard practice. Some companies restrict their remote control to closing only, and make it necessary for an operator at the valve to control the opening. This practice eliminates a certain amount of hazard due to a possible accidental or mistaken opening of the valve when men are working below it. Remote control of both closing and opening is the usual practice.

Details of Design

The allowable unit stresses in valves parts depend on the importance of the installation and vary somewhat with the type of valve. In general they should be the same as for other high grade machinery of the same character. With the increase in sizes and pressures, marked economies have resulted from the use of high strength alloy steels and bronzes for certain vital parts and for bolts.

The details of valve seats vary widely with the type of valve and with different manufacturers. For seats with sliding contact, various types of bronzes have been used, with a tendency on the part of some to follow the recommendations of the U. S. Bureau of Reclamation for the composition of the bronze. Seats and disk rims of butterfly valves are usually specified to be bronze, but the composition of the bronze is usually left to the manufacturer's judgment. Needle and plunger valves have only pressure contact between seats and the materials used vary greatly. Such valves have been made with seats of steel, of bronze, of bronze on steel and steel on bronze. There is no definite opinion as to the best practice.

Seats of small heavy gate valves are usually peened in, and for the larger sizes clamped in place between adjacent parts or screwed in.

In some plunger valves the seats are circular and of roughly triangular cross section, pressed into the valve body or shrunk on the plunger. Some difficulties have been experienced due to these seats working loose, and in some cases coming entirely out. Bronze rings cannot be reliably attached by shrink or press fit alone, and the best practice for bronze seats is a positive bolted or clamped fastening.

The unit pressures between valve seats have been the subject of much discussion without any definite conclusion. For seats in pressure contact only, as in plunger valves, the pressures in some valves now in use are several thousand pounds per square inch, and no troubles have been reported due to these pressures. For gate valves some attempts have been made to limit the contact pressures, with the valve fully closed, to 500 lb. per sq. in. For small or low pressure valves this is possible, but on large gate valves for extremely high heads, the seat pressures cannot be reduced in some cases below 2500 lb. per sq. in., and it would appear more logical to develop bronzes or other alloys to withstand these high rubbing pressures than to attempt to enlarge the contact surfaces.

Furthermore, in gate valves, having annular seat and disk rings, the entire seat pressure is concentrated upon two small diamond-shaped bearing areas as soon as the disk has been raised a small distance. Bearing pressures in this case may amount to twenty times the pressure on the seats in full contact. To obviate this, some gate valves have been built with side guides which are in contact the full length of the stroke.

Cylinders and pistons for hydraulic valve operation present no unusual difficulties. Cylinders are usually bronze lined, with arrangements for preventing the bulging of the liner should pressure get behind it. Pistons have been packed with cup leathers, flax packing and bronze snap rings.

Limit switches are commonly used in all motor operated valve gears, whether mechanical or hydraulic. Where motors are of considerable size, operating the valve through reduction gears, they should also be provided with solenoid brakes to prevent overrun and fix more definitely the operating point of the limit switch. Solenoid brakes have been found particularly desirable on motor operated butterfly valves.

Slip friction clutches between the motor and the valve gear are not considered reliable. When new the coupling may be set to slip at the proper torque, but after some time the setting will vary and cannot be relied upon. In a number of instances these slip clutches have been replaced by positive couplings.

Provision usually is made so that penstock valves can be moved from the line without tearing out the adjoining pipe. This has been accomplished by split ring bolted joints, by placing expansion joints close to the valve, and by providing a riveted flange that can be cut loose and driven back on the pipe. Gate and butterfly valves usually are arranged so that the parts most likely to wear can be replaced without removing the valve bodies from the line.

Conclusion

In presenting this progress report, it is hoped and expected that those who are interested in the subject, whether as designers, manufacturers or operators, will send in their comments on the statements made, and contribute any additional information which would be of value to the industry.

Actual operating experiences and tests particularly are desired. Further accurate information is wanted on the loss of head through valves, on the sliding friction between valve seats, the proper materials for valve seats, and the actual power required to operate butterfly valves.

MANUFACTURERS' STATEMENTS

The Hydraulic Power Committee does not accept responsibility for any manufacturers' statements.

STATEMENT BY THE ALLIS-CHALMERS MANUFACTURING COMPANY

Butterfly Valves

The Allis-Chalmers Manufacturing Company has always advocated the use of butterfly valves for penstock and casing inlet valves for heads up to 600 ft. and over. The company has now built these valves in sizes up to 27 ft. in diameter. Its position has been that a correctly designed and built butterfly valve represents the simplest, least costly, and more reliable type of valve from a mechanical standpoint. A shape of wicket has also been determined upon which makes this type of valve very comparable in head loss to other more expensive and complicated designs. The success of building butterfly valves to eliminate leakage has been largely a question of rigidity in the valve body in order to resist deformation due to exterior strains imposed by the penstock. In addition, this company always has been confronted with the problem of eliminating leakage around the shaft. In view of the fact that it is not always possible to eliminate deformation, various types of sealing devices between the outer periphery of the wicket and the valve body have been resorted to, with varying success. The device which is in most common use consists of a sealing ring placed in the outer diameter of the wicket and expanded against the valve body by means of the penstock water pressure when the wicket is in closed position. Fig. 9 shows these rings inserted in the wicket.

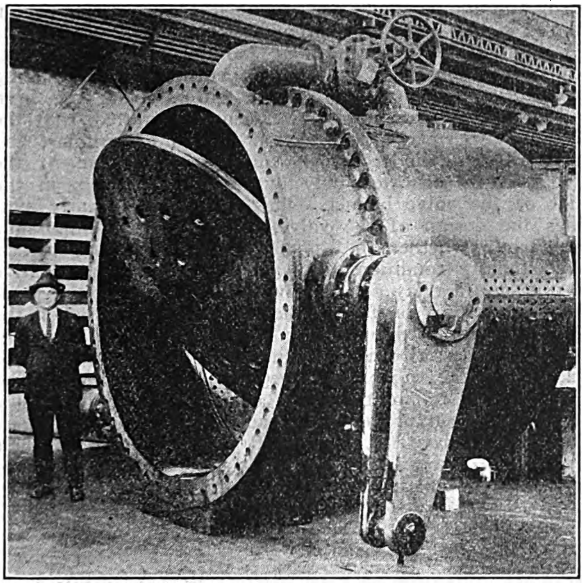


FIG. 9—96-IN. DIAMETER CAST STEEL BUTTERFLY VALVE.

For the Conowingo butterfly valves, a new method of sealing is used by employing rubber hose set into the valve housing and subjected to pressure, thereby pressing same against the periphery of the wicket. Shop tests have proved very satisfactory, and it is expected that the field results will also show the desired results.

Practically all butterfly valves of any size, and especially those built for the higher heads, are tested at the factory before shipment. The leakage of a 108-in. valve in such a test was less than 1 gallon per second under 200 lb. pressure. Table IV lists actual leakages as obtained under shop tests with various sized valves and under various pressures.

It has been common practice with this company to make the valve bodies and wickets of cast steel in all cases except where the stresses are unusually low due to small sized valves and low head. In the case of the Niagara Falls valves, the wickets were made of steel plate with cast steel end pieces and cast steel outer rings. The plate steel construction of wicket was found to be very acceptable for this operating condition. The Conowingo butterfly valves, which are 27 ft. in diameter, were made with wickets of cast steel on account of higher stresses due to a head of 90 ft. in the place of 60 ft. head with the Niagara Falls valves, and also due to the fact that the water contained a great many impurities that were conducive to corrosion.

TABLE IV.
BUTTERFLY VALVE - LEAKAGE TESTS

SIZE INCHES	TEST PRESS. LBS/SQ. INCH	WORKING PRESS. LBS/SQ. INCH	LEAK. UNDER TEST PRESS. G.P.M.	LEAK. UNDER WORKING PRESS. G.P.M.
84	175	90	42	27
84	175	90	27	12
108		185		28
84	225	150	33	27½
108	185	100	102	65
96	125			28
84	A VALVE			25
84	B VALVE			21
84	225	150	54½	49
84	175	100	52	26

The 23-ft. and 27-ft. diameter valves built for the Niagara Falls Power Company and the Susquehanna Power Company have vertical operating shafts, as it permits placing the operating mechanism directly over the casing or penstock inlets, and in this way does not necessitate any additional space on either side of the valve body. There is also an additional advantage in erection of this machinery, as with the operating shafts in the vertical position the sections can be split in a horizontal plane, which would not be practical in the case of a horizontal shaft, and the weight of shaft and wicket can be carried in a thrust bearing outside of the flow of water and accessibly lubricated. In the larger valves and under higher heads it is found necessary to provide a means of taking the water load on the wicket when it is in closed position and under full pressure.

Where it is desired to provide for removal of the valve, the company's standard practice is to make the face of one valve body flange at a small angle to the other face. In other words, the planes of the flanges are made wedge shape. Ordinarily with heads up to 400 ft. no packing is inserted between the penstock and casing flanges and the body flanges. With heads above 400 ft., provision is made for inserting a round rubber packing in a groove provided in the valve body flange. This groove is made tapered to the outside so that the pressure of the water will elongate the rubber ring, forcing it tight in the groove against the two flanges.

An important element that enters into the mechanical design of butterfly valves is the question of moment when closing the valve against maximum velocity. This moment varies in the ratio of the cube of the valve diameter and also the square of the velocity, and it has been found in many cases to represent a stress several times that encountered when opening or closing the valve under full penstock pressure but no velocity. This design feature together with a design of valve to resist deformation has usually resulted in a heavy design of valve compared with other standard designs which have been based largely on water works requirements.

Various kinds of operating devices have been used for butterfly valves. The common type is a motor and hand operated device connected to a lever mounted on one end of the operating valve shaft. In the larger valves it is necessary to go to a greater power ratio between operating mechanism and valve shaft, in which case a gear or worm segment is used. This type of mechanism has the advantage that normally it is under control of an electric motor with limit switches placed at the opening and closing position of the wicket to bring the valve wicket in correct position for opening or closing and to avoid overloading of the motor. In case of failure on the motor, the hand regulating device is used, and while considerably slower in operation, it provides a definite and positive means of closing or opening the valve. Operating mechanisms are all self-locking, so as to prevent motion of the handwheel due to reaction from the wicket. With the larger valves a mechanical operating device is cumbersome, and hydraulic operating cylinders have been substituted. With the higher heads, the operating pressure is obtained from the penstock with auxiliary means for operating the valve when no water pressure is available. In the case of the larger diameter valve and under low head, a separate oil pressure system may be used. This arrangement is satisfactory only if oil pressure is available under all conditions of operation. An operating cylinder was used for the Niagara Falls Power Company valve. The diameter of the operating cylinder is small on account of using an oil pressure system under 150 lb. working pressure, as compared with the stroke required for operating the valve. The control of the oil or water pressure to the operating cylinders can be made either hand or motor operated. A relay is sometimes placed on the control device so as to provide a uniform opening and closing rate of the valve wicket, or else diaphragms must be provided to limit the rate of motion.

Gate Valves

The Allis-Chalmers Manufacturing Company has not entered into the manufacture of gate valves to any appreciable extent except under high heads and when a special design of valve is required which is not included in the standard valve manufacturer's design. The company's principal contribution in this field has been in adding a follower ring onto the valve disk. This ring fills the opening required for the disk when in the open position, thus eliminating all eddy losses, protecting the valve seat against the scouring action of the flowing water, and preventing chattering of the valve disk because of a larger leverage guiding the sliding disk. The Allis-Chalmers high head gate valves have all been operated by means of cylinders which receive their operating pressure from the penstock. Fig. 10 shows the eight valves built in 1913 for the Big Creek plants No. 1 and No. 2 of the Southern California Edison Company. Here four hand-operated valves are used for the control and diaphragms are inserted in the piping leading to the operating cylinder, so as to limit the rate of travel of the piston, and the valve disk. A valve of similar but improved design has a single control valve of the sliding disk type instead of the four hand-operated valves. The control valve is hand, or motor-operated from the switchboard, and the contacts are provided for operating green and red lights showing position of valve.

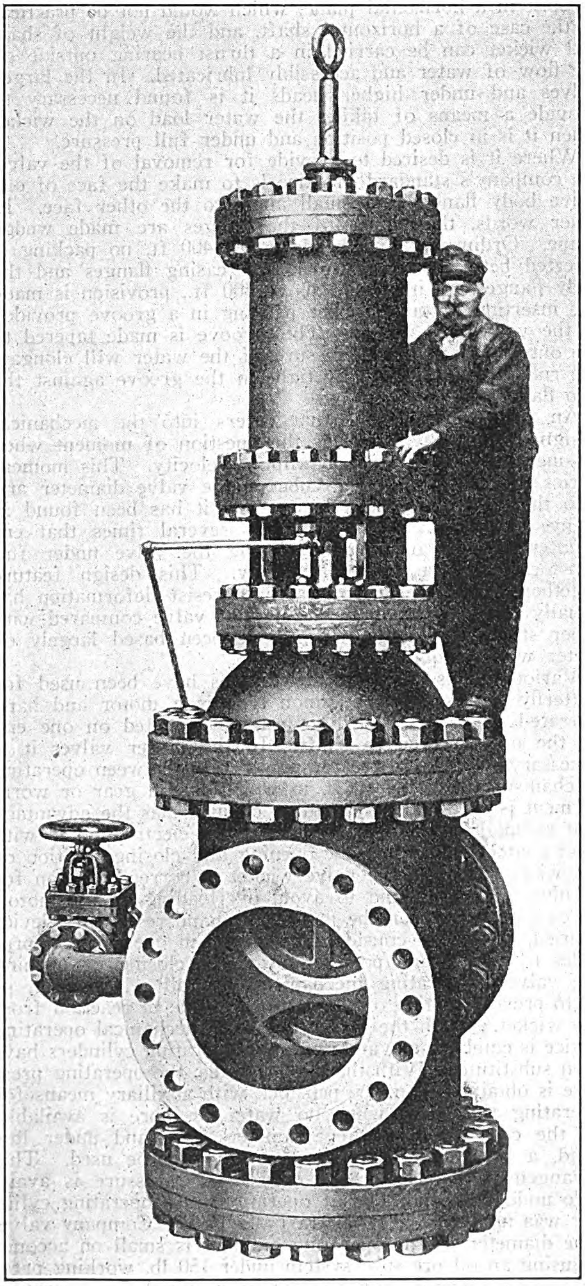


FIG. 10—24-IN. HYDRAULICALLY OPERATED GATE VALVE.

A 42-in. valve for a head of 350 ft. built by the company twenty years ago is still in operation without having required any repair. This valve differs from the high head design in that the follower ring is omitted, that the valve body is of elliptical section instead of circular, and the operating cylinder is not entirely independent of the valve, but is separated only by one packing box in the inside of the valve bonnet. This, of course, greatly simplifies the design of the valve, but renders it impossible to ascertain whether the submerged stem packing box is in satisfactory condition. This design makes it imperative to either use a relay for positive rate control, or the pressure must be left on top of the operating piston when the valve is kept closed under penstock pressure on upstream or on both sides, as otherwise due to leakage along the stem packing box the valve may creep into open position. The simplicity and reliability of the company's high head gate valves have been proved under actual operation for many years. They have not been used as extensively as their merit would warrant, but it is felt that greater consideration will be given this type of valve in the future.

STATEMENT BY THE COFFIN VALVE COMPANY

The only type of penstock valve furnished by The Coffin Valve Company is the Dow Disk-Arm Pivot Valve, and a description of this valve appeared in the 1924 report of the Hydraulic Power Committee. (N. E. L. A. Proceedings, 1924, pp. 802-803.) Since that time the company has furnished a considerable number of these valves, and so far as it has been able to check up on the actual operation of the valves, has found them to be eminently satisfactory.

The Coffin Valve Company has been able to make these valves remarkably tight and inclose a list of shop tests for leakage on various valves. It will be noted from this list that the tightness of the valves has gradually improved, due to improvement in design and workmanship. Where records were obtained from the field, it has been found that the leakage under actual working conditions has not exceeded that shown in the shop, and in some cases is much less. For instance, the 60-in. valve tested in the shop in March, 1926, showed a leakage of 1½ gallons. This was on account of the fact that the disk was not closed as tight as it should have been, and it was reported to the company by the customer that the valve, after it was put in the line, showed practically no leakage.

A successful automatic operation for these valves has been also worked out. Valves automatically operated have been generally installed in pump discharge lines, but where it is desirable that a penstock valve automatically close, this type of operation can be used. A sleeve type of control valve actuated by a solenoid is used by the company, and as long as the solenoid is energized the pivot valve will remain open, but as soon as the solenoid becomes de-energized, the pivot valve will close. Fig. 11 shows a valve of this type.

A method has been developed of operating valves by electricity which differs in principle from those now on the market. This company has always contended that the motor should not be shut off by a limit switch when a valve is closing, because the complete closure cannot be made by the motor and it is necessary to supplement this operation

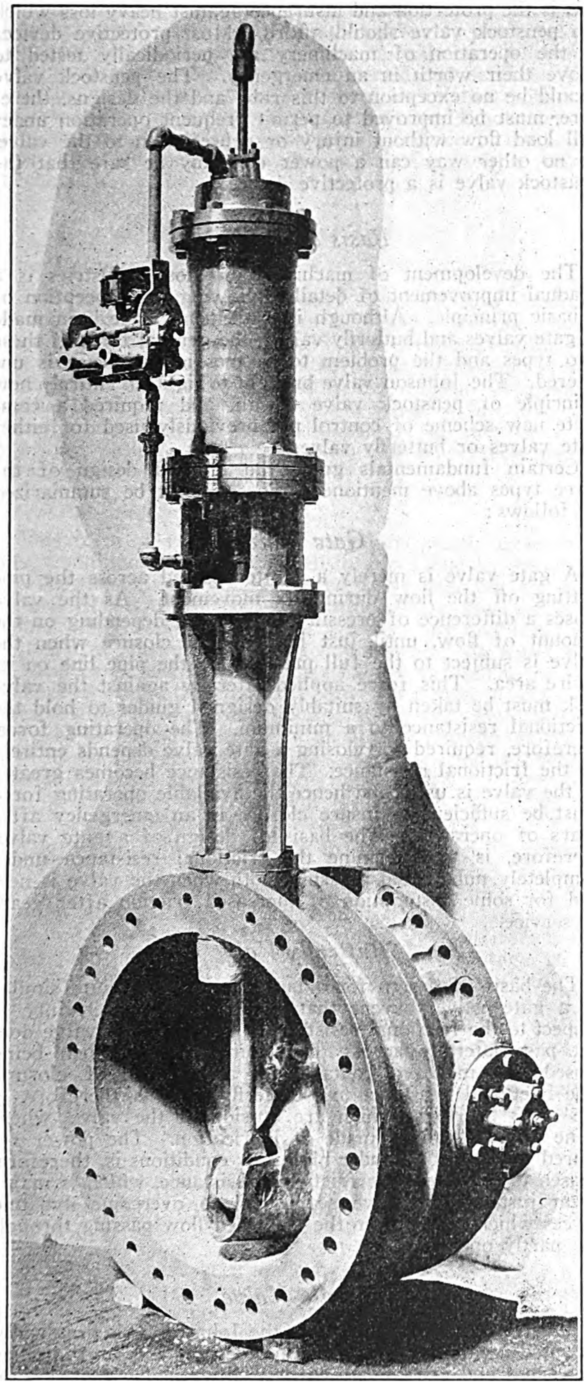


FIG. 11—PIVOT VALVE, HYDRAULICALLY OPERATED AND SOLENOID CONTROLLED.

by hand operation to obtain a tight valve. Use, therefore, is made of a multiple disk friction clutch, which contacts on the outside of the clutch, to take care of stopping the motor after the valve is closed. This type of operation is particularly adaptable to pivot valves because the tightness of the pivot valve depends on jamming the disk hard into its seat, and our type of motor operation completes this before the motor is stopped. Fig. 12 shows a 60-in. pivot valve equipped with motor operation. This valve is installed in a penstock just ahead of the turbine in the power plant of the Vermont Marble Company.

Mention should have been made above that the solenoid-operated sleeve type of control valve, used for automatic operation of hydraulically-operated valves, provides successful remote operation for hydraulically-operated valves.

STATEMENT BY THE NEWPORT NEWS SHIPBUILDING AND DRY DOCK COMPANY

Believing that the butterfly valve is the most economical type of penstock valve, with due consideration for features of reliability, long life and safety, the N. N. S. and D. D. Co. regularly build only this type. The constantly increasing demand for butterfly valves to be used under widely varying conditions of head and flow furnishes gratifying evidence of the correctness of this policy.

The Newport News valves are provided with a patented self-adjusting, renewable bronze sealing ring fitted to the valve disk, and special provisions are made to reduce the leakage around the shaft to a practicable minimum. Rubber composition sealing rings are not used because they are easily damaged and subject to excessive wear. Experience has shown also that a properly designed and manufactured adjustable metal sealing ring can be made amply tight for practically any service. As an example of this construction, a recently installed 150-in. butterfly valve showed a leakage of less than five gallons per minute under a head of 130 ft. Similarly, in case of a 102-in. valve under 52 ft.

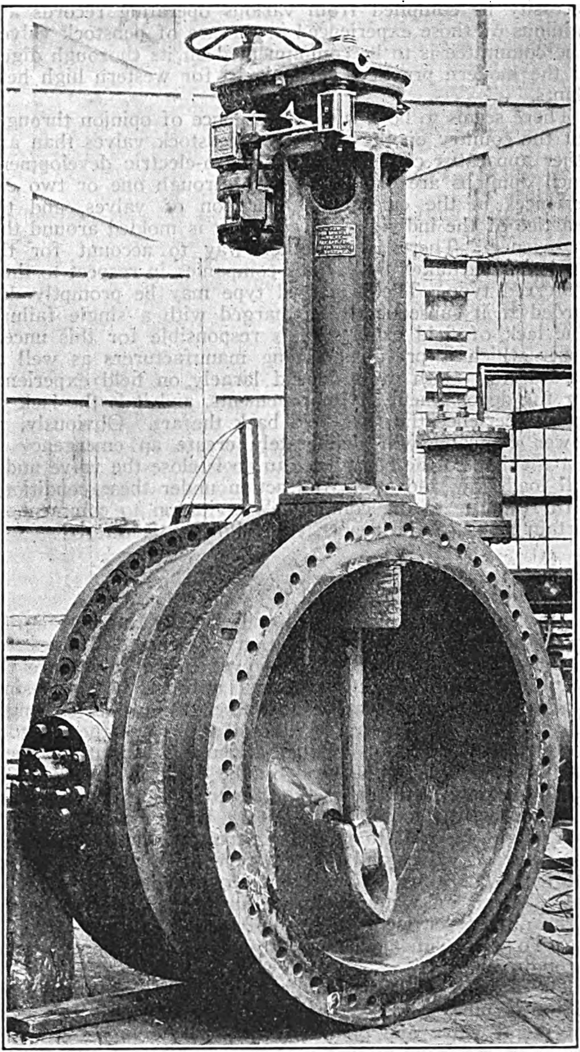


FIG. 12—60-IN. MOTOR-OPERATED PIVOT VALVE.

head, the leakage was reported as "too small to measure." Exceptional shop and crane facilities enable this company to handle advantageously valves of any practicable size and for any reasonable head.

A standard line of mechanical operating stands has been developed suitable for either motor or hand operation, or both. Where motor operated, a limit switch is provided to restrict the valve movement in either direction, and provision may be made for remote control when desired. Hydraulic operation will be furnished for any size valve if specified, but mechanical operation usually is recommended on account of the lower cost of upkeep, elimination of accessory equipment, such as pumps, etc., and the ease with which it can be made self-locking.

Little information is available relative to the power required to operate a butterfly valve under various conditions of flow. The company has investigated this in considerable theoretical detail, and steps are now being taken to supplement these data with a series of tests on an actual model valve in the Newport News Hydraulic Laboratory. It is expected that this series of tests will add much to the engineering information on this subject which is now available.

STATEMENT BY THE I. P. MORRIS CORPORATION

(Now I. P. Morris & De La Vergne, Inc.)

On account of the lack of test data the report must of necessity be compiled from various operating records and opinions of those experienced in the use of penstock valves. The committee is to be complimented on its thorough digest of the modern practice, particularly for western high head plants.

There seems to be a wider divergence of opinion throughout the country on the subject of penstock valves than any other apparatus connected with hydro-electric development. Such opinions are usually formed through one or two experiences in the emergency operation of valves, and the practice of the individual or company is molded around this experience. There is no other way to account for the definite stand taken by various companies in respect to their preferred type. The preferred type may be promptly discarded if it subsequently is charged with a single failure. The lack of field experience is responsible for this uncertainty which is prevalent among manufacturers as well as purchasers. Both must depend largely on field experience for the development of improvements, and it is the lack of such experience that has held back the art. Obviously, no power company will deliberately create an emergency to test a valve, so the best they can do is close the valve under full load flow and study the action under these conditions.

In response to the committee's invitation to comment on certain parts of the report, the following is offered:

Purpose and Location of Valves

This subject is well covered and there is complete agreement as to the suggested location of penstock valves for high head developments. The power house valves are the operator's chief protection against a break in the casing, broken guide vane links or any other failure which might cause a flood or runaway. Valves at the top of the penstock constitute a protection against a penstock failure. These latter valves, where the head on the plant is less than 250 ft., are seldom installed, as the danger of a broken penstock is exceedingly remote.

It might be well to consider carefully the real purpose for penstock valves and the service which they are intended to give. There are two operating requirements:

1. To shut off water from the turbine whenever a unit is taken out of service.
2. To close in an emergency with high flow passing through the unit.

The first is an operating necessity to permit unwatering of the turbine casing and inspection or repairs. A reasonably tight valve and one that will operate under balanced conditions will meet this requirement. The second is the requirement that should be adequately met by the design, as this is the protection and insurance against heavy loss which the penstock valve should afford. Most protective devices in the operation of machinery are periodically tested to prove their worth in an emergency. The penstock valve should be no exception to this rule, and the designs, therefore, must be improved to permit frequent operation under full load flow without injury or depreciation to the valve. In no other way can a power company be sure that the penstock valve is a protective device.

Basis of Design

The development of machinery in most industries is a gradual improvement of details following the conception of a basic principle. Although improvements have been made in gate valves and butterfly valves, the general form of these two types and the problem to be met in each case is unaltered. The Johnson valve brought to light an entirely new principle of penstock valve design, and required a complete new scheme of control not previously used for either gate valves or butterfly valves.

Certain fundamentals guide the finished design of the three types above mentioned. These might be summarized as follows:

Gate Valve

A gate valve is merely a shutter passed across the pipe cutting off the flow during its movement. As the valve closes a difference of pressure is built up, depending on the amount of flow, until just before final closure when the valve is subject to the full pressure of the pipe line on its entire area. This force applied laterally against the valve disk must be taken by suitably designed guides to hold the frictional resistance to a minimum. The operating force, therefore, required for closing a gate valve depends entirely on the frictional resistance. The resistance becomes greater as the valve is used, and hence the available operating force must be sufficient to insure closure in an emergency after years of operation. The basis of design of a gate valve, therefore, is to determine the frictional resistance under completely unbalanced pressure, both when the valve is new and for some assumption of increased friction after years of service.

Butterfly Valve

The basis of design for a butterfly valve is quite similar to a gate valve, except that there is less uncertainty in respect to the frictional resistance. The butterfly valve does not pass laterally across the seating surface when being closed, but makes a contact seat at the end of closure. The frictional resistance in a butterfly valve is, therefore, in the shaft bearings, which are outside of the valve, where some attempt can be made at lubrication. The power required for operation under high flow conditions is, therefore, chosen to overcome the frictional resistance, which is maximum just as the valve seats, and to overcome dynamic forces which result from the disturbed flow passing through the partly opened valve.

Needle Valve

A valve of this type, such as the Johnson or hydraulically operated needle valve, is a distinct departure from the other two types and involves an entirely different basis of design, since the friction element resisting closure is completely eliminated. The moving element of the Johnson valve travels parallel to the direction of flow, and hence cuts off the opening through the valve with the least possible disturbance. The motion of the valve element is exactly the same as a needle nozzle for an impulse wheel. The frictional resistance to closure being eliminated and the disturbed flow condition reduced to a minimum, makes this form of valve an easier design problem so far as determining the necessary operating force is concerned. The chief problem is to secure absolute control of movement irrespective of changes of pressure or flow. With this feature properly met by a simple and reliable control mechanism, the valve becomes the most reliable of any of the various forms.

The above discussion in respect to the basis of design of the three types shows that the gate valve must make use of either electric power or hydraulic power to overcome the frictional resistance when new and to make due allowance for increased friction after long periods of service. The butterfly valve has the same problem, except that with reasonable care the frictional resistance should not increase with service. There is no problem of friction in the needle type valve, but the problem here is one of a positive control mechanism.

Characteristics of Three Types of Valves

Gate Valve

This valve causes a moderately disturbed flow condition as it is closing, it develops high frictional resistance against closure, the bearing surface and seat deteriorate with service which decreases the reliability of the valve, and requires replacement of parts to prevent serious leakage. This valve is the least desirable of the three types to be used continually under high flow conditions. It is, therefore, not a proper design to test frequently for emergency service as suggested above.

Butterfly Valve

This form of valve could be tested frequently under high flow conditions, provided the disturbance due to the water passing through the partly opened valve does not set up a serious vibration. If such a vibration occurs, then the valve would better be operated in dead water only and could not be tested frequently for emergency service. Various forms of snap rings and spherical seats have been used to prevent leakage through this form of valve, but these devices are questionable, as the force holding the valve closed against the seat is not adequate. It is usual for butterfly valves to develop rather serious leakage after a period of service unless the seats are repaired.

Needle Valve

The needle valve is probably the most expensive form of valve, but it has two distinct advantages in that it can be operated safely and positively under any conditions of flow without appreciable wear or deterioration. It is the only type that can be safely tested at regular intervals for closure under high flow conditions. A further advantage is the fact that the valve seats on a diagonal surface with the full pressure of the pipe line against the moving element. This form of valve is therefore the tightest design and will remain tight with little or no repairs. Of the two types of needle valves the Johnson valve is the simplest form to install, as it does not require a bend in the penstock, but is self-contained with operating chambers incorporated as a part of the moving element.

Improvements Offered by the I. P. Morris Corporation

Gate Valve

Gate valves have been made by this company in the past, but they have proved very expensive if they are designed with sufficiently wide surfaces to insure frequent operation under unbalanced pressure. This form of valve has not been advocated by this company, as it is little, if any, better than the butterfly valve and is not as reliable as the Johnson valve. For this reason no improvements have been offered.

Butterfly Valve

Several types of butterfly valves are offered for penstock service, either operated hydraulically or by electric power. For high head valves a restoring mechanism is advocated if hydraulic power is chosen with the usual form of hydraulic piston cylinder element. In this way the motion of the valve element is held to a uniform rate and the proper operation is not dependent on the skill of an operator. The changes of force necessary to move the valve element are very pronounced under high flow conditions, and hence any fixed port openings in an operating cylinder would give a variable rate of stroke. A restoring mechanism, on the other hand, coordinates either a hand wheel or small motor with the movement of the valve element, and hence controls its rate irrespective of changes in the pipe line. The restoring mechanism is not required for low head butterfly valves.

The most marked improvement in this field is the rubber seal ring, which has recently been adopted for the 27-ft. Conowingo butterfly valves. A rubber tube is inserted in a recess located in the valve body. When the valve disk is moved to its closed position the rubber tube is expanded by water pressure so that the surface of the tube bears hard against the periphery of the disk. This cuts off leakage entirely through the valve and renders a butterfly valve exceedingly tight. The flexible nature of the rubber has another advantage in that it will conform to the edge of the disk, even if it be slightly off center or if it be damaged by closure against an obstruction. The rubber will follow any slight depressions or close around sticks or other foreign matter which may adhere to the edge of the disk. This characteristic makes the rubber seal preferable to any form of mechanical seal such as snap rings or spherical seats. Shop tests have indicated the entire success of this form of seal and indefinite life for the rubber is assured by the rubber companies since it is located in water and kept away from light.

In large valves, such as the 27-ft. diameter Conowingo valves, the rubber tube is 3-in. outside diameter and 2-in. inside diameter. The valve disk is somewhat smaller than the inside bore of the body, so that when closed there is a 3/16-in wide opening around the disk. This opening is closed off completely by expanding the rubber tube. When the valve is to be opened the pressure in the rubber tube is exhausted, allowing it to assume its original circular form and opening the 3/16-in. wide space around the valve. The operating gear of the valve and the pressure supply and exhaust for the rubber tube are interlocked so that the rubber tube can be supplied with pressure only when the valve disk is closed. Smaller sizes of valves would require smaller tubes and less clearance space around the disk. Incidentally, the clearance space around the disk can be used to good advantage for priming the wheel casing prior to operating the valve.

Tests of the Conowingo valves showed a leakage of 0.28 sec. ft. at 89 ft. head, and a deflection of the center of the valve disk of 0.14 in. under the normal head of 89 ft. and 0.27 in. under 127 ft. test head.

Johnson Valve

The original design and form of Johnson valve has remained unaltered since the first installation in 1910. The development in respect to this valve has been confined almost exclusively to the control mechanism. Even this has not offered a serious problem until high head installations were encountered, where dynamic forces and the pressure changes during the closure of the valve occur suddenly. For low head valves an ordinary four-way cock or ported piston valve are amply sufficient to control the movement of the plunger even when used by an inexperienced operator. This basis of control has been altered and extended to include a means of automatically priming the casing and effecting automatic closure of the valve in case of a break in the wheel casing. During the past three years the ported piston valve has been used almost universally in conjunction with a restoring mechanism so that the movement of the valve plunger is controlled with precision and pre-determined by the speed of a hand wheel or electric motor.

In closing the valve with this form of control and in flowing water the valve plunger cuts off the opening through the valve for the first part of the stroke but with little or no change in the amount of flow until spouting velocity exists. From this point on the plunger completes the closing stroke and cuts off the flow. There is no problem involved in controlling the plunger during the initial part of the closure stroke or during the final part of the closure stroke. The first part of the stroke is made with no appreciable pressure difference on the two sides of the valve plunger. Therefore, the control mechanism supplying and exhausting pressure to the operating chambers is leading the movement of the plunger. At some intermediate point in the stroke the pressure difference will become great enough to cause the plunger to lead the control and reverse the setting of the control valve. From this point on the plunger will continue to lead the control until it is closed. The movement of the plunger during the transition from a following to a leading position must be coordinated with the restoring mechanism and lap on the control valve so that only a slight motion of the plunger is necessary to reverse the setting of the control. For low head valves this has been very easily met by merely choosing a proper percentage of restoring and a proper lap and width of ports in the control valve.

In view of experience in high head developments, it seemed advisable to develop a control which would make use of a restoring mechanism without levers or gears of any description. In this way the lost motion present in most control mechanisms is entirely eliminated and the restoring effect is secured directly between the valve plunger and the control valve itself. The valve is a combination of the original penstock valve and the present well-known free-discharge regulator used for continual service in controlling the flow in dam outlets. Very desirable operating characteristics are secured in this manner as the control valve is operated at an entirely definite and pre-determined rate by the outside mechanism, while the plunger must follow exactly the motion of the control due to the exact coordination between the control valve and the port in the nose of the plunger. Whenever a point in the stroke is reached where the plunger tends to lead the control it requires only about ¼-in. motion of the plunger to produce the proper corrective effect on the opening through the port in the nose of the plunger. This transition takes place when the pressure in the flow line beyond the valve drops to 8 or 10 lb. per sq. in. below the pressure in the valve body regardless of the amount of flow. Therefore, there is no change in the rate of stroke of the plunger when the larger pressure changes occur just as the flow is approaching spouting velocity. The seat ring inserted in the neck of the valve body is recessed to permit some travel of the plunger after the flow has been entirely cut off. When the valve is closed with a very slight flow the pressure change occurs close to the seat. The recess is used to provide for uniform motion of the plunger under extremely small flow conditions when the pressure change occurs close to the seat. The conversion to the characteristic form of free discharge regulator is made long before free discharge takes place and hence the motion of the plunger is precise during the entire range of high velocity conditions.

Loss of Head in Penstock Valves

The information available in this company's records in respect to this subject is confined to loss of head through Johnson valves. Various reports have been received from different sources showing the loss of head through butterfly valves and the figures seem to indicate that there is little to choose between a butterfly valve and a Johnson valve so far as this feature is concerned.

The Johnson valves manufactured by this company are carefully formed to minimize the loss of head and a large accumulation of test data from various installations has fairly well established the loss of head curve shown on Fig. 13. The test data have been compiled from valves ranging in size from 4-in. outlet diameter to 14-ft. outlet diameter. The actual field figures have varied from 2/10-ft. to 8/10-ft. for the medium size valves, but the inconsistencies can generally be accounted for.

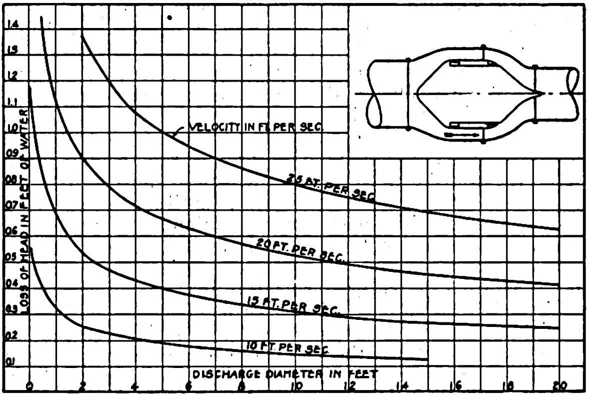


FIG. 13—LOSS OF HEAD IN JOHNSON VALVES.

It is a well established fact that piezometer measurements taken close to the valve outlet show losses higher than exist. Several piezometers located at short intervals beyond the valve outlet show increased readings for a distance below the valve equal to about two diameters. Whenever readings are taken for establishing loss through a valve of this form, it is important that they be taken at a point about two diameters below the valve and then corrected to allow for the friction in this length of pipe.

A long series of tests were conducted at the Queenston Station of the Hydro-Electric Power Commission, Niagara Falls, Ontario, and at Shawinigan Falls, Quebec, to establish correct figures for loss through a Johnson valve. These tests, together with miscellaneous tests on smaller valves, have affirmed the accuracy of the accompanying curve.

Conclusion

This company believes that the improvement in respect to making tight a butterfly valve is a distinct advance in the art and offers a reliable and positive sealing device. The revised control of the Johnson valve has definitely answered any uncertainties in respect to the movement of the plunger when pressure changes occur in the pipe line and renders this form of valve just as reliable in every respect for high head plants as it has proved for years past in low and medium head plants. A valve chosen and purchased for entirely safe operation under all conditions of flow should be tested frequently to prove its complete reliability. The Johnson type of valve therefore is offered by this company as the best suited to meet this specification.

Many power companies have never had occasion to depend on a penstock valve for closure under high flow conditions and therefore do not attach great importance to the emergency or insurance value of such a valve. For this reason their requirements are confined to stop valve service and they are prepared to run whatever risk may exist in the closure of their penstock valve in an emergency. The butterfly valve with the rubber sealing device is manufactured by this company to meet these less severe operating requirements.

Johnson High Pressure Penstock Valve

Fig. 14 shows the form of valve described. The plunger or moving element, A, is in the wide open position, allowing

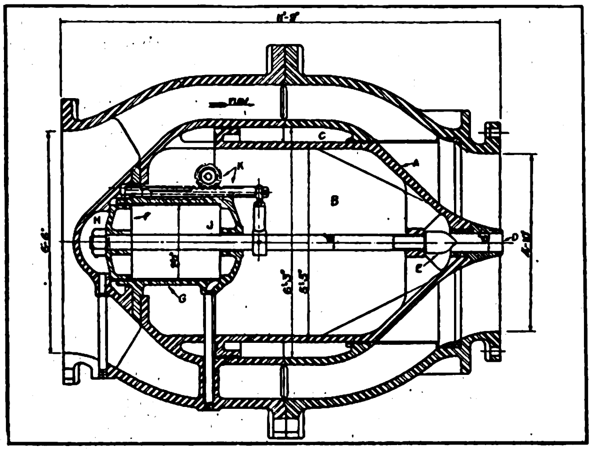


FIG. 14—JOHNSON HIGH-PRESSURE PENSTOCK VALVE.

water to flow in the direction of the arrows. The two main operating chambers, B and C, supply the necessary force for moving the valve plunger. An orifice, D, is closed or opened by a pilot valve, E. The pilot valve in turn is operated by piston F, contained in the cylinder G. The supply of pressure to chambers H and J of the operating cylinder, is controlled through a four-way needle valve located on the outside of the main valve body. Communicating pipes are shown leading into chambers H and J. The motion of the internal pilot valve E, is transmitted through a rack and pinion, K, to the exterior of the valve. The pinion shaft passing through the valve body is arranged with a restoring arm coordinated with the four-way needle valve so that piston F can be moved in the cylinder at a regular and predetermined rate. If desirable, in some installations, the rate of movement of piston F can be automatically retarded when the main valve plunger is approaching the seat.

To close the main valve, pressure is exhausted from chamber J and supplied to chamber H. Operating chamber C is connected at all times with the main water passage, while operating chamber B also has a restricted communication with the main water passage. The first motion of piston F causes pilot valve E to close off orifice D. The plunger is moved toward the seat by the force developed in cylinder G, so long as there is little or no drop in pressure beyond the valve. When a slight drop of pressure occurs, plunger A will tend to lead pilot valve E, thus opening the orifice D and establishing communication through the orifice with chamber B. The plunger is now moving forward by hydraulic pressure in chamber B, which is sufficiently higher than the pressure beyond the valve to overcome the slight friction and the pressure in chamber C. This is the characteristic regulating valve control wherein the pressure in chamber B is automatically controlled to hold the plunger in exact balance throughout the stroke. Any tendency for the plunger to move away from the control valve E, would open wider the orifice D and thus lower the pressure in chamber B so that no further forward movement is possible. The plunger will follow exactly the movement of the pilot valve and hold automatically a fixed relationship to maintain a perfect hydraulic balance of the plunger throughout the stroke.

When the valve is finally closed, the main plunger seats in the neck of the valve body and the pilot valve E shuts off completely the orifice D. To open the valve, the pilot valve E is opened first to discharge pressure from chamber B. As soon as the orifice is opened sufficiently to drop the pressure in chamber B to about 25 per cent of normal pressure, the valve plunger will be unseated and the casing primed through the main valve. The balance of the opening stroke is performed hydraulically if there is considerable flow through the valve. If there is little or no flow through the valve, the final opening is produced by the force established in operating cylinder G.

The valve can be arranged to close automatically in case of a break in the wheel casing, the closure taking place at the same rate as when operated for regular service.

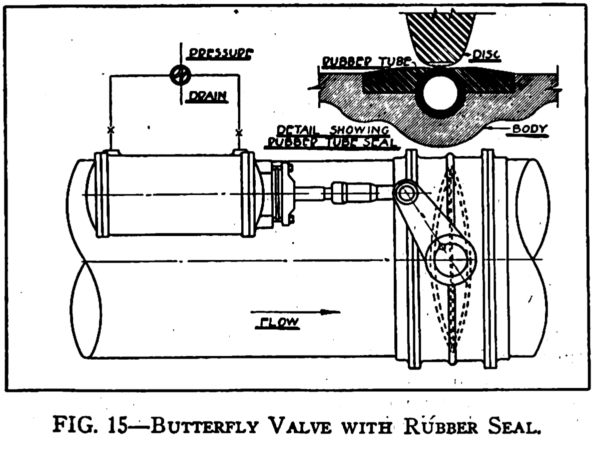


FIG. 15—BUTTERFLY VALVE WITH RUBBER SEAL.

Butterfly Valve with Rubber Seal

Fig. 15 shows the general outline of a hydraulically operated butterfly valve and an enlarged detail illustrating the manner in which the rubber seal is expanded against the edge of the valve disk. The rubber is held in position by suitable strips which are removable in case it should ever be necessary to replace the rubber.

MEMORANDUM REGARDING EMERGENCY CLOSURE OF JOHNSON VALVE FOR NO. 15 UNIT AT ONTARIO POWER CO., NIAGARA FALLS, ONTARIO

Written by G. O. Phelps, Supt.

The valve is a 9-ft. diameter type B Johnson valve operating under a static head of 60 ft. and designed to withstand a total head of 90 ft. This valve is used to cut off the supply of water to No. 15 unit at the Ontario Power Company, Niagara Falls, Ont.

The valve was installed and placed in commercial service June 19, 1919, and was used on an average of once in two weeks for shutting down the unit.

On April 20, 1922, an accident happened to the unit, resulting in a broken wheel casing, and the valve was used to cut off the flow of water which was pouring on to the

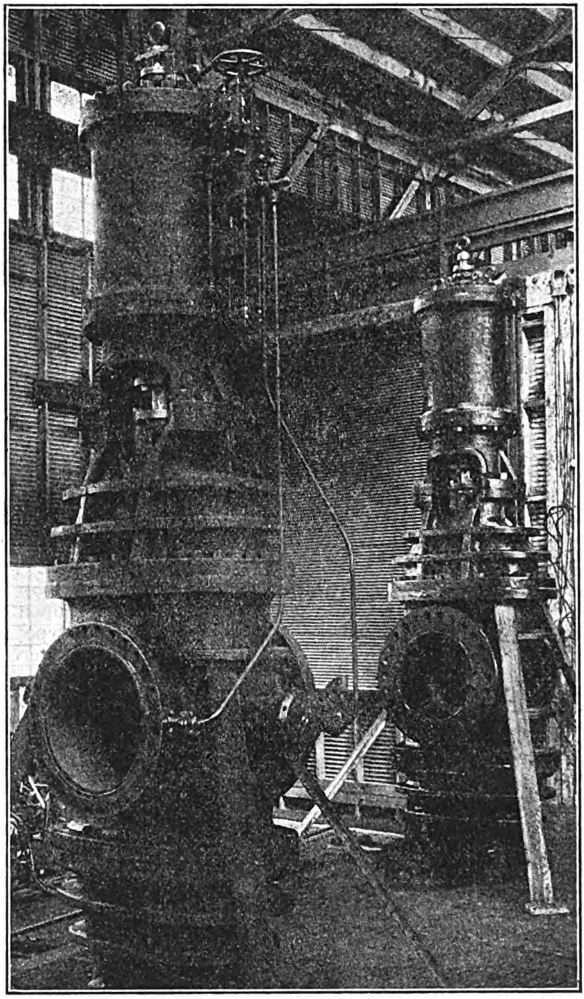


FIG. 16—28-IN. PELTON HYDRAULICALLY OPERATED FOLLOWER RING GATE VALVES.

main power house floor. An interval of approximately four minutes elapsed from the time that the casing was broken until the valve was shut, three minutes of this time being necessary to telephone operator and allow him to reach the valve.

The valve was closed without any trouble at all, its closing characteristic in this emergency being the same as for ordinary operation. The water was discharging through the outlet of the valve at approximately spouting velocity.

The value of this service in an emergency might be best illustrated by stating that if it were not for the quick and safe operation of the valve there would have been ten additional 11,000 h.p. generators flooded and rendered unfit for service for a period from three to four months. The loss of this power over such an extended period, involving not only loss in revenue and the cost of putting the machines back into service, but also the resulting loss to manufacturers and customers who would be forced to close down during this period is an item, the amount of which would total up into the millions.

The valve was left in the closed position and was not touched for a year and a half, during which time the unit was rebuilt and this end of the power house restored to its original condition. On Dec. 1, 1923, the unit was completed and the Johnson valve opened to prime the penstock and supply water to the turbine. It is interesting to observe that the valve opened in exactly the same manner as though it had been in regular operating service, in spite of the fact that the manufacturers advise the operation of this type of valve at least once a month. The sliding surfaces consist of brass plate against cast iron and in spite of its long period of idleness, there was not enough corrosion on the cast iron to have the slightest effect on the opening of the valve. It might also be added that during the year and a half of rebuilding the unit the penstock below the valve was perfectly dry, there being no leakage whatsoever around the valve seat.

The valve is normally opened in about one to two minutes and closed in about one minute, and the priming of the penstock is accomplished by just cracking open the valve and allowing it to remain in this position until the penstock is completely full of water. This particular valve and others like it in this plant are not equipped with the automatic closing device which is being used on the valves manufactured today. Had this been in use at the time these valves were purchased it is believed that the valve would have closed instantly following the break and the flood in the power house would have lasted for a space of about one minute rather than four minutes.

STATEMENT BY THE PELTON WATER WHEEL COMPANY*

High Head Penstock Valves

In the fall of 1928 this company completed shop test and successfully finished an exhaustive field test upon two 28-in. hydraulic cylinder operated follower-ring type gate valves with automatic hydraulic controls. These were installed at the El Dorado Plant of the Western States Gas & Electric Company on the American River, California, and operate under a head of 2111 ft., for which a test of 1575 lb. per sq. in. was required. They were operated under conditions approximating as closely as possible, emergency closure under unbalanced conditions, and were found to perform with entire satisfaction.

In addition to these two gate valves, four 32-in. hydraulic cylinder-operated gate valves have just been put into service for controlling main power water supply to two of this company's double overhung water-wheel units, carrying loads in excess of 45,000 h.p. each under a head of 2230 ft. These are for the Serra Plant of the Sao Paulo Tramway, Light & Power Company not far from Santos in Brazil.

A recently completed contract for the Feather River Power Company includes five 26-in. hydraulic cylinder-operated gates with automatic hydraulic control of our patented type. Four of these valves are for main power house control to two 30,000 h.p. double overhung Pelton water-wheel units, and the fifth is for shut-off purposes in a cross-connected pipe upstream of the water wheel gates.

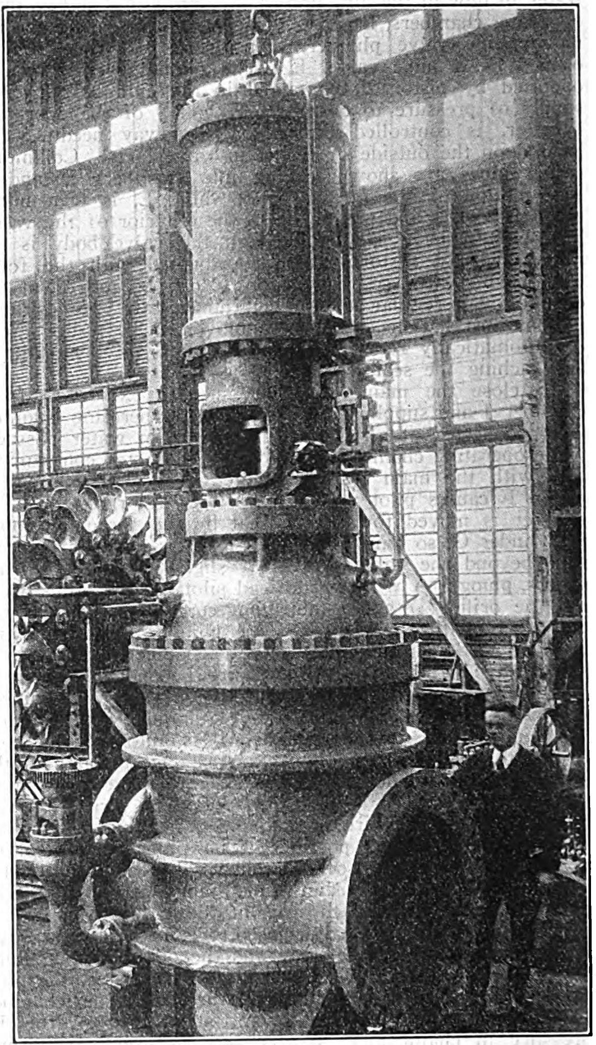


FIG. 17—32-IN. HYDRAULICALLY OPERATED GATE VALVE.

In addition, a Pelton water-motor-operated gate valve is being constructed for operation under 1400-ft. head. This is the fifth gate valve of this kind in use at the Drum Power House of the Pacific Gas & Electric Company.

Butterfly Valves

Recent installations of butterfly valves for penstock purposes include three 108-in. for main power water control to three 33,000 h.p. Pelton turbines at the Pit No. 3 plant of the Pacific Gas & Electric Company. The highest known head to which a butterfly valve has been used as a main stop penstock control, it is believed, is the one at the Oak Grove Plant of the Portland Electric Power Company. This valve operates under 930 ft. head and controls water supply to a 35,000 h.p. vertical turbine. Butterfly penstock valves are under construction in our shops at the present time for heads as high as 700 ft.

Most of these valves are electric motor operated, although one recently completed and installed for the Glines Canyon Plant of the Northwest Light & Power Company is hy-

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* Accompanying this statement are a number of illustrations of the various types of valves listed.

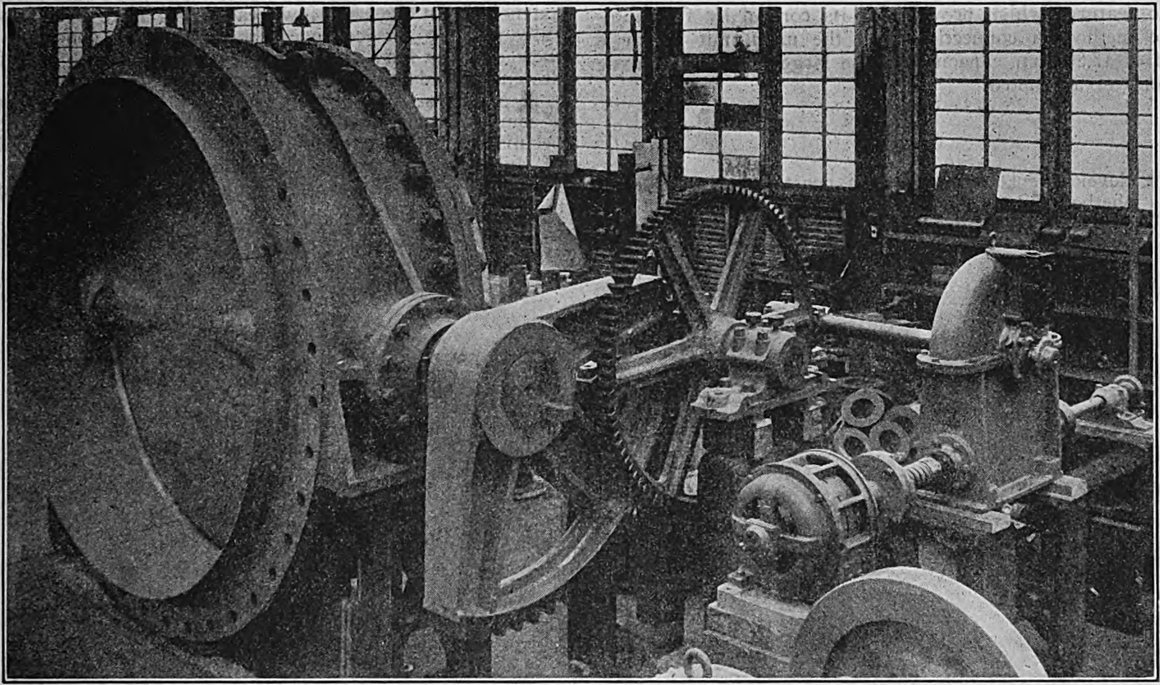

FIG. 18—108-IN. PELTON BUTTERFLY VALVE FOR WATER MOTOR AND ELECTRIC MOTOR OPERATION.

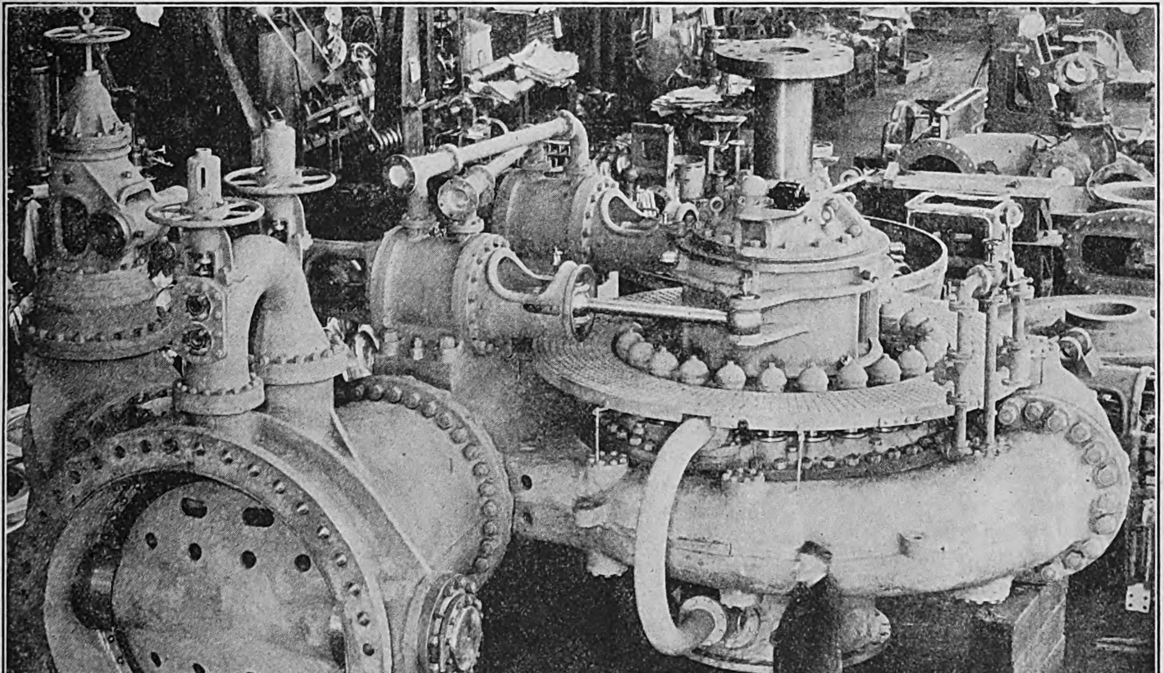

FIG. 19—MAIN INLET BUTTERFLY VALVE AT OAK GROVE PLANT OF PORTLAND ELECTRIC POWER CO., HEAD 930 FT.

draulic cylinder operated and is fitted with several automatic features which provide for its control by full automatic method in connection with the main unit which is itself of 17,500 h.p. capacity and the largest single automatic station yet attempted.

General

The developments and design of penstock valves for all heads whether high or low and whether of gate valve, Johnson needle valve, or butterfly valve types, have been perfected extensively in the past few years. All have been successfully put into service under the most trying conditions and their controls have been made extremely safe. All of the designs are adaptable to automatic plant operation.

A selection of a proper valve for any service requires a complete understanding of all of the conditions that are peculiar to each individual installation. It is the opinion of this company that no conclusion as to the proper penstock valve for any service should be reached without individual study.

SPILLWAY GATES ON OR ADJACENT TO DAMS

INTRODUCTION

An abundance of excellent material in the form of articles and papers published on the subject of spillway gates, or directly contributed by members of the Committee, was available for this report. The problem has been that of selection and reduction, with the idea always foremost in mind to produce a report that would include typical examples of the several types of gates under consideration, and at the same time reflect the best engineering practice in the different parts of the United States and Canada. Considerable valuable information also was gathered from European sources. It is realized that the report does not begin to cover the field of spillway gates, either from the standpoint of examples, or with respect to all the details that enter into the design and construction of a single type of gate. Time and available means for publication both precluded an attempt at too complete a treatise on the subject. Not the least among the useful features of the report is the bibliography found at the end. The scope of the subject is at once apparent when one considers that the extensive bibliography includes only matter published during the past five or six years.

It should be pointed out here that the report is confined to the design, construction and operation of spillway gates in actual use by operating companies. An endeavor has been made to select typical installations and types of equipment which might be of interest and value to operators and designers of such gates. Some data have been taken from the 1924 report of the Hydraulic Power Committee of the N. E. L. A. without specific reference.

There is an increased tendency to install permanent and substantial crest gates on dams rather than renewable flashboards. Clear-crest dams have become the exception rather than the rule. There still remains considerable room for improvement in the design of deep-crest gates and their operating mechanism to insure simple and reliable operation and low maintenance, as well as low first cost. Recent floods in several sections of the country, particularly in California, with intensities of runoff in many cases more than twice as great as any previously recorded, have shown the necessity for more liberal design and substantial construction of crest gates.

Spillways

Location—The location of spillways is governed mainly by topographic and foundation conditions and type of dam. Often questions of cost and economy may influence the location. These factors will also determine whether the spillway shall be located on or separate from the dam. The siphon type of spillway is usually located in the main dam structure.

In many cases it may be desirable to locate the spillway away from the main dam because of the erosive action of the overpour. In the case of storage reservoirs this is often possible because many storage dams are built to the same height as the surrounding ridges, where a saddle may be found through which the spillway can be constructed. If no such saddle exists, it becomes necessary to blast a spillway channel out of the rock adjacent to the dam.

At the Davis Bridge dam of the New England Power Company and the Gibson and Owyhee dams of the United States Reclamation Bureau, circular, funnel-shaped spillways were constructed. The spill is designed to discharge into a vertical shaft, which is connected directly to a concrete-lined tunnel. The Davis Bridge spillway is controlled by flashboards which may be removed during floods by tripping a latch. The Gibson spillway is not gate-controlled, but provision has been made in the design so that drum gates may be installed at some later date, thus increasing the storage capacity by 15,000 acre-ft. without raising the crest of the dam. The Gibson shaft and tunnel are 29.5 ft. in diameter and have a capacity of 50,000 sec.-ft. The Owyhee dam is controlled by a ring gate. The shaft has a diameter of 22.5 ft., while that of the tunnel is 22 ft., giving a capacity of 30,000 sec.-ft. when the lake is at its normal level.

Where the spillway cannot be placed on the dam and no natural site is available, the side-channel spillway often is used, as at Don Pedro, Arrowrock, McKay and Tieton dams. This type of spillway often effects a saving in excavation and the spill is discharged well away from the dam.

For diversion dams the problem of separating the spillway from the main dam becomes more difficult for the following reasons: (1) The dam usually is low and the topography of the surrounding country does not as a rule offer a suitable site; (2) the diversion dam usually is located lower down the stream, has a greater drainage area above it and has to pass greater floods than the storage dam. Therefore, it becomes difficult to construct economically a separate spillway, owing to the larger dimensions required, and recourse is made to an overpour diversion dam. The relatively smaller height of diversion dams fortunately lends itself to the crest type of spillway.

Where the spill is over the crest of a masonry dam the normal seasonal flood should be confined to the center of the structure, where the excess energy may be dissipated in a stilling basin. The stilling pool may be either natural or artificial. To obtain additional spill capacity for the exceptional flood, gate openings may be provided on each side of the center and used only during such floods. This will protect the abutments of the dam from continual seasonal wear.

Much study has been given to the design of dam aprons to prevent erosion of the foundation at the toe. The Conowingo, Norwood and Pit River No. 3 and No. 4 dams are notable examples of apron design based on experimental research. An auxiliary dam was constructed downstream from the

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Publication No. 289-84, Serial Report, Hydraulic Power Committee.

main Martin dam, forming a pool, or cushion of water, 22.5 ft. deep. This pool is designed to destroy the energy of the water flowing over the portion of the spillway which will be used normally.

Formulas and Coefficients—A spillway of the simplest type consists of an unobstructed overflow, the water rising and spilling over the crest as the flow increases. There is a great divergence of opinion regarding the coefficient of discharge for the usual spillway crest. It is the common opinion that 3.33 is too low a value for "C" for spillways of any appreciable depth. As pointed out in *Engineering News-Record,* Vol. 99, No. 4, a large coefficient is found because the depth of flow over the weir usually is measured too close to the crest. If the head is measured at the proper distance upstream so that the velocity head is negligible the formula for discharge may be expressed as:

$$Q = 3.087\ L\ H^{3/2}$$

Where Q = discharge in sec.-ft.
H = head on crest in feet (measured at a point above drop in nappe).

W. F. Martin formula deduced from stream gaging of the U. S. G. S.; *Engineering News,* Sept. 29, 1910, p. 321:

Merced Dam .... $Q = 2.491\ L\ H^{1.77}$
Austin Dam .... $Q = 3.196\ L\ H^{1.59}$
Yakima Dam .... $Q = 3.110\ L\ H^{1.65}$
La Grange Dam .... $Q = 3.088\ L\ H^{1.5}$

If the formulas are recomputed to show the variation in the value "C" in the formula $Q = CLH^{3/2}$, the results given in Table I are obtained. With the exception of the La Grange dam, which is curved in plan, the coefficient increases as the head increases.

TABLE I

VALUES OF "C"

Head, ft.	Merced Dam	LaGrange Dam	Austin Dam	Yakima Dam
0.5	2.065	3.088	3.003	2.803
1.0	2.491	3.088	3.196	3.110
1.5	2.780	3.088	3.315	3.305
2.0	3.003	3.088	3.402	3.451
2.5	3.190	3.088	3.473	3.568
3.0	3.352	3.088	3.524	3.668
4.0	3.623	3.088	3.620	3.829
5.0	3.849	3.088	3.694	3.960
6.0	4.041	3.088	3.754	4.071

The following values of "C" were found by current meter measurements of the flow over the spillway of the Sherman Island plant of the International Paper Company. This spillway dam is built in the form of a horseshoe and is described in detail with the plan and profile shown in Fig. 2 and 11, respectively, of the paper by H. de Parsons in the *Transactions A. S. C. E.,* Vol. 88, 1925.

H	C
0.5	4.26
1.0	3.39
1.5	2.99
2.0	3.19
2.5	3.34
3.0	3.52
3.5	3.66
4.0	3.79
4.5	3.90

In designing the spillway for the Grand Lake dam, Newfoundland, the formula $Q = CLH^{1.5}(1 - 0.05\ n\ H)$ was used to calculate discharge. The crest was favorable for flow, and the piers were thin and pointed. The coefficient "C" varies from 3.30 to 3.90 with heads from 1 ft. to 10 ft., and "n" denotes the number of end contractions.

Discharge measurements were made on the spillway of the Keokuk dam to determine an accurate spillway rating. These studies were supplemented by tests on a laboratory model. Volumes of flow averaging about 4000 sec.-ft. were measured in the 30 ft. of spillway width with the normal operating head of 10.8 ft. It was found that opening the gates adjacent to the spillway where the water was being measured had a very marked effect on the discharge coefficient, tending to increase the discharge for a given head. In the formula $Q = CLH^{1.5}$, the coefficient "C," for the normal operating head of 10.8 ft., varied from 3.71, when a single spillway was discharging, up to 3.90, when many spillways were discharging. The gagings also showed clearly that with a crest unobstructed by piers, "C," for a 10.8-ft. head, increased to 4.00.

The experiments on the laboratory model duplicated the results observed at the dam with remarkable reliability. Experiments were performed on the model when its surface was both smooth and rough, and with and without a fill of sediment upstream from the dams. Results showed that the relative amount of friction caused by the varying surface conditions of the model was of small significance.

The effect of piers upon discharge is best estimated by considering that each pier causes end contraction, thus more or less diminishing the effective length of the spillway crest, depending on whether the upstream nose of the pier is rounded or abrupt. The Keokuk tests showed that extending the pier nose upstream, or giving it a tapered form so that it attained its full thickness a short distance downstream from the highest part of the spillway crest, increased the discharge. The recommended reduction for each contraction, verified by the Keokuk tests, is 0.04 H for sharp-nosed piers and 0.1 H for thick, blunt piers.

Crest Regulation

Crest regulation is necessary where it is desired to keep the pond level as high as possible during periods of low or moderate stream flow (either to gain additional storage or additional head) and at the same time to allow flood flows to pass without raising the pond level to a dangerous height.

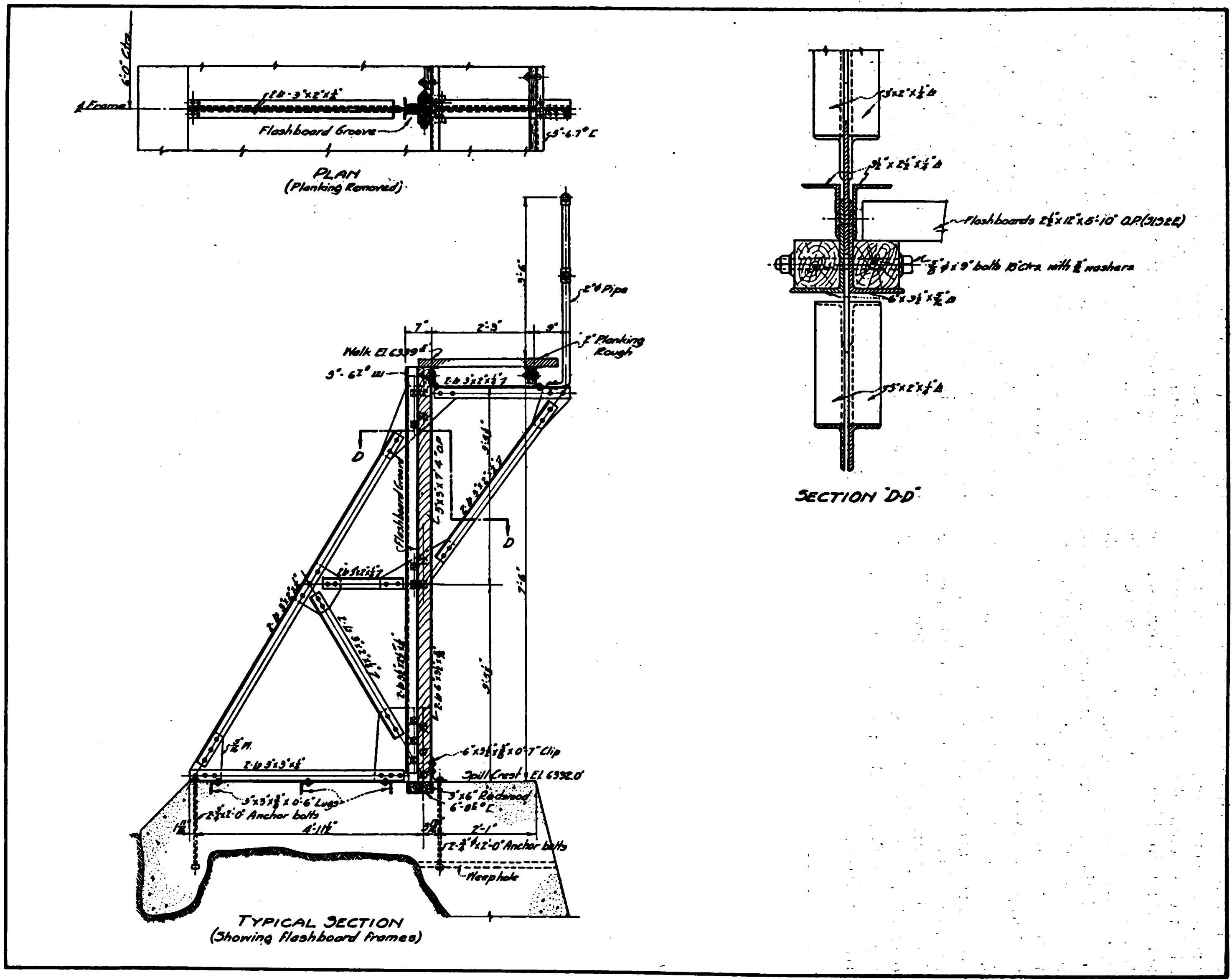

6'-0" Ctrs.
℄ Frame
2-L 3"x2"x¼"
Flashboard Groove
5"-6.7# [
PLAN
(Planking Removed)
2"⌀ Pipe
2" Planking Rough
7"
2'-3"
9"
9'-6"
Walk El. 6339.5
5"-6.7# [
2-L 3"x2"x¼"
D
Flashboard Groove
5"x5"x7'4" O.P.
7'-6"
9'-5½"
6"x3½"x⅝"x0'-7" Clip
Spill Crest El. 6332.0
3"x6" Redwood
6"-8.2# [
3"x3"x⅜"x0'-6" Lugs
2-⅞"x2'-0" Anchor bolts
4'-11½"
2'-1"
2-¾"x2'-0" Anchor bolts
Weephole
TYPICAL SECTION
(Showing Flashboard Frames)
3"x2"x¼" L
3½"x2½"x¼" L
Flashboards 2½"x12"x5'-10" O.P. (3132E)
⅝"⌀x9" bolts 15" Ctrs. with ⅝" washers
6"x3½"x⅝" L
3"x2"x¼" L
SECTION "D-D"

FIG. 1—FLASHBOARD SPILLWAY, LAKE FORDYCE DAM, PACIFIC GAS & ELECTRIC CO.

For cases where water is very valuable it is essential to adopt a type of control that is tight and will not waste the flow during periods of drought. For rivers containing much ice or a large amount of debris during floods, the crest must be unobstructed or provided with piers that are sufficiently far apart to prevent stoppage. It is obvious that the need for close control is greater in low-head developments than in high-head plants because, for the latter, a few feet variation of head affects the output a relatively small amount. Devices that only partly control the fluctuations frequently are used since they are relatively less expensive, but the tendency is toward more complete regulation of diversion and storage reservoirs.

Flashboards, Needles and Stop Logs—Flashboards ordinarily are used on storage reservoirs to conserve water, but they are not adaptable for flow regulation. They are put in place on the spillway crest to catch the last of the excess runoff and at such time as the inflow to the reservoir about equals the draft therefrom.

Where the dams are of concrete and can stand a slight overtopping, the spillway is flashed to the height of the dam. If the dam is of rock-fill, a minimum freeboard of about 3 ft. is allowed, and if of earth, a minimum of 5 ft. or more is maintained. Gates for controlling spillways for rock-fill or earth fill dams should be of positive action, as the failure of the dam by overtopping would follow the failure of the gates to function when needed in an emergency. Where lake tenders are in constant attendance, the feature of positive action is not of such importance, providing it is possible manually or otherwise to open the gates under all circumstances. Many old rock-fill and earth dams in California are protected by flashboard spillways and have given years of continuous service. These spillways have been zealously watched during the run-off season, and care is taken in placing the flashboards to be certain that the end of the run-off peak has been reached. In some emergency cases it has been necessary to use dynamite to remove the flashboards quickly, when an unexpected flood peak occurred,

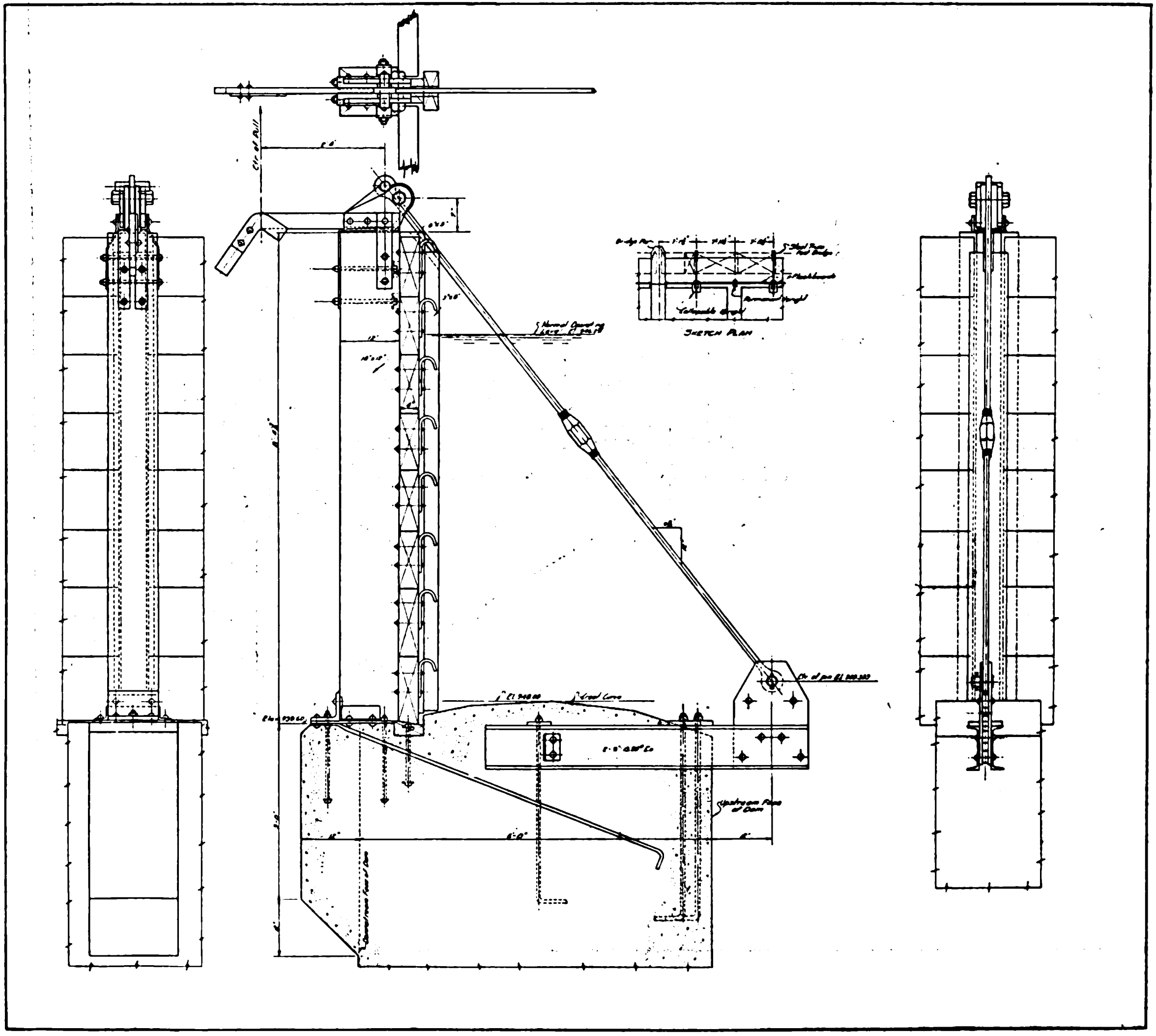


FIG. 2—COLLAPSIBLE FLASHBOARD, KERN CANYON DAM, SAN JOAQUIN LIGHT & POWER CORP.

or to remove debris which threatened to choke the narrow spillway openings. In that case it usually is impossible to replace the flashboards, and the upper part of the reservoir storage is lost for that year.

On diversion dams the normal use of flashboards is to cheaply increase the head on the plant, and they must be supplemented with more easily operated gates for the regulation of flow.

A simple type of spillway where the flashboards are adjusted by hand is shown in Fig. 1. In this design the walkway is placed on the opposite side from the A-frame support. This arrangement permits the line of flashboards to be located closer to the spill lip than in the usual type. When the openings are partially flashed, the sheet of overflowing water then will clear the spill crest. The flashboards rest against wooden shoulders fitted and bolted to the upright steel members of the frame. The flashboard openings are limited to 6 ft., the maximum size one man is considered capable of handling.

The spillway for the Crane Valley rock-fill dam of the San Joaquin Light & Power Corporation is a concrete structure consisting of four bays, each 17.6 ft. long and separated by 2-ft. piers. The crest, which was formerly controlled by flashboards, has been reconstructed to insure more positive control. Manually operated radial gates have been fitted in two bays. These will serve for all ordinary regulation. The other two bays are controlled by collapsible flashboards, three sets being placed in each bay in H-column supports. The boards are normally added or removed by hand. In emergency, when the flow cannot be handled by the two radial gates, a link device on top of the collapsible supports, which are hinged at the bottom, can be tripped, thus allowing all the flashboards to go out. When the emergency has passed, the collapsible supports are erected again and new flashboards placed. A study of runoff and operating records indicated that the possibility of having to trip out the flashboards to take care of an emergency flood was very remote. If conditions were otherwise the arrangement would not be considered satisfactory.

The forebay pond of the Kern Canyon plant of the same company is controlled by collapsible flashboards, as shown in Fig. 2. Ordinary crest regulation is maintained by adding or removing flashboards by hand. This is accomplished by engaging hooks on the flashboards in an iron yoke fastened to a long handle. It is necessary to use a chain block supported from the steel truss spanning the dam for pulling the lower boards. In emergency, the device on top of the collapsible posts can be tripped, thus allowing all the flashboards to go out. The boards and wooden posts are prevented from being washed away by chains which fasten them to the I-beam posts. When the emergency passes, the collapsible posts are erected again and the flashboards replaced.

The Big Bend diversion dam of the Great Western Power Company is provided with 10-ft. needles to increase the pondage and head during the low-water season. The length of the arched crest is 330 ft. The 4-in. Oregon pine needles are beveled from 7¾ to 7⅜ in. in width to facilitate removal and are supported on timber frames bolted to angle irons curved to fit the ogee of the dam.

It is proposed to use needles for crest regulation when the Merced Falls dam of the San Joaquin Light & Power Corporation is reconstructed. The 6 in. x 6 in. x 11 ft. timber needles will rest at the bottom on a structural steel angle and bear against the concrete of the dam, while at the top they will be supported by means of an I-beam attached to a structural steel A-frame, as shown by Fig. 3.

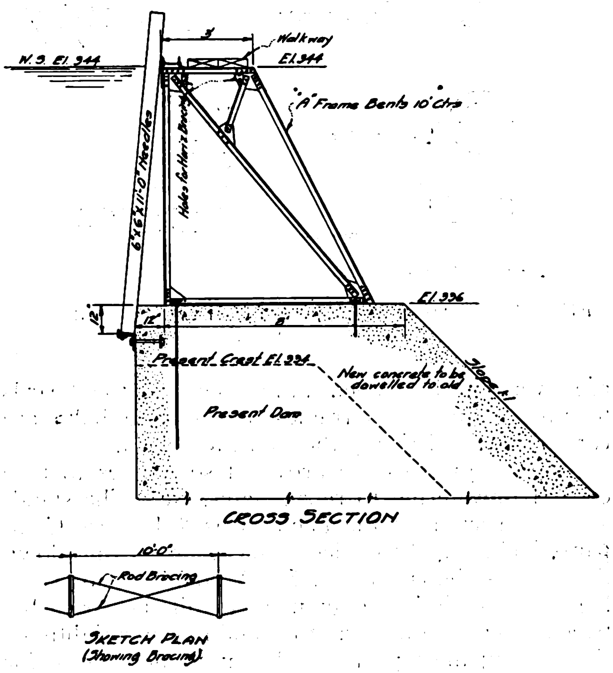


FIG. 3—PROPOSED NEEDLE SPILLWAY, MERCED FALLS, SAN JOAQUIN LIGHT & POWER CORP.

In cold climates ice has caused serious trouble with needle spillways. If ice is allowed to freeze to the needles, they are lifted over the sill when the pond level rises and the diversion will be lost temporarily. Operators are required constantly to prevent ice formation on the needles.

The simplest form of flashboard control consists of a series of panels supported by pins or pipes which are inserted loosely in holes in the top of the dam. The pins are designed to bend over and loosen the flashboards when the water surface in the pond reaches a certain elevation, thus automatically lowering the crest to pass floods. The boards are fastened loosely to the supports and are lost when the supports bend over, unless removed before anticipated high water. Various tripping devices have been used to allow the flashboards to be opened, but not carried away in case of emergency, the Hinckley type being illustrated in Fig. 4.

A variation of the pin support is an A-frame held in place by anchor and release bolts. The bolts are designed to fail in tension when the flashboards

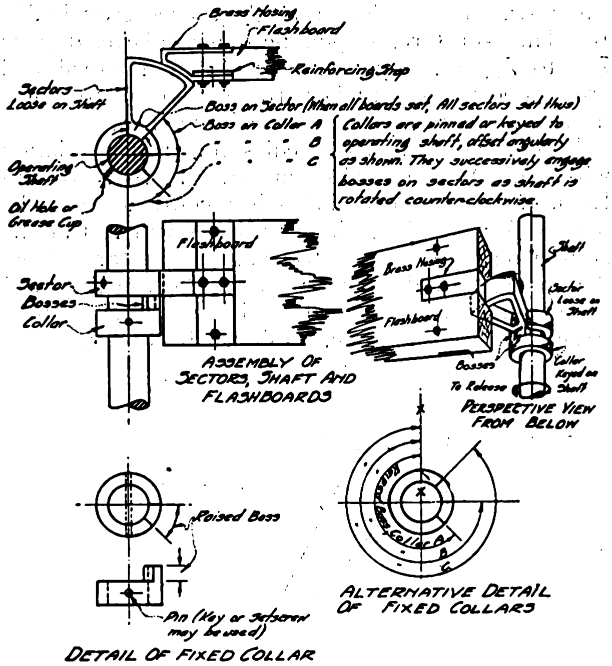

Brass Hosing
Flashboard
Reinforcing Strap
Sectors Loose on Shaft
Boss on Sector (When all boards set, All sectors set thus)
Boss on Collar A
" " " B
" " " C
Collars are pinned or keyed to operating shaft, offset angularly as shown. They successively engage bosses on sectors as shaft is rotated counterclockwise.
Operating Shaft
Oil Hole or Grease Cup
Flashboard
Sector Bosses
Collar
ASSEMBLY OF SECTORS, SHAFT AND FLASHBOARDS
Brass Hosing
Flashboard
Shaft
Sector Loose on Shaft
Bosses
Collar Keyed on Shaft
To Release
PERSPECTIVE VIEW FROM BELOW
Raised Boss
Pin (Key or Setscrew may be used)
DETAIL OF FIXED COLLAR
Raised Boss
Collar A
B
C
ALTERNATIVE DETAIL OF FIXED COLLARS

FIG. 4—DETAILS OF HINCKLEY TYPE, COLLAPSIBLE FLASHBOARDS.

are overtopped. When failure occurs, the boards together with the A-frames and release bolts are carried away, leaving the spillway clean.

Stop-log grooves are provided sometimes to take care of unwatering to repair gates, etc. The standard construction of the Pacific Gas & Electric Company, including the device to facilitate jacking down the logs, is shown in Fig. 5. A double set of stop-logs is used, it being intended to fill the space between them with dirt to obtain water-tightness. Some companies prefer slide or Stoney gates for similar purposes, due to the saving in time in case a unit is out of order, and again because the stop-logs, which may have been provided when the plant was constructed, often are warped and sometimes even used for other purposes. At the Conowingo dam guides were set in the piers to receive a 22.5 ft. x 40 ft. service gate, which will be handled by a gantry crane. This gate is of the fixed roller type and will be used to close the gate-opening when it is necessary to remove one of the crest gates for painting or repairs.

A compressed air system for preventing ice formation along spillway flashboards has been in successful operation since 1925 at the Norway plant of the Indiana Hydro-Electric Power Company. Spillway control works consist of three Stoney gates and an overfall spillway 225 ft. long. This spillway has an ogee section, the crest of which carries 2 ft. of flashboards supported on steel pins. Pond level is generally carried within 6 in. of the top of these boards, and if ice were allowed to form against the boards they would soon be carried away. In the past an open channel had been maintained along the boards by hand chopping, the men standing on the narrow ledge behind the boards.

Hand chopping was hazardous and expensive, and the compressed air system was installed. Air is supplied to a 1¼-in. header pipe by an electric, motor-operated compressor having a capacity of 13 cu. ft. of free air per min. at a pressure of about 10 lb. per sq. in. The air nozzles, which are pipe caps with proper sized holes drilled in them, are spaced on 10-ft. centers; ⅜-in. drop pipes being used to fix the outlets about 20 ft. below the water level. The outlets are graduated in size from 1/32 in. nearest the supply to 5/32 in. at the farthest outlet. An open channel 4 to 8 ft. wide is maintained in front of the flashboards in the most severe weather. No trouble arises from drift ice because the velocity in the pond is very low.

Slide Gates—Sliding lift gates are seldom used for crest regulation because of the large capacity of the hoist required to overcome the friction in raising and lowering. Usually it is found more economical to use fewer piers and to adopt a larger sized gate of a type more easily operated.

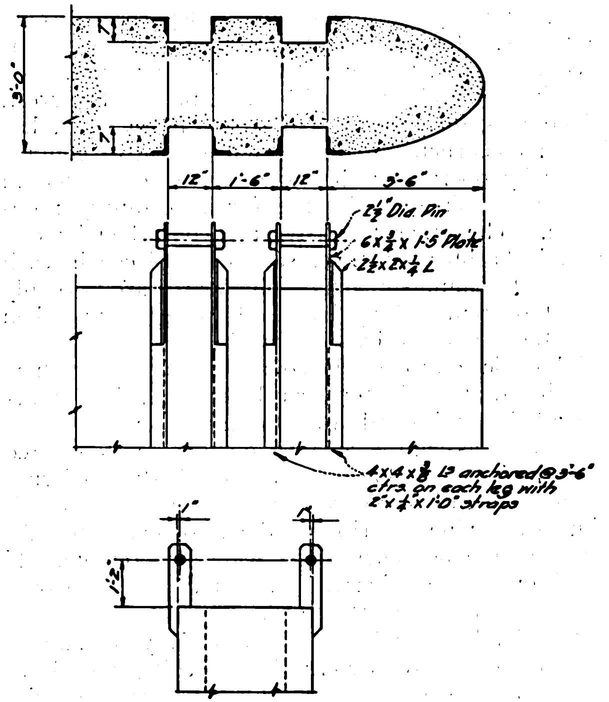

3'-0"
12"
1'-6"
12"
3'-6"
2½" Dia. Pin
6 x ¾ x 1'-5" Plate
2½ x 2 x ¼ L
4 x 4 x ⅜ Ls anchored @ 3'-6" ctrs. on each leg with 2" x ¼ x 1'-0" straps
1"
1"
1'-2"

FIG. 5—STOP LOG GROOVE DETAILS, PACIFIC GAS & ELECTRIC CO.

The steel gates on Keokuk dam are of the plain sliding variety without rollers. They are 11 ft. high and 32 ft. wide, and operate in slots 14 in. deep in the concrete piers. The gates, see Fig. 6, are finished on the bottom with a timber sill, which makes the water seal against the carefully finished concrete crest of the dam. The gates are raised by electrically operated traveling cranes and are always lifted clear of the water surface, so that a spillway discharges to its full capacity. There are, in all, 119 spillway sections.

Radial Gates—Tainter, or radial, gates are perhaps the type most commonly adopted for use on

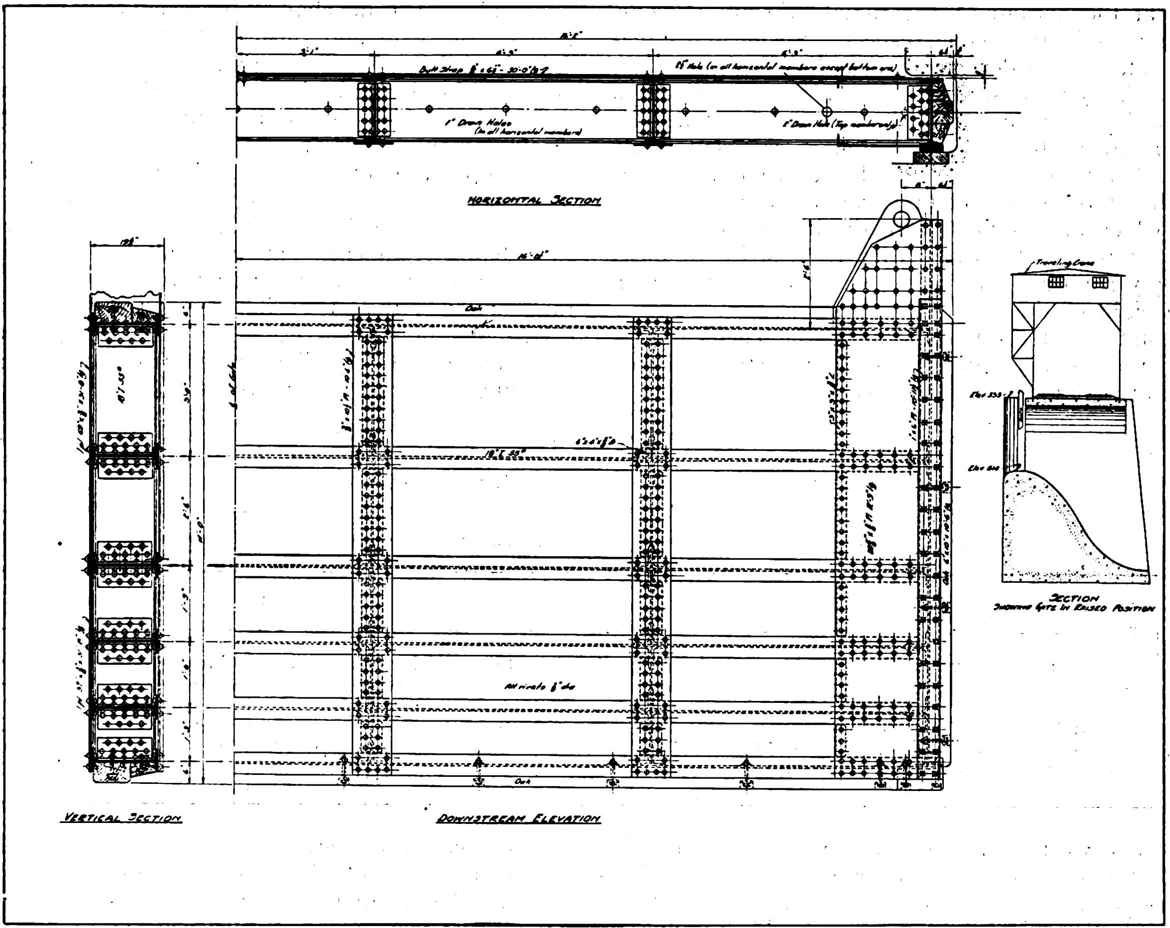


FIG. 6—DETAILS OF STONEY GATES, KEOKUK DAM, MISSISSIPPI RIVER POWER CO.

dams controlling medium-sized drainage areas where floods are not excessive.

In general radial gates for large hydro-electric or irrigation developments must be designed for the particular use to which they will be put. Manufacturers' standard sizes may be obtained in stock from 4 ft. wide x 3 ft. high to 12 ft. wide x 7 ft. high. Where stock sizes and details are applicable some economies may be effected by their use instead of special designs.

Operating mechanisms vary from the individual hand-hoist for the smaller sizes to motor-operated hoisting cars where a series of large radial gates are installed side by side. In either case the gate is lifted by ordinary plough-steel cables, special flat plough-steel cables, or hoisting chains which wind on drums. Where very large chain is used, it may be preferable to pass it over a toothed sheave and permit it to pile up on the floor. Two sources of power are desirable to insure continuity of supply. Auxiliary gas engines generally are considered undesirable. Hand power should be provided wherever practicable. Ordinarily no mechanical effort is required to lower a radial gate, the weight being sufficient to overcome friction.

The introduction of a worm-gear in motor-operated lifting mechanism is highly desirable to safeguard against a sudden power shutdown and dropping of the gate. Care should be taken, however, to avoid high-speed worm-gear reductions; much trouble has been experienced by heating of this type of drive with resulting binding and cutting.

Radial gates may be made practically watertight if care is used in setting and adjusting the gate on its bearings and in selecting the type of side and bottom seals and in setting them. The usual side seal is a piece of rubber belting bolted to the upstream face of the gate and held against a rubbing surface on the side wall or wall guides by the pressure of the water. Rubber side seals range from 6 in. wide, 3-ply strips for heads up to 6 or 8 ft. to 7 in. wide 8-ply strips for heads up to 20 ft. The rubbing surface generally is a channel-beam curved to fit the face of the gate and flush with the side walls of the water channel. The bottom seal for gates with wood faces frequently is a wooden sleeper flush with the bottom of the channel and against which a special bearing block on the bottom of the gate sets.

Wood sills are likely to be bruised by ice or logs shooting under the gate as it is being opened. It is advisable, therefore, particularly in large installations, to use an iron or steel sill. If a small amount of leakage is not a serious objection, the steel knife edge at the bottom of the radial gate offers some advantages in the above respect. Such an installation entails considerable care and difficulty in setting. A more desirable type of bottom seal is a double layer of rubber belting securely fastened on the upstream bottom edge of face and extending somewhat beyond it. These layers fold under the weight of the gate and press against a channel-iron seat which also is flush with the bottom surface of the masonry. The layers vary from strips of 3-ply to 5-ply rubber, 4 in. to 5 in. wide, depending upon the weight of the gate.

Results of tests to determine the coefficient of friction of rubber belting on structural steel and concrete are tabulated in Table II.

TABLE II
FRICTION COEFFICIENT OF 5-PLY RUBBER BELTING

Load Lb. per sq. in.	New Structural Steel				Rusty Structural Steel				Concrete			
	Dry		Wet		Dry		Wet		Dry		Wet	
	Start	Move	Start	Move	Start	Move	Start	Move	Start	Move	Start	Move
4	0.52	0.47	0.80	0.80	0.88	0.82	0.88	0.83	0.67	0.65	0.56	0.50
8	0.53	0.50	0.75	0.75	0.79	0.75	0.88	0.83	0.72	0.70	0.70	0.65
12	0.48	0.42	0.73	0.73	0.75	0.73	0.82	0.80	0.62	0.60	0.70	0.63

Results of the various trials were fairly consistent. On steel there is a decrease in the coefficient of friction as the load increases. When the surfaces are wet, the friction is increased evidently due to the vacuum effect.

Bullards Bar dam of the Pacific Gas & Electric Company is equipped with radial gates for the regulation of spillway (see Fig. 7). There are 19 gates each 10 ft. wide x 20 ft. long. These gates were designed for an existing dam in which journal-box holes were already provided. A county roadway over the gate openings made the design difficult. Chain boxes were set in the concrete roadway in which the excess chain may be stored when the gates are lifted, so that obstruction to traffic may be avoided. These gates were designed to give a maximum free opening when lifted in order to permit legs and debris to pass without striking the framework. In March, 1928, a flood of 57,000 sec.-ft. was passed, with a depth of water of 13.8 ft. on the crest. No damage was done to the gates or dam. Each gate journal boxing was made separate to permit the gates to be adjusted independently. The gates are motor-operated from a hand-drawn dolley car. Each gate weighs about 8500 lb.

Regulation on the Kerckhoff Diversion dam of the San Joaquin Light & Power Corporation is accomplished by 14 radial gates 20 ft. wide x 14 ft. 4 in. high. The piers on the crest vary from 1 ft. 10½ in. to 3 ft. 9 in. thick. They are approximately 21 ft. high and are spanned by a reinforced concrete operating platform 8 ft. wide provided with an iron railing for protection. The rubbing surface for the side seals is a 6-in. channel-beam curved to fit the face of the gate and flush with the side walls of the water channel. Twelve-in. stop-log grooves are provided in the piers in front of the gates; these are used only in case of an emergency or if gate repairs become necessary.

The operating track is of 50-lb. rail imbedded in the concrete on a 36-in. gage. Slots 6 in. x 1 ft. 10 in. are provided in the platform through which two chains from each gate pass up to be engaged by the operating mechanism when it is desired to raise or lower the gates. The gates are operated by a traveling hoist (see Fig. 8) using electric power from an overhead trolley system for hoisting and traveling. In case the power supply were cut off, the hoist can be operated by hand. The gates, which may be used at a maximum head of 14 ft., give very little trouble from leakage and are easily operated. Some little trouble was experienced at first by the chains breaking. This was eliminated by the use of heavier chains. The gates are designed to withstand the normal pressure due to a maximum head of 19 ft. plus 25 per cent for impact. The weight of each gate is approximately 14,500 lb.

Crest regulation at the Prospect dam of the California Oregon Power Company is accomplished by steel radial gates. The gates are operated through remote control from the power house. Hand control is provided for emergency use. In addition, slide gates, or undersluices, are interlocked with the radial headgates, it being expected that the radial spillway gates need be operated only to care for flood discharge. Hoist chains are of extra-strength steel, but it is thought that an equalizer between lifting chains would work to advantage. There is a small roller at each upper corner of the gates to prevent binding during raising. The shaft of the hoisting drum is placed on an inclined plane to reduce the angle between the hoisting chain and the gate during the process of lifting. All motor-operated gates are provided with protective relays.

The pond level of the Chippewa Falls plant of the Northern States Power Co. is regulated by 13 radial gates, each 40 ft. long and 13½ ft. high, having their tops normally 6 in. above the flow line. These gates have rubber seals at the sides, moving in grooves formed in the piers, and when lowered they seat on 8 x 10-in. oak sills imbedded in the crest of

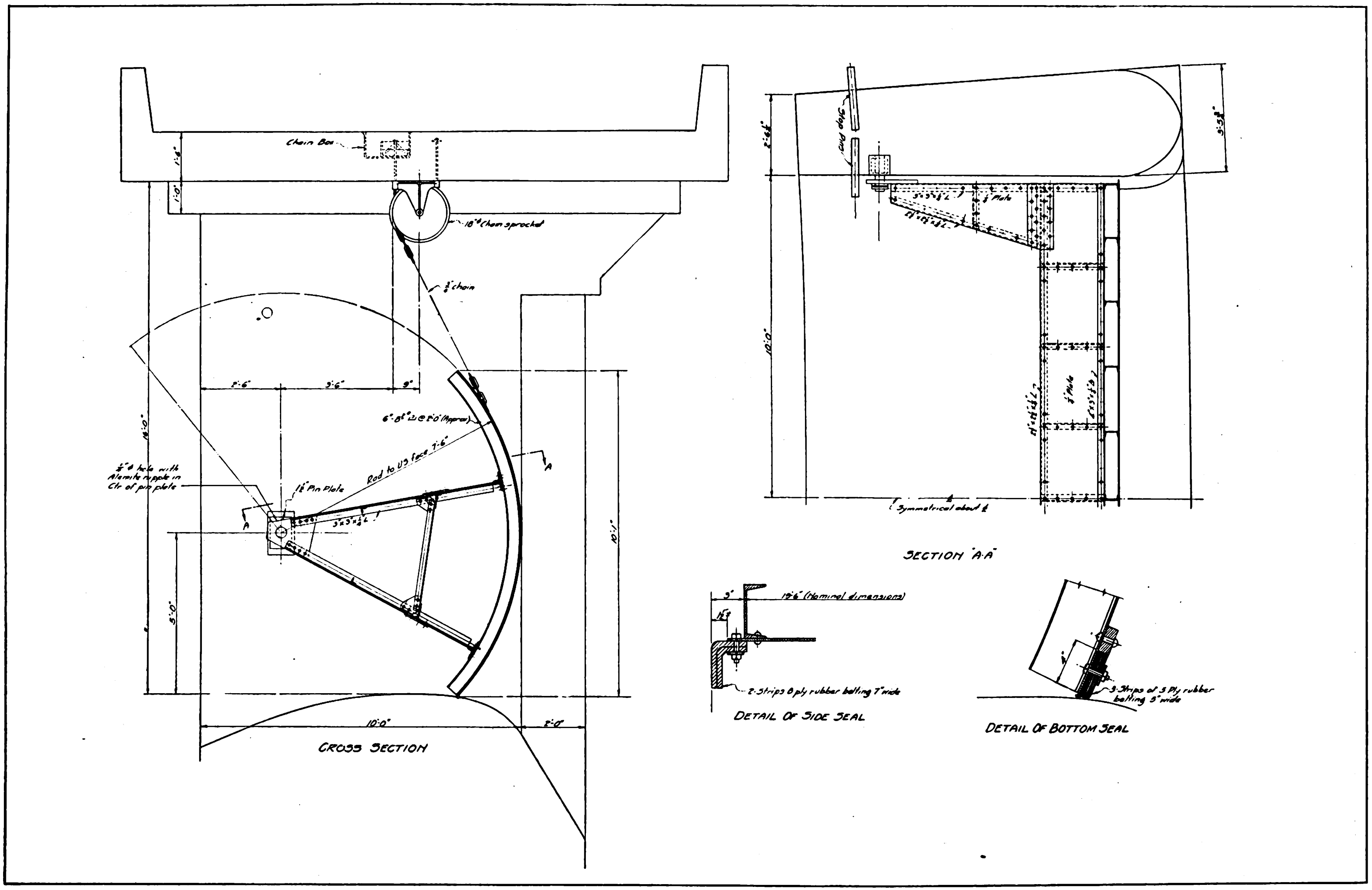
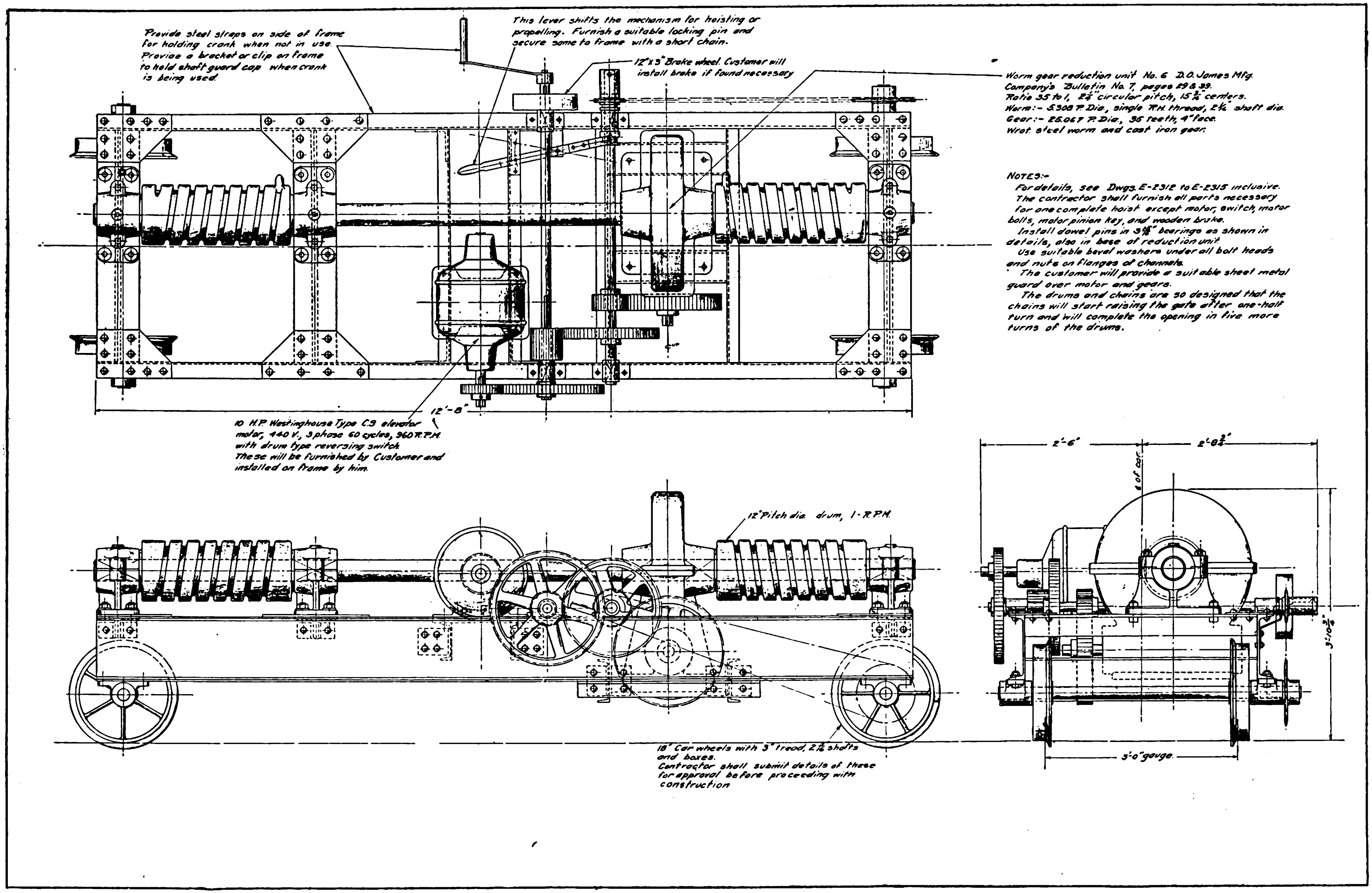

Chain Box
1'-6"
1'-0"
18"⌀ Chain sprocket
¾" chain
2'-6"
3'-6"
9"
6"-8.6# ⊔ @ 2'-0" (Approx)
Rod to U/S face 7'-6"
A
A
¾"⌀ hole with Alemite nipple in Ctr of pin plate
1½" Pin Plate
3"×3"×¼" L
15'-0"
5'-0"
10'-1"
10'-0"
2'-0"
CROSS SECTION
Stop Pins
2'-6¾"
3'-5⅝"
10'-0"
¼" Plate
Symmetrical about ℄
SECTION "A-A"
3"
1⅝"
19'-6" (Nominal dimensions)
2-Strips 8 ply rubber belting 7" wide
DETAIL OF SIDE SEAL
3-Strips of 5 Ply rubber belting 5" wide
DETAIL OF BOTTOM SEAL

FIG. 7—RADIAL GATES FOR BULLARDS BAR DAM, PACIFIC GAS & ELECTRIC CO.



Provide steel straps on side of frame for holding crank when not in use. Provide a bracket or clip on frame to hold shaft guard cap when crank is being used.

This lever shifts the mechanism for hoisting or propelling. Furnish a suitable locking pin and secure same to frame with a short chain.

12"x3" Brake wheel. Customer will install brake if found necessary

Worm gear reduction unit No. 6 D.O. James Mfg. Company's Bulletin No. 7, pages 29 & 39.
Ratio 35 to 1, 2¼" circular pitch, 15$\frac{9}{16}$" centers.
Worm:- 5.308 P. Dia., single R.H. thread, 2$\frac{7}{16}$" shaft dia.
Gear:- 25.067 P. Dia., 35 teeth, 4" face.
Wrot. steel worm and cast iron gear.

NOTES:-

For details, see Dwgs. E-2312 to E-2315 inclusive.

The contractor shall furnish all parts necessary for one complete hoist except motor, switch, motor bolts, motor pinion key, and wooden brake.

Install dowel pins in 3$\frac{15}{16}$" bearings as shown in details, also in base of reduction unit.

Use suitable bevel washers under all bolt heads and nuts on flanges of channels.

The customer will provide a suitable sheet metal guard over motor and gears.

The drums and chains are so designed that the chains will start raising the gate after one-half turn and will complete the opening in five more turns of the drums.

10 H.P. Westinghouse Type C.S elevator motor, 440 V., 3 phase 60 cycles, 960 R.P.M. with drum type reversing switch. These will be furnished by Customer and installed on frame by him.

12" Pitch dia. drum, 1·R.P.M.

18" Car wheels with 3" tread, 2$\frac{7}{16}$ shafts and boxes. Contractor shall submit details of these for approval before proceeding with construction

FIG. 8—GENERAL ARRANGEMENT OF MOVABLE HOIST, FOR TAINTER GATES, KERCKHOFF DAM, SAN JOAQUIN LIGHT & POWER CORP.

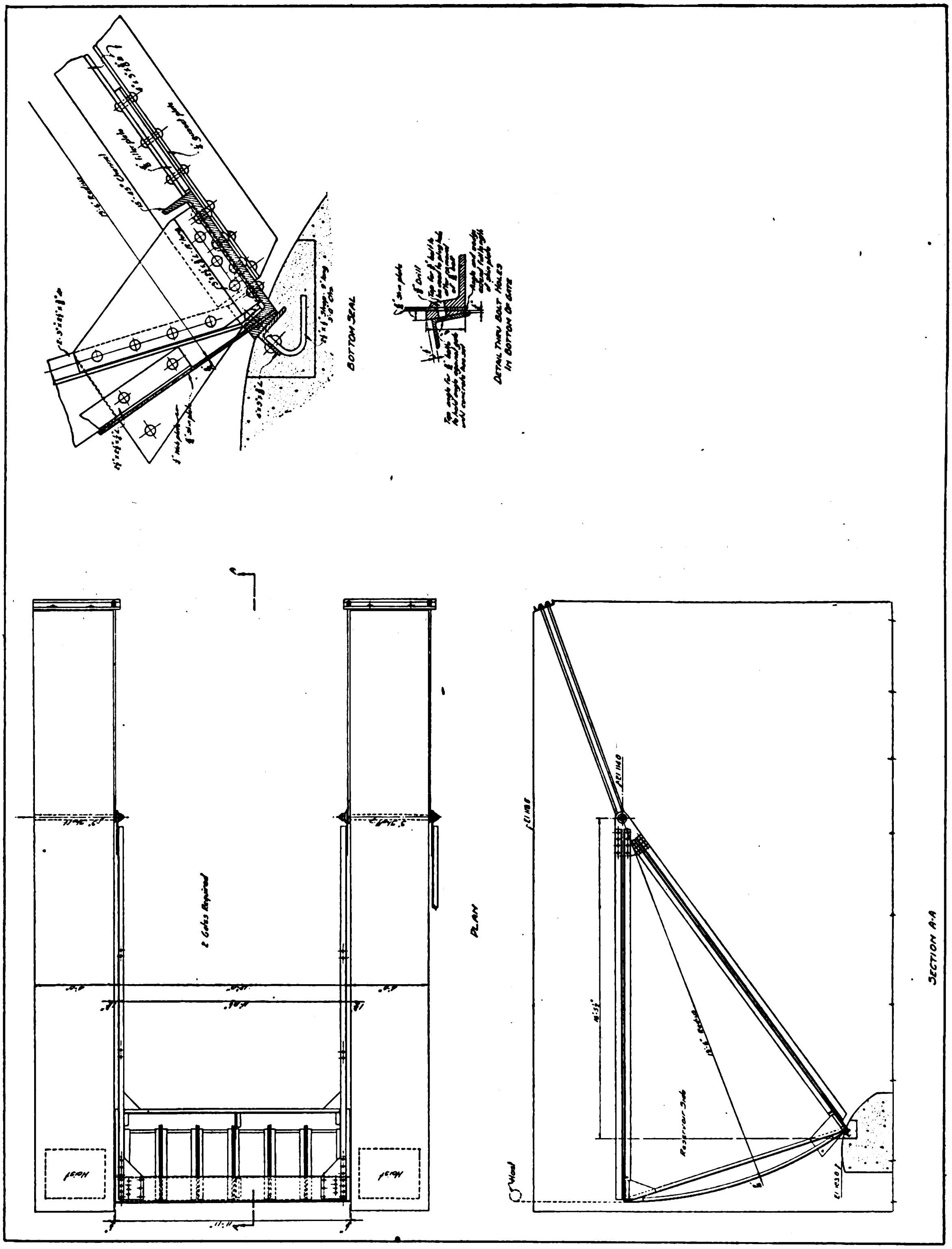

BOTTOM SEAL
DETAIL THRU BOLT HOLES IN BOTTOM OF GATE
2 Gates Required
PLAN
SECTION A-A
Reservoir Side

FIG. 9—REVERSED TAINTER GATES, EAGLE RIVER, WISCONSIN.

the dam. Because of the great length of these gates it would be difficult if not impracticable to place ordinary stop logs to shut off a gate for inspection or repair. Therefore, a 40-ft. steel frame is provided which can be handled by a derrick and lowered into guides in the piers, stop logs being then placed to fill the panels in this frame or emergency gate.

These large radial gates are equipped for both motor and hand operation by means of machinery located on the operating bridge carried by the piers. For each gate there is a line shaft of practically the same length as the gate. The motor and a speed-reduction unit are located at the middle, while the ends of the shaft are provided with worm gears driving the drums which carry the operating chains attached to the gate. The motors of the two gates nearest the power house are arranged also for remote control from the station switchboard, in order to provide for promptly releasing the excess water in case of loss of load on the plant or the necessity of quickly shutting down one or more of the power units.

Radial gates in which the members are stressed in tension were designed for use at Eagle River, Wis., and are shown in Fig. 9. This rather unusual design was made to economically meet a local situation. Reversed Tainter gates were used so that the hinges could be anchored in the existing piers, thus saving the expense of extending these piers downstream. The bottom seal is made by wedging action of the bottom edge of gate against a structural steel angle set in the concrete of the dam crest.

Tainter gates, 25.5 ft. high and 24.5 ft. wide, were used at the Chickasha plant of the Chickasha Gas & Electric Company. These gates have a timber face and were designed to facilitate transportation and erection in small units. The southern yellow pine facing consisted of 8 x 8-in. timbers at the bottom and 6 x 6-in. timbers at the top of the gate. The edges of the timbers were finished on radial lines to give a watertight fit. The hollow 12-in. diameter hinge pins were placed at the same elevation as the top of the gate in order to give the maximum clear opening when the gates are raised.

Where it is necessary to place the hinge pin at a high elevation to obtain spillway clearance, it is often preferable to counterweight part of the dead weight. This was done at the Echo dam of the U. S. Reclamation Bureau and on the Champlain and other sections of the New York State Barge Canal. The four Tainter gates at Echo dam are 17 ft. high x 18 ft. wide. The hinge pin is 15 ft. above the spill crest. The concrete counterweights are attached to a plate steel extension of the gate frame. The unbalanced weight is raised by a fixed electric motor-operated worm-gear hoist on the operating platform. The Barge Canal gate is 26.3 ft. high x 50 ft. long. The hinge pin is 24.4 ft. above the spillway crest. The gate is partially balanced by concrete counterweights, which are supported by an extension of the gate frame and controlled by a link arrangement.

Tests have been made by the Pacific Gas & Electric Company to determine the lifting forces for radial gates. The results show that the forces varied from 88 to 100 per cent of the total weight of the gates. In all cases, the center of the axles is at the exact center of the line of thrust on the curved gate face.

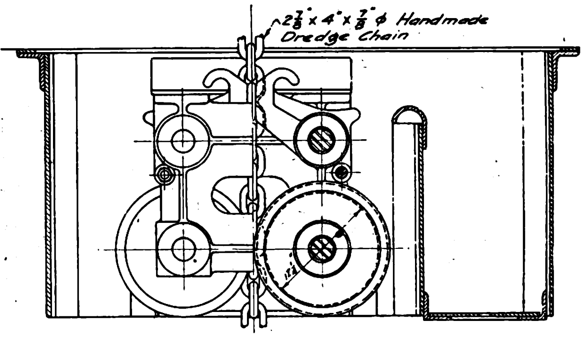


FIG. 10—CHAIN DOG AND SHEAVE FOR TAINTER GATE, BARTLETTS FERRY DAM, COLUMBUS ELECTRIC & POWER COMPANY.

When chains are used for hoisting the radial gates, slotted lock plates may be employed to hold a gate in any position. These plates slip over the chain links and rest on the operating platform. A chain dog and sheave used on the large Tainter gates of the Bartlett's Ferry dam, are shown in **Fig. 10.** The sheave guides the lifting chain and holds it in position so that it can be locked by the dogs when slacked off. The housing of the sheave is set flush with the operating platform and serves as a chain box. Direct braking on part of the lifting mechanism or the use of pawls on the gears to hold the gate in any desired position is not recommended, but under certain conditions may be necessary.

An approximate formula for estimating weights of radial gates was given in *Engineering News-Record,* Vol. 96, No. 12, as follows: "Weight (lb.) = area (34 + 0.114 width x av. head)." The formula is said to give results approximately correct for small gates and about 10 per cent too high for large gates. See Table III for dimensions and weights of radial spillway gates in service.

Sector or Drum Gates—The drum or sector gate has fulfilled the need for a crest gate which will give close spillway regulation by automatic or remote con-

TABLE III

RADIAL SPILLWAY GATES

Company	Dimensions		Weight (each) lb.	Number of Gates	Year Installed
	Height Ft.	Width Ft.			
Calif. Oregon Power Co..	12.58	34	29,600	3	1927
Calif. Oregon Power Co..	11.75	11	12,300	2	1927
Calif. Oregon Power Co..	11	26	19,800	5	1925
San Joaquin Light & Power Corp..........	14	20	14.500	14	1921
Pacific Gas & Elec. Co...	10	20	8.500	19	1927
Columbus El. & Pow. Co.	22	25	48,000	19	1926
U. S. Reclamation Bureau (McKay Dam).......	10	20	14,750	6	1926

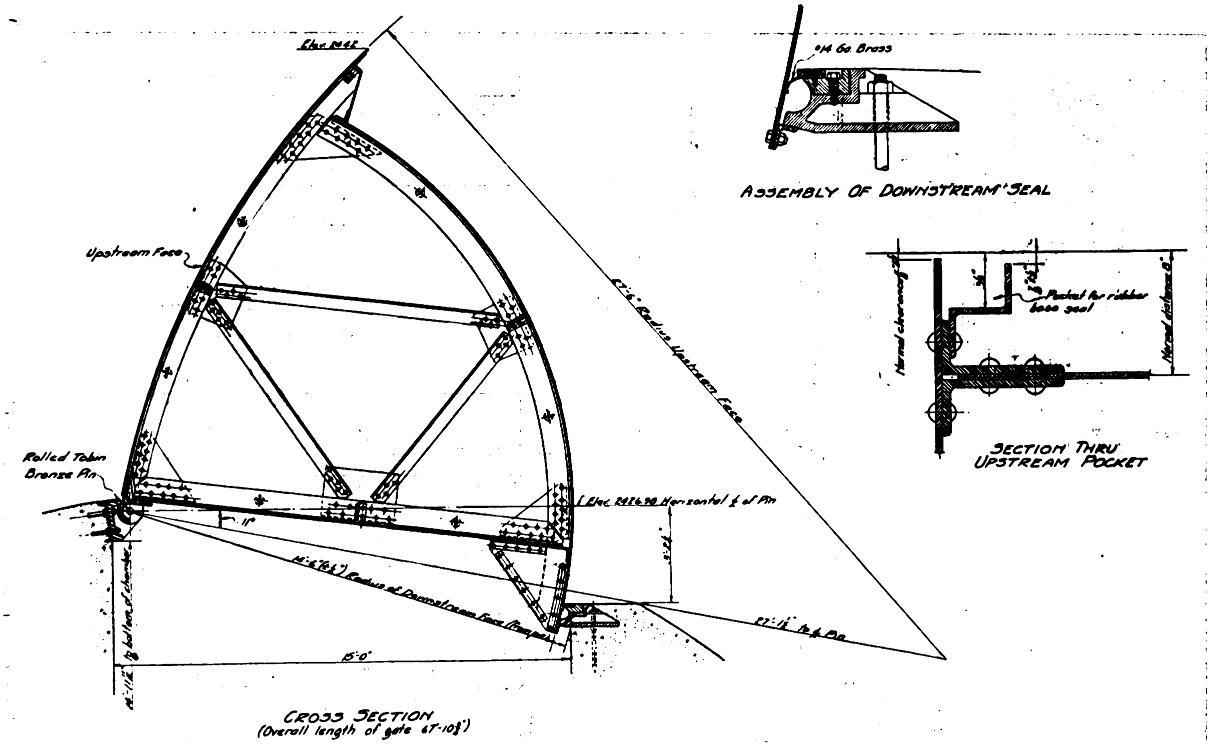

Elev. 2442
Upstream Face
Rolled Tobin Bronze Pin
27'-6" Radius Upstream Face
Elev. 2426.90 Horizontal ℄ of Pin
11°
14'-6¾" Radius of Downstream Face
27'-1½" to ℄ Pin
15'-0"
to bottom of chamber
14'-11½"
CROSS SECTION
(Overall length of gate 67'-10½")
#14 Ga. Brass
ASSEMBLY OF DOWNSTREAM SEAL
Normal clearance
Pocket for rubber hose seal
Normal distance
SECTION THRU UPSTREAM POCKET

FIG. 11—DRUM GATE, PIT RIVER NO. 4, DIVERSION DAM, PACIFIC GAS & ELECTRIC CO.

trol and permits large, unobstructed opening for the passage of flood flow. Sector gates have proved to be secure and easy to operate under the most adverse conditions and are not affected by ice or drift. This type of gate has been selected as the standard spillway gate by the U. S. Reclamation Bureau.

In general, drum gates are pivoted on a continuous casting anchored along one edge of the gate recess with pin bearings at approximately 4-ft. centers. The gate is floated up by pressure from underneath and lowered by gravity upon relieving the pressure. One of the earliest examples of this type of gate was installed by H. M. Chittenden on the Osage River about 1896. This gate had a height of 7 ft. and consisted of a sector including 67½ deg. of angle. The interior framing of the gate was made of iron while the covering was of wood.

Details of the 14½ x 68-ft. drum gates installed in the Pit River No. 4 dam of the Pacific Gas & Electric Company are shown in Fig. 11. Operation is not automatic, although the movement of the gates may be remote controlled from the Pit No. 3 power house if desired. It was difficult to find a suitable spring brass for the downstream seal, but the brass seal material selected has given very little leakage in service. Each gate weighs 210,000 lb.

The Southern California Edison Company installed two 12 x 51-ft. drum gates at the Florence Lake dam in 1926 (see Fig. 12). High-water level at Florence Lake is at El. 7327.5 ft. and the reservoir serves to regulate the flow of the South San Joaquin River for diversion to Huntington and Shaver Lakes. The gates may be operated either by automatic or by hand-control. Control apparatus is housed in the end piers.

Both drum gates are alike in structural details and mode of operation. Each gate consists of a watertight, sheet-steel drum, caulked and welded and with a flat bottom and cylindrical sector faces. The drum is built up of ⅜-in. plate riveted over a ribwork on the three sides. A channel imbedded in the concrete by anchor bolts runs along the upstream face of the spillway and forms the foundation for the hinge anchor castings for each gate. Each drum is pivoted upon 14 hinges which are built up to a thickness of about 2½ in. for bearings on the hinge pins. Each hinge anchor is fitted with eccentric bushings to facilitate alignment.

Considerable study was given to the design of seals because the accuracy of automatic control depends upon the amount of leakage past the seals from the pit. Spring brass was used as a seal at the upstream toe of the gate along the hinge casting. The seal at the downstream seat casting and at the downstream end of the side plates consists of 6-in., 8-ply conveyor belting. On the upstream end of each side plate is a hollow recess formed by the legs of two angles. A 3½-in. suction hose in this recess tends to flatten under the pressure of the water and acts as a seal.

The drum rests on the bottom of the pit until water in the lake rises sufficiently to enter the inlet pipe, which is at the same elevation as the bottom of the drum pit. As the lake rises, the drum floats in its pit until it reaches the limiting elevation when it strikes the stop on the gate seat casting. Further rise in the lake level brings the automatic control into operation to regulate the spill. A state of balance is maintained between the lake level and the position of the gate so that the elevation of the lake never

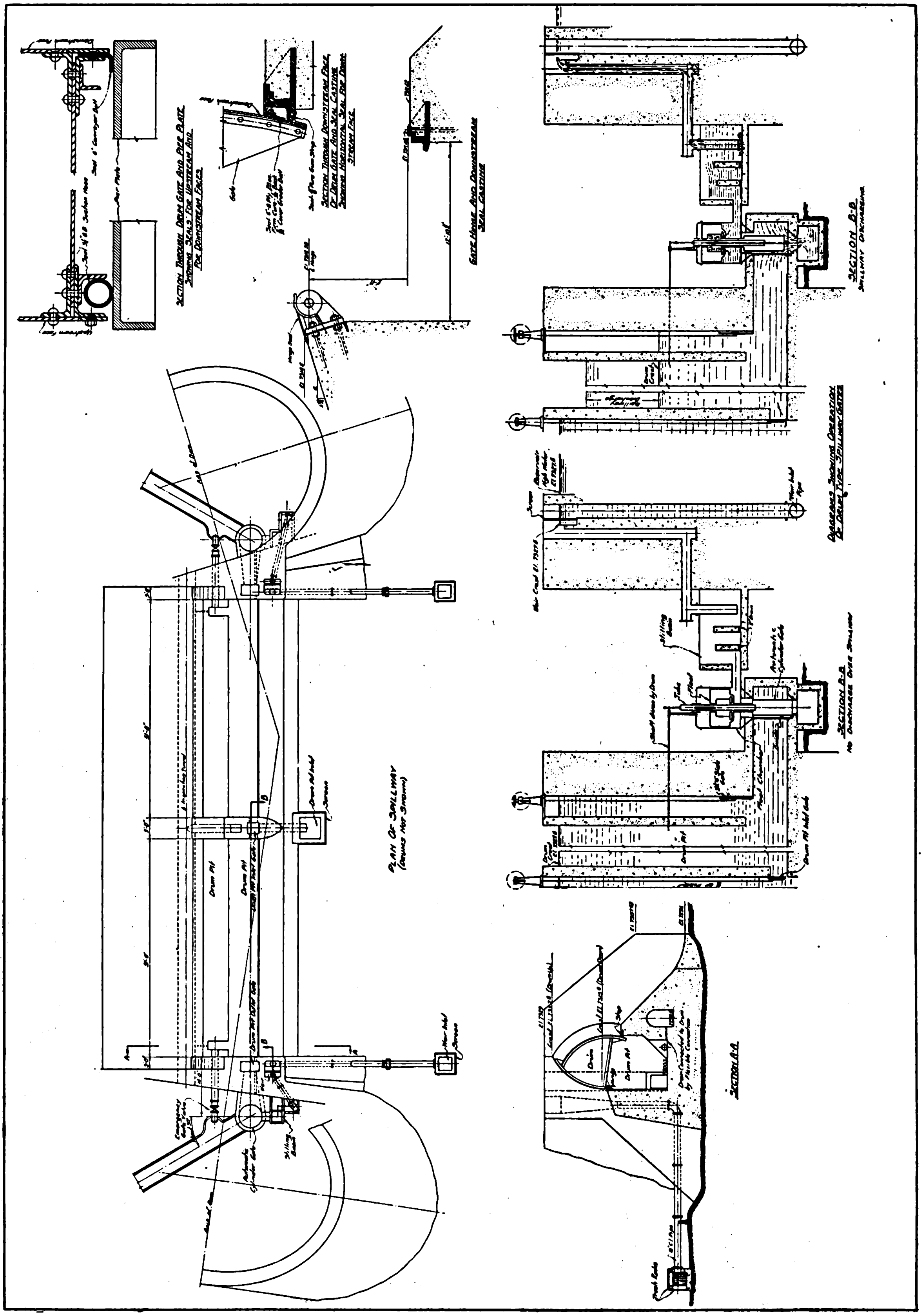

Section Through Drum Gate And Pier Plate Showing Seals For Upstream And For Downstream Faces
Section Through Downstream Face Of Drum Gate And Seal Casting Showing Horizontal Seal For Down Stream Face
Gate Hinge And Downstream Seal Casting
Plan Of Spillway (Drums Not Shown)
Section A-A
Section B-B No Discharge Over Spillway
Section B-B Spillway Discharging
Diagrams Showing Operation Of Drum Type Spillway Gates

FIG. 12—Drum Gates for Spillway, Florence Lake Dam, Southern California Edison Co.

is appreciably greater than the crest of the drum gates when in their maximum position.

No difficulty is encountered from ice conditions, since the lake is drawn down below the level of the gates during the winter months and the gates remain in their lowered position with no water in the drum pits. Trash and logs are easily passed over the gate crests during run-off season.

Each gate was manufactured in seven sections to facilitate transportation. The sections were riveted together in the field with inside butt-straps; all seams which were not caulked were electric welded. A tolerance of only ⅛ in. in the radius of the downstream face was allowed. All structural steel was specified to conform with A. S. T. M. standards and steel castings to specifications A 27-24, Class B, medium grade, of the A. S. T. M. Hinge pins and hinge anchor bushings were made of forged manganese bronze having a minimum elastic limit of 30,000 lb. per sq. in. Stresses in structural steel were not allowed to exceed 16,000 lb. per sq. in. in tension and 12,000 lb. per sq. in. in shear.

The European type of sector gate differs from the above American type, since it is hinged at the downstream side (see Fig. 13). At Raanaasfos in Norway there are two sector gates each having a length of 164 ft. and a regulating height of 12.3 ft. In a normal year in Norway several million logs are floated down each primary stream. Sector gates may be opened and closed quickly to pass logs which have collected above the dam. The gates are regulated by automatic or by hand control. Seals are of flexible brass. The Raanaasfos gates are not operated in winter, but are kept locked in their highest position. Winter operation is not impossible because the sector gates at the Weser dam at Bremen, Germany, have been operated without difficulty during long periods when the temperaure was as low at —4 deg. fahr. The total weight of each Raanaasfos gate is 232 tons.

Several sector gates, similar in general arrangement to the European type, are in use in New York State, together with two gates on the Chicago Drainage Canal. The two gates most recently installed were built for the Court Street dam of the Rochester Gas & Electric Corporation in 1926. Each gate is 110 ft. long and has an operating height of 11.1 ft. A gate is approximately a 28 deg. sector of a cylinder having a radius of 27.25 ft., built up of a steel framework and hinged at the downstream side. The 6-in. diameter bronze shaft is hollow to allow a heating pipe to be run through it from a central heating plant with a return line through the chamber under the dam near the hinge. This was done to prevent the formation of ice which might hinder the operation of the gate in the winter season. Heating pipes were also inserted back of the plates which form the end of the sector chamber. Rubber belting is used for the end seals. A gate may be locked in its raised position by means of keyed dogs. The weight of each sector is 160 tons, while the hinge, shaft, etc., weigh an additional 103 tons.

TABLE IV

SECTOR OR DRUM SPILLWAY GATES

Installation	Number of Gates	Length ft.	Operating Height ft.	Weight	Date of Installation
Florence Lake	2	51.00	12.0		1927
Pit River No. 4	2	68.00	14.5	210,000	1927
Arrowrock	6	62.00	6.0		1915
Tieton Dam	6	65.00	8.0		1925
Melones	9	57.16	10.0	82,360	1927
Don Pedro	10	57.00	8.5		1923
Black Canyon	3	64.00	14.5	216,000	1924
Guernsey Dam	2	64.00	14.5		1927
Chicago Drainage Canal	1 1	12.00 48.00	18.0 18.0		1908 1908
N. Y. Barge Canal	2	55.00			1918
Court St. Dam	2	110.00	11.1	320,000	1926
Genesee River	2	100.00			1917
Raanaasfos, Norway	2	164.00	12.3	464,000	1922

Ring Spillway Gates—A radically new spillway gate, a modification of the sector type, was designed and is being constructed for the Owyhee dam of the U. S. Reclamation Bureau (see Fig. 14). The circular spillway is the lip of a funnel formed at the head of a shaft discharging into the diversion tunnel 240 ft. below the tunnel intake. The funnel is surrounded by a structural steel ring gate 12 ft. high and 60 ft. in peripheral length, constituting a floating crest. It is planned to build the gate in 12 shop-riveted segments, to be joined in the field. A needle valve is used for control of the gate. This arrangement follows closely the recent sector gate installations of the U. S. Reclamation Bureau. The spillway shaft has a diameter of 22.5 ft., while that of the tunnel is 22 ft., giving a capacity of 30,000 sec. ft. when the lake is at its normal level.

Roller Gates—The roller gate is a heavy-duty gate which has not come into general use in this country. It consists of a cylinder or trussed sector. The roller has at each end a circular geared bearing which rolls on a geared inclined track laid in a recess in the pier. The gate is lifted by a cable or linked chain encircling the gate near the bearing. A modification of this type is the rolling sector gate of the Washington Water Power Company (see Fig. 15), which utilizes trusses as the main members which carry the water load to the end bearings. The main advantages of the roller gate are the accessibility of the structure when the gate is open and the long, clear widths of spillway openings.

An important feature of the roller gate, of comparatively recent development and application, is the arrangement whereby it can be partially lowered. There are often serious objections to the great wastage of water and loss of head attendant to opening the gates for sluicing out ice or debris. By the new design, the gate may be dropped 1 to 4 ft. below the pond level, which allows ice and other floating matter to pass over the gate. For normal operation the gate is raised to give full required opening underneath.

At the Lewiston, Idaho, development of the Inland Power & Light Company three roller gates were in-

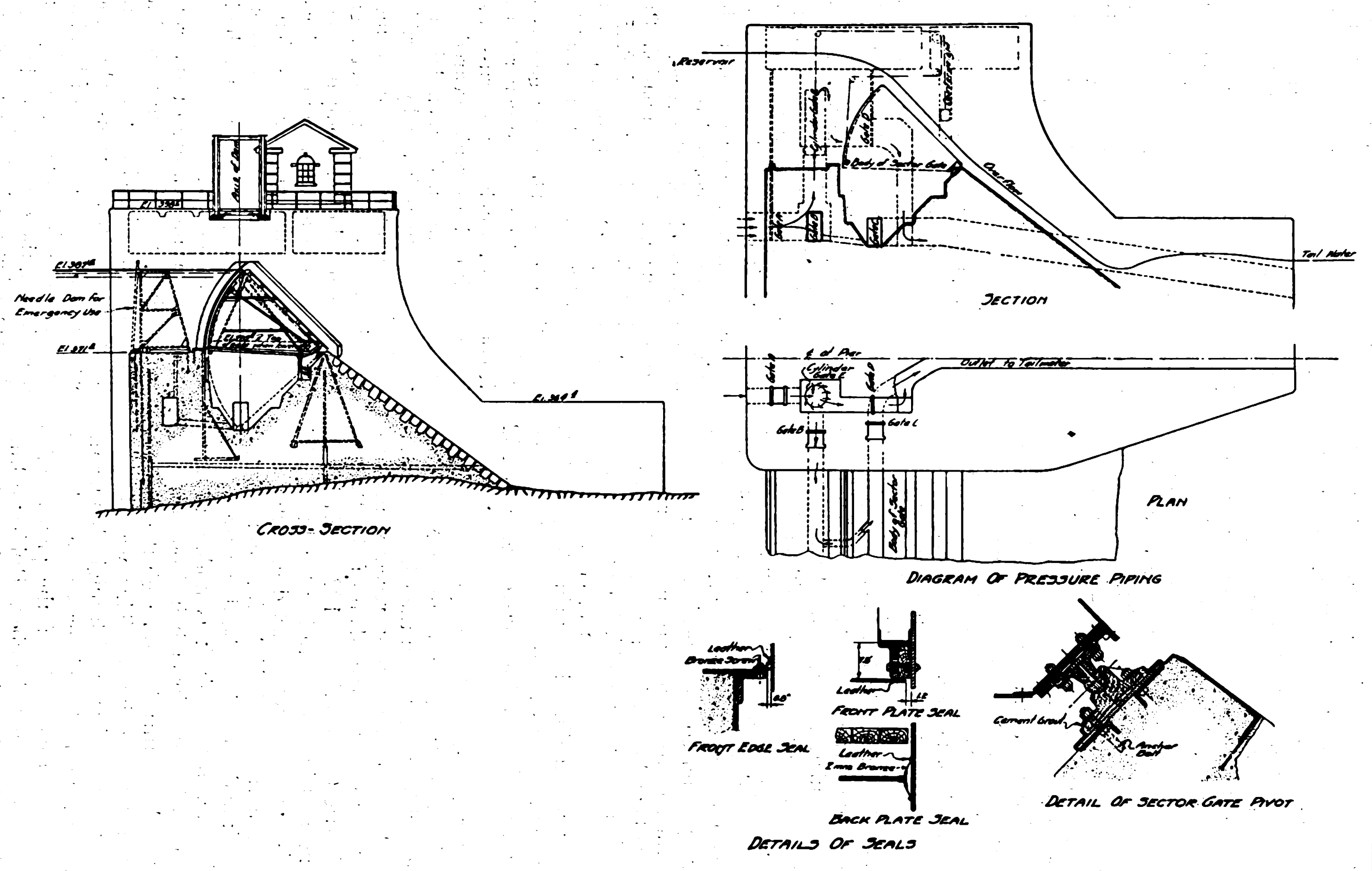

El 330.5
El 307.6
Needle Dam for Emergency Use
El 291.8
El 289.6
Cross-Section
Reservoir
Cylinder Gate
Gate D
Body of Sector Gate
Over Flow
Tail Water
Section
¢ of Pier
Cylinder Gate E
Gate D
Outlet to Tailwater
Gate B
Gate C
Body of Sector Gate
Plan
Diagram Of Pressure Piping
Leather
Bronze Screw
20°
Front Edge Seal
15
Leather
12
Front Plate Seal
Leather
2 mm Bronze
Back Plate Seal
Details Of Seals
Cement Grout
Anchor Bolt
Detail Of Sector Gate Pivot

FIG. 13—SECTOR GATE, RAANAASFOS DAM, NORWAY.

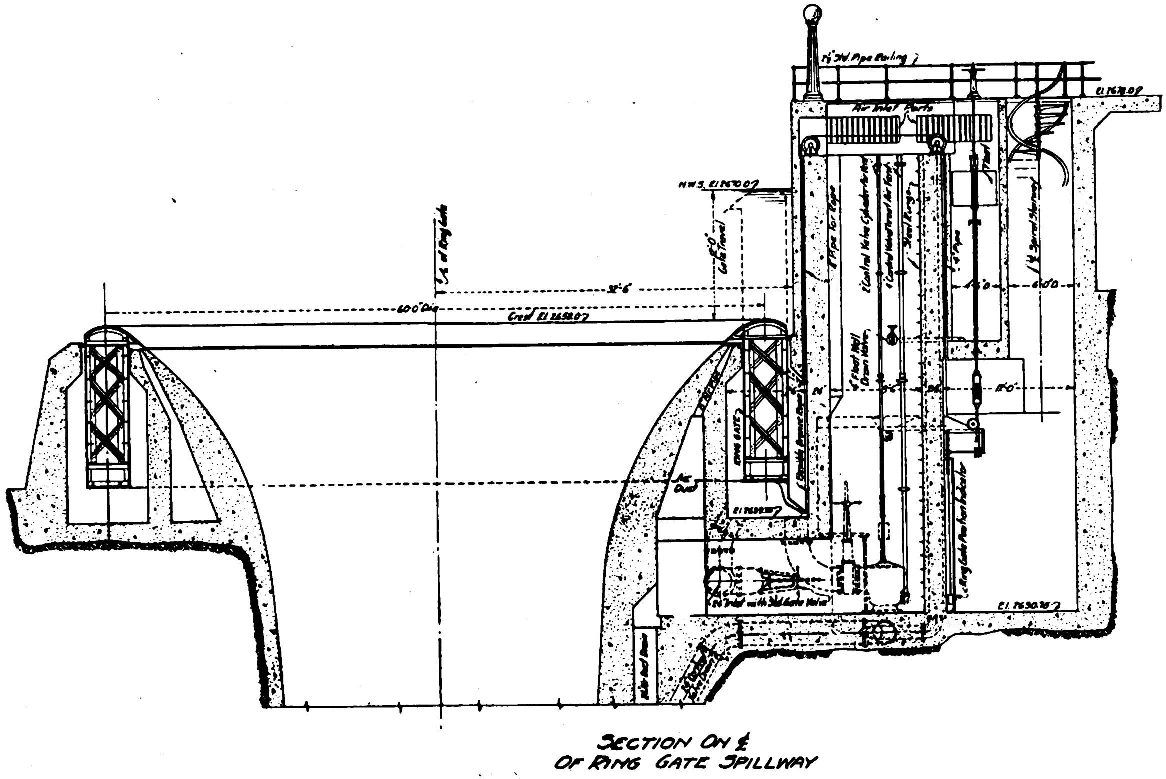


FIG. 14—RING GATE SPILLWAY, OWYHEE DAM, U. S. RECLAMATION BUREAU.

stalled for the control of all ordinary floods. Each gate is 105 ft. long and 18.5 ft. deep. Each consists of 17 cylinders fastened together by field-riveted, milled, butt-strap joints. A hoist mechanism operates a link chain on the driven end of the gate. Two roller gates, each 18 ft. high and 115 ft. long, were installed at Bellows Falls by the New England Power Association. Severe ice conditions are to be expected at this plant in winter, and the roller gate possesses marked advantages over other types of gates where certainty of operation during the cold season is essential.

Many installations of roller gates have been made in Germany and Scandinavia, where they are used for winter regulation as well as during the flood season (see Fig. 16). Electric heating elements installed in a recess back of the end plates keep the gate ready for operation under the most adverse conditions. Logs are not passed under the roller gates. Normal operation is by electric motor, but if the electric energy should fail, the gates may be raised by hand-operated hoists.

Table V gives dimensions of noteworthy roller gates now in operation.

TABLE V

ROLLER SPILLWAY GATES

Installation	Number of Gates	Length ft.	Operating Height ft.	Weight Each Gate lbs.	Date of Installation
Lewiston	3	105.0	18.5		1927
Spokane (sector)	2	60.0	20.0	156,400	1921
Long Lake	2	100.0	19.0		1910
Post Falls (sector)	1	100.0	12.5	175,100	
Hood River	2	25.0 75.0	7.67 6.25		1924
Grand Valley	6	70.0	10.25		1915
Wallenpaupack	2	67.5	14.0		1925
Bellows Falls	2	115.0	18.0		1928
Raanaasfos, Norway	1	147.5	21.3	546,000	1922
Solbergfos, Norway	3	98.5	28.7	298,000	1924
Vamma, Norway	2	65.6 91.9	8.2 11.5		1915
Forshuvud, Sweden	2	55.7	29.0		1917
Trollhatten, Sweden	2	65.7	13.12		1907
Kleinwallstadt, Germany	3	115.0	19.05		1926
Viereth, Germany	2	98.4	19.7		1922
Trasquila, Mexico	1	80.0	11.8		1911

Butterfly Gates—At each end of the Exchequer dam there is a spillway 168 ft. wide equipped with seven vertical-shaft butterfly gates. This type was selected because it was possible to construct the dam with a thinner crest than would have been feasible with the more commonly used type of gate. Operation of the gates is effected by a 20-h.p. motor mounted on a car which moves along the dam crest engaging the several gate-operating mechanisms successively.

The outside dimensions of the gates are: Length, 24 ft.; height, 14 ft., and thickness, 3 ft. The gates are built up of structural steel consisting chiefly of 3/8-in. plates and angles of suitable size and spacing. The gates are hollow except for the internal bracing

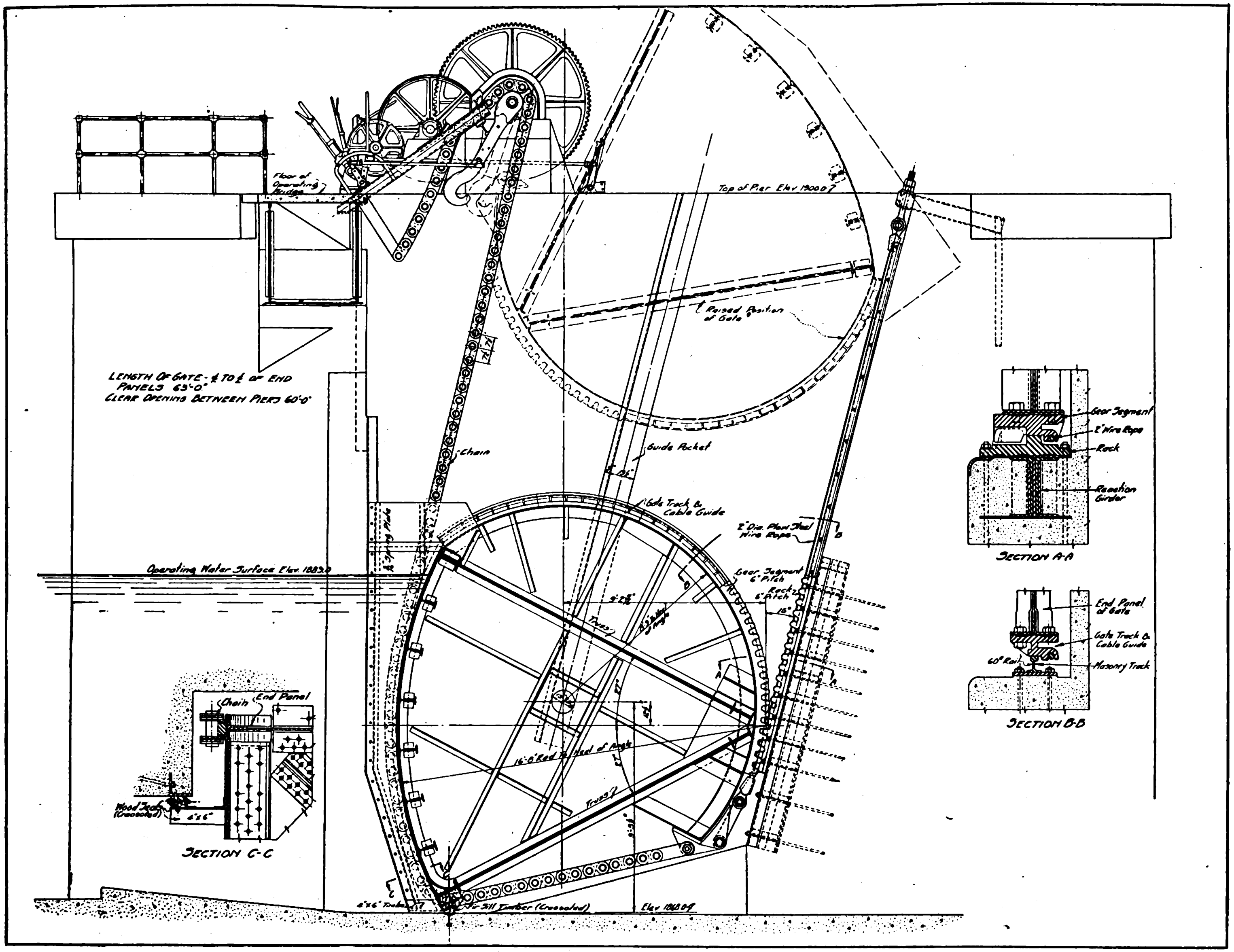
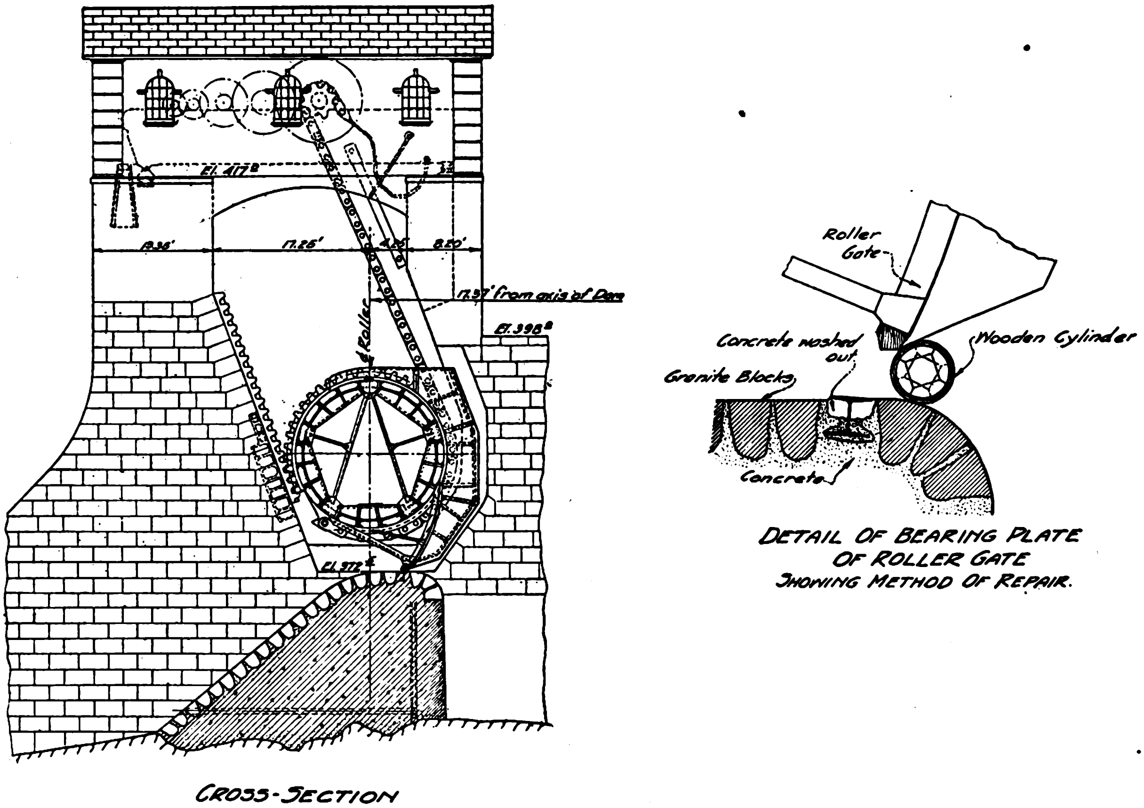

Floor of Operating Bridge
Top of Pier Elev. 1900.0
Raised Position of Gate
Length of Gate - ℄ to ℄ of End Panels 63'-0"
Clear Opening Between Piers 60'-0"
Chain
Guide Pocket
Gate Track & Cable Guide
2" Dia. Plow Steel Wire Rope
B
Gear Segment 6" Pitch
Rack 6" Pitch
16°
9'-2¾"
Truss
A
16'-0" Rad. to Heel of Angle
Truss
Operating Water Surface Elev. 1883.0
Elev. 1868.0
Sill Timber (Creosoted)
6"x6" Timber
Gear Segment
2" Wire Rope
Rack
Reaction Girder
SECTION A-A
End Panel of Gate
Gate Track & Cable Guide
60# Rail
Masonry Track
SECTION B-B
Chain
End Panel
Wood Seal (Creosoted)
6"x6"
SECTION C-C

FIG. 15—Rolling Sector Gate, Spokane, Upper Falls Power Station, Washington Water Power Co.



Cross-Section

Detail of Bearing Plate of Roller Gate Showing Method of Repair.

FIG. 16—Roller Gate, Raanaasfos Dam, Norway.

and the hollow cast-steel shaft, 24 in. square and 2¼ in. thick, which extends through the center of the gate from top to bottom. To facilitate shipment the gates were made up in the shop in three pieces which were riveted together in the field. The weight of the rotating part of each gate is about 19 tons.

There are no piers between the gates. The rounded ends of adjoining gates fit against each other when they are in the closed position. Leakage is prevented by a brass strip fitted to one end of each gate and arranged so that the spring is pressed tightly against the adjoining gate when in the closed position.

Stoney Gates—The Stoney gate has not met with favor in western United States. This type of gate is used in the southern and eastern states and in Canada, primarily because of its simple design and ease with which it can be operated and kept free from ice in the winter season. The Stoney gate has been used with a depth of water of 50 ft. for openings 50 ft. wide, and for lesser depths for widths up to 80 ft. The gate moves in vertical grooves in masonry piers on trains of rollers. In some cases the gates are partly operated by counterweights amounting to 75 to 80 per cent of the weight of the gates, and partly by powerful gearing arranged to be worked by hand or by power, which serves to raise or lower the unbalanced weight. The counterweights have been omitted from many recent installations, the gates being lifted by gantry cranes. This arrangement is preferable where there are a number of such gates in a spillway.

The Dominion Bridge Company, Ltd., Montreal, Quebec, comments on bedded parts, roller trains and sealing devices as follows:

"In the design of bedded parts, the all-important point to keep in mind is the method and facility of erection, and secondary only to this is the ease of machining and retention of their alignment during handling and when set in place in the field. To adequately take care of these features one must be fully acquainted with conditions at the site and the method to be adopted in placing the bedded parts in their final position.

"As a rule, the best procedure is to construct the mass concrete of the piers first, leaving a void large enough to take the bedded parts with sufficient grouting room behind them, and placing in the forms of the mass concrete sufficient anchors, to which the bedded parts can be readily attached and adjusted for final alignment by the field engineer before the grouting is poured behind them to make a monolithic whole with the mass already set.

"Attempts have been made to set the bedded parts by attaching them to the forms for the mass concrete and pouring the whole of the concrete work with the steel work in place. This has not been very successful up to the present time. In the first place, it must be remembered that the bedded parts are often thirty or more feet in length, and the forming and pouring of the concrete can only be done in suitable lifts of ten feet or so, thus allowing an unsupported length of steel to be standing in the air subjected to warping and deflection while the lower portion of the concrete is being placed. Secondly, it is almost impossible to keep the steelwork in true alignment due to the contraction and expansion of the forms under the varying atmospheric conditions during the operations. In one instance, where the general direction of the dam was north and south, the readings for the alignment of the steel would vary morning and evening, depending on the position of the sun.

"The general idea of placing the steel at the same time as the mass concrete is a good one, and is still being given serious consideration in some quarters, as it allows the whole of the concrete work at that place to be done at one time. However, if it is to be successful the bedded parts should be provided with a very rigid set of temporary bracing which would definitely determine and fix the alignment in all planes, or the bedded parts of adjacent gates should be built as rigid towers, which would be self-supporting during the pouring of the mass concrete. This, of course, means that the order for the gate work should be placed early enough to allow the bedded parts to be on the site before the masonry contractor starts work on this portion of the development.

"Sometimes bedded parts have to be provided for gains already left in the masonry, originally provided for the extension of an existing plant, where there is no provision for anchors and no room left for grouting between the steel and the existing concrete. This is a condition which should be avoided under all circumstances, as it entails an enormous amount of extra work in unwatering and drilling for the anchors and cutting away concrete in places where it is unsuitable for the steelwork. Also, it is almost impossible to obtain an alignment of the steel which will provide a satisfactorily watertight gate. The design of steel work in such cases would have to be specially considered for each installation and generally causes trouble in both shop and field due to a want of rigidity of the member in consequence of the unrestrained room at one's disposal for the placing of the steel.

"Bedded parts should provide for roller or sliding paths, sealing faces for the sides, bottom and top where required, guides for the roller trains where necessary, and both back and end guides for the gate. These provisions should be designed as separate units and the field engineer must be relied upon to place them in their correct relationship to the concrete.

"A better arrangement, however, is to design the whole of the bedded parts as a complete steel unit, definitely spacing the various parts in their correct location and assembling them as a complete frame in the shop for final field alignment by the anchors, additional temporary bracing being used where necessary, the use of such bracing always being an advisable precaution in order to ensure good results.

"Anchors for bedded parts have been made by providing through pipes in the piers, which were set in place during the forming of the mass concrete, and through these pipes were inserted long rod bolts with double nuts at each end to secure the bedded parts in their correct positions. It is, however, a difficult matter to place the heavy and unwieldy bedded parts on the anchors, and the arrangement of such anchors generally provides for adjustment only in one direction.

"A later and better arrangement is to bed, in the mass concrete, angles having the two legs flattened together at the ends, and holes drilled at each end to take independent hook bolts at the required intervals and arranged in such a manner that the bedded parts can be aligned in both planes, necessary holes being provided in the steel to take the hook bolts. These bolts are provided with two nuts for adjustment, or wedge blocks may be provided between the steel and concrete and the bolts tightened against the blocks. This arrangement of anchor and hook bolts has the advantage that the bedded anchor angle does not have to be as accurately placed in the forms, as in the case of the bedded pipes.

"The location of anchors should be so arranged that projecting nuts and ends of bolts cannot by any means foul the gate or moving parts, and it is preferable, if possible, to place the anchors so that the gate and roller trains move in a perfectly smooth gain, as projections are not only liable to foul moving parts under unforeseen conditions, but also form a place where debris, floating objects, and ice can lodge and possibly cause considerable trouble.

"For the same reason the guides for the gates and roller trains should be of smooth construction throughout and places of entry should be well set back, chamfered, or rounded, to permit ease of entry of the gate and prevent any jamming taking place during operation. It might be well to mention here that all conditions should be considered and provided for by the designer, however improbable they may seem to be.

"The earlier forms of roller trains consisted of live steel rollers rotating on bronze pins located in such a manner that the spacing of the rollers is evenly proportioned to the head of water, thus providing a uniform unit pressure on each roller. The bronze pin is supported by steel bars, bar and angle, or angle sides to give a stiffness to the member as a whole, in the direction of the flow of the water, and the sides projecting beyond the face of the roller to form a guide for the train on the edge of the roller path.

"This type is quite satisfactory for low heads and low velocities, and might even be so with head gates where the velocity does not exceed about 10 ft. per second, but with the advent of larger gates and higher heads and velocities it was found necessary to provide a very definite guide to the roller train in both the direction of the flow and at right angles to the same.

"Moving roller paths apply to Stoney roller gates only, since in the case of gates with fixed rollers the path on the gate is dispensed with. These paths, which are usually made of a rolled or forged steel bar, require to transmit the water pressure from the web of the end girders into the rollers, and should act in such a manner as to transmit the pressure uniformly over the face of the roller. To do this under varying deflections of the cross girders of the gate, and in order to provide for any inaccuracy of alignment of the fixed roller paths, it is necessary that the moving path should be capable of equalization over the web of the girder. The best method of accomplishing this is to project the planed edge of the web of the girder beyond the flange angles and plane a groove down the back of the roller path to fit very loosely over the projected web of the girder, so as to restrain the path from any side displacement, and at the same time to allow the path to rock freely on the planed edge of the web.

"The path is then drilled and counterbored for the attaching bolts which are provided with pipe spacers of sufficient length to keep the path from falling off the edge of the web and at the same time allow a reasonable rock to the path.

"Sealing devices may generally be divided into two types: the stanching rod type, and the flat, more or less, spring type. The former are preferable for crest or sluice gates where they will be subjected to severe ice conditions, on account of their greater mechanical strength, while the latter are better for head and all totally submerged gates, where ice conditions are not effective, on account of their greater degree of watertightness.

"In the case of the round stanching rod, the matter of attachment is a most important one. It should be flexible enough to allow the pressure of the water to take the sealing rod up to the sealing faces under all positions of the gate, and at the same time it should be strong enough to resist action from the ice and allow the removal of the ice for winter operation.

"The best method of attachment is by means of a heavy flexible suspension from the upper end, capable of resisting both the upward and downward thrust which occurs when the gate is being operated, but entirely free in the direction parallel to the skin plate of the gate. The rod is restrained within the required limits of flexibility by strong steel retaining fingers placed at intervals along the rod and fastened to the gate by heavy bolts. These fingers and bolts should be made in such a manner that they are not easily damaged by ice and can be cleared of ice without loosening or breaking the attaching bolts. The design of the sealing attachments is one that will bear considerable thought and study.

"The spring type of seal is sometimes made from a thin flat brass strip with a D-shaped brass bar reinforcing one edge, or alternatively, of a thin flat brass strip bent with an offset to keep it away from the face of the gate and allow a space for attaching bolts, also having the front edge bent back to allow practically a line contact with the sealing face under all conditions. The seal is usually attached to the downstream face of the gate in such a manner that the water pressure will force it against the sealing face.

"The above mentioned methods of sealing apply to gates of the Stoney and fixed roller types, and in both cases particular attention should be given to clearance between the moving seals and fixed parts of the bedded members. This clearance should be ample in all positions of the gate and

> should allow for a maximum amount of adjustment of the side rollers, and at the same time provide against any possible chance of the seal leaving or even approaching the edge of the sealing face.
>
> "In the case of gates of the Stoney roller type, the provision of clearances between the seal and the moving roller train should be carefully looked into, and it should be remembered that there is bound to be some relative movement sideways, between the gate and the roller train, the maximum of which should also be taken into consideration and duly provided for.
>
> "The question of the effect of deflection of the top girder of the gate, under maximum head, on the top seal should be taken into account when considering the clearance between the top seal and the lintel of the bedded parts and concrete above this lintel.
>
> "The bottom seal of the gate is generally formed by the fit of the planed sill beam bedded into the concrete and forming one of the members of the bedded parts. In cases where the gate is too wide to make this fit by planing, the sealing bar has to be chipped to fit, or the sill beam may be attached to the gate by temporary lug angles and wedged firmly against the bottom of the gate after it is in place, and then the concrete poured and allowed to set before the clips are removed and the gate lifted.
>
> "In some cases the necessary sealing is obtained by means of a heavy planed oak beam attached to the web of the lower beam, in which case care should be taken to see that the sealing edge is in reasonably close vertical alignment with the sealing face of the vertical seals to prevent leakage at the corners. A further precaution of a hemp rope or rubber hose partially bedded into a groove in the sealing timber will often assure a more watertight seal at this point."

Three Stoney gates are provided to control the spillway of the Stoney Gorge dam, of the United States Reclamation Bureau, an Ambursen type structure (see Fig. 17). Each gate is a 30 x 30-ft. structural steel leaf of the overflow type. The gates are operated by large screw stem hoists driven by electric motors. The gates are mounted on a 45 deg. slope and slide down the upstream face of the dam in opening. The overflow type of gate was adopted on account of the large amount of drift carried by the river during the flood stage; and also on account of the smaller head required to pass corresponding floods than with the underflow type of gate.

The north spillway of the Guernsey dam, also of the U. S. Reclamation Bureau, is controlled by an electrically operated Stoney gate 50 ft. in height and, 54.62 ft. wide, which closes a clear opening 50 ft. in width (see Fig. 17). The gate leaf, weighing 434,000 lb., is counterweighted by concrete blocks, each counterweight weighing 187,000 lb.

This gate leaf is built up of twelve plate girders 6 ft. deep, laid horizontally, with diagonal bracing, and covered on the water side by a 9/16-in. skin plate. The sliding friction is taken care of by six sets of rollers on either side, riding on an H-beam. Any deflection in the girders that would tend to throw the rollers out of plane is taken care of by the flexibility of the web of this H-beam track. The side seals on the upper side of the leaf are of brass pipe moving on lugs riveted to the skin plate. This pipe is forced by the water pressure against the 6 x 6-in. seal angles embedded in the concrete.

The crest gates of the Conowingo dam are of the Stoney type, 22.5 ft. high x 40 ft. wide, with timber seals at the bottom and rubber-covered staunching seals at the sides (see Fig. 18). Fifty crest gates are provided. Upstream from the crest gates additional guides are set in the piers to receive a service gate. This gate is of the fixed roller type and will be used to close the gate opening when it is necessary to remove one of the crest gates for painting or repairs.

The crest gates will be handled by gantry cranes. Three cranes are provided for this purpose, and also for handling the sectional head gates and trash racks. For handling the crest gates the cranes are equipped with special lifting beams, which are arranged for an operator to ride when he operates the locking device and attaches it to the gates. When the gates are raised to their open position they will be held in

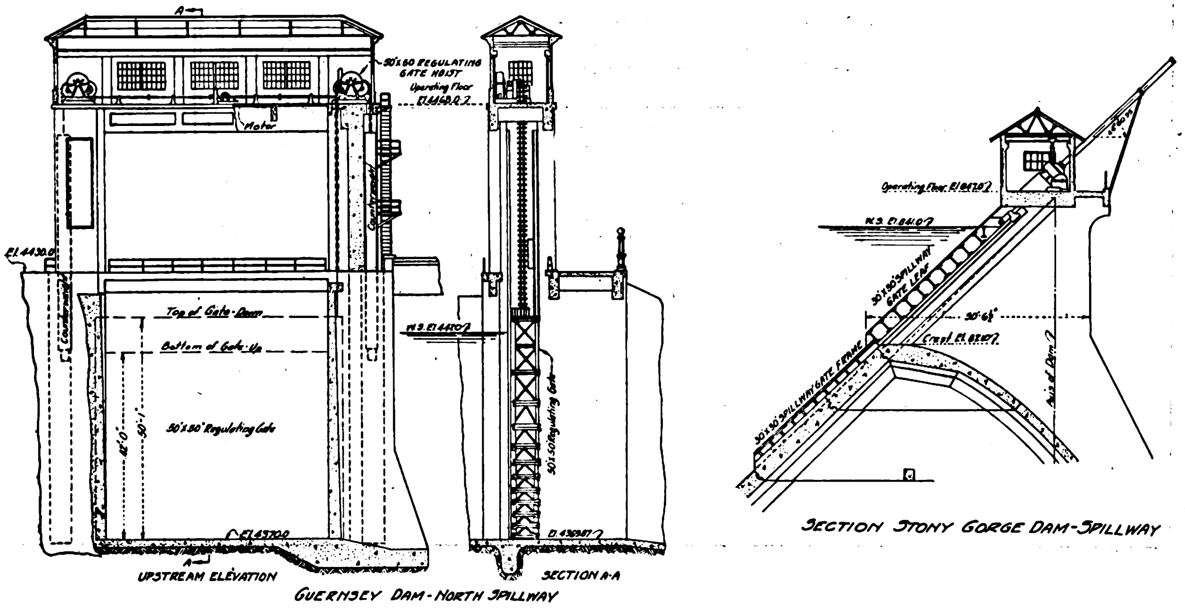


FIG. 17—Stoney Spillway Gates, U. S. Reclamation Bureau.

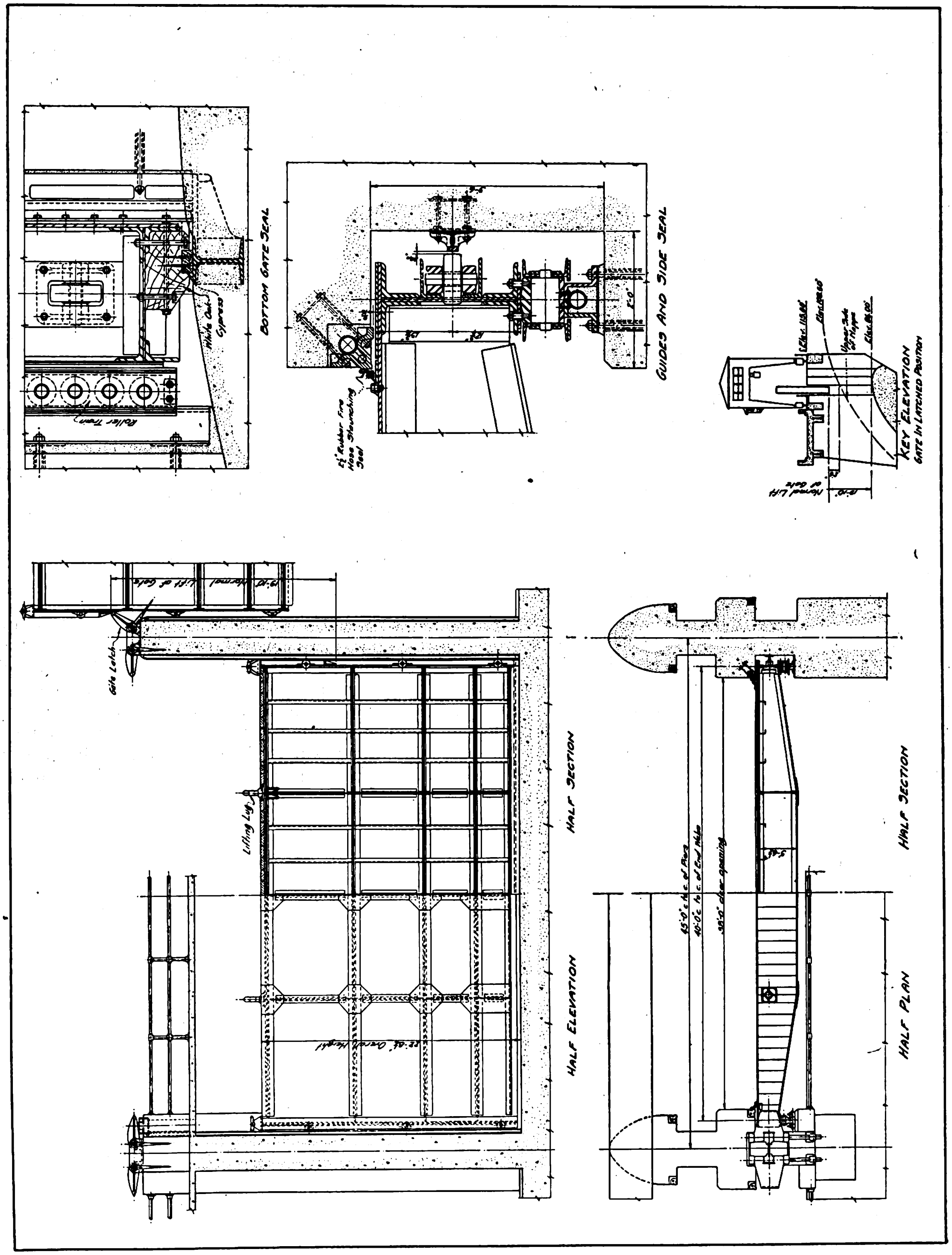

Bottom Gate Seal
White Oak
Cypress
Roller Train
Guides and Side Seal
2½" Rubber Fire Hose Staunching Seal
Key Elevation
Gate in Latched Position
Normal Lift of Gate
Gate Latch
Lifting Lug
Half Section
Half Elevation
Half Section
Half Plan
45'-0" c. to c. of Piers
40'-0" to c. of End Holes
38'-0" clear opening

FIG. 18—STONEY CREST GATE, CONOWINGO DAM, PHILADELPHIA ELECTRIC CO.

place by means of pawls engaging suitable stops on the ends of the gates, thus permitting the crane to move on to the next gate. The duty cycle of these cranes requires about 9 min. to lift a crest gate.

The Stoney type of gate with roller trains is used by the Laurentide Power Company, Ltd., for spillway regulation. The roller trains move vertically when the gate is moved and are held in position laterally by a steel angle bolted to the concrete structure. Originally this extended from the bottom of the roller train at its closed position to the top elevation of the gate when closed. As a consequence, when a gate was open the swirl of water passing through tended to loosen the fastenings of these guide angles. The remedy was to change the location of the guide angles by raising them so the lower end would not be exposed to this action of the water.

These gates have bronze seal rods vertically attached at each end. They are loosely attached and are forced into their sealing position by the pressure of the water. They are very effective, but have occasionally become loosened when it became necessary to operate gates in the winter with several feet of ice on the pond.

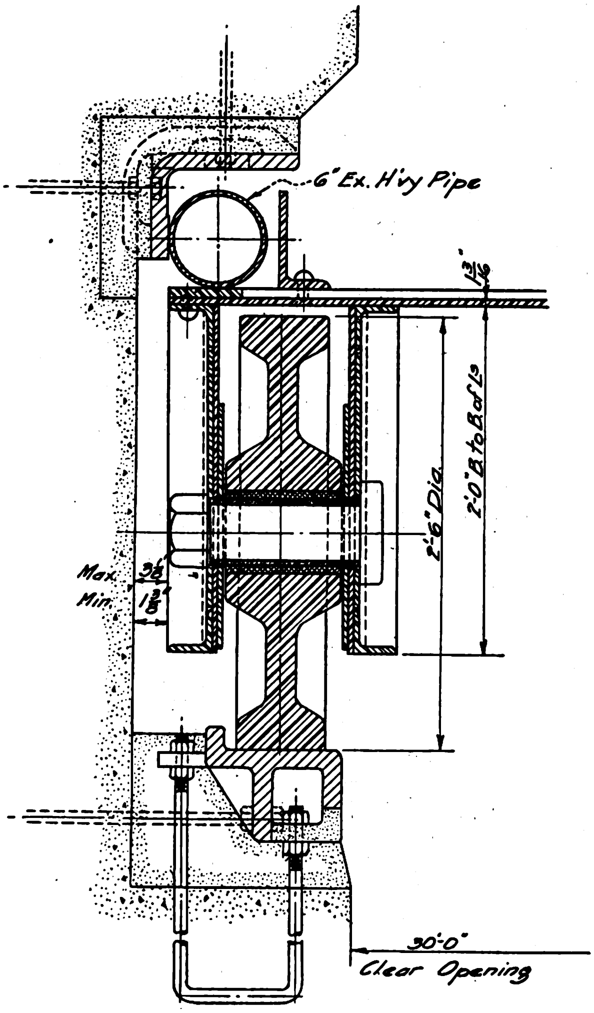


FIG. 19—Guide and Seal for Stoney Gate, Lock 18, Alabama Power Co.

The practice has been to paint these gates about every third year, but for the most part this has been for improvement in appearance rather than due to necessity on account of rusting. Practically speaking, rusting need not be taken care of more often than once every five years. An important cause for rusting is abrasion of the skin plate due to rise and fall of the ice cover on the pond. The resulting abrasion is not serious, and merely removes the paint here and there, especially on the rivet heads. A high grade of red lead paint is used.

Fig. 19 shows details of the Stoney gates used by the Alabama Power Company with the roller train and sealing arrangement. The gates are operated by a traveling hoist. The Lock 18 spillway gates are 18 ft. high x 30 ft. wide.

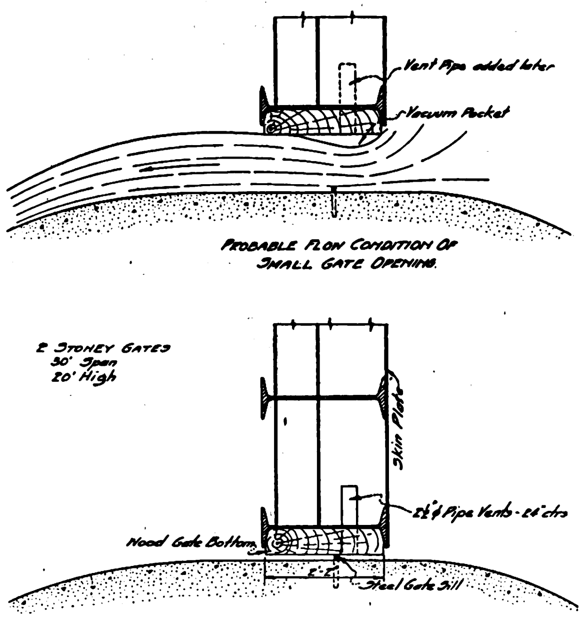
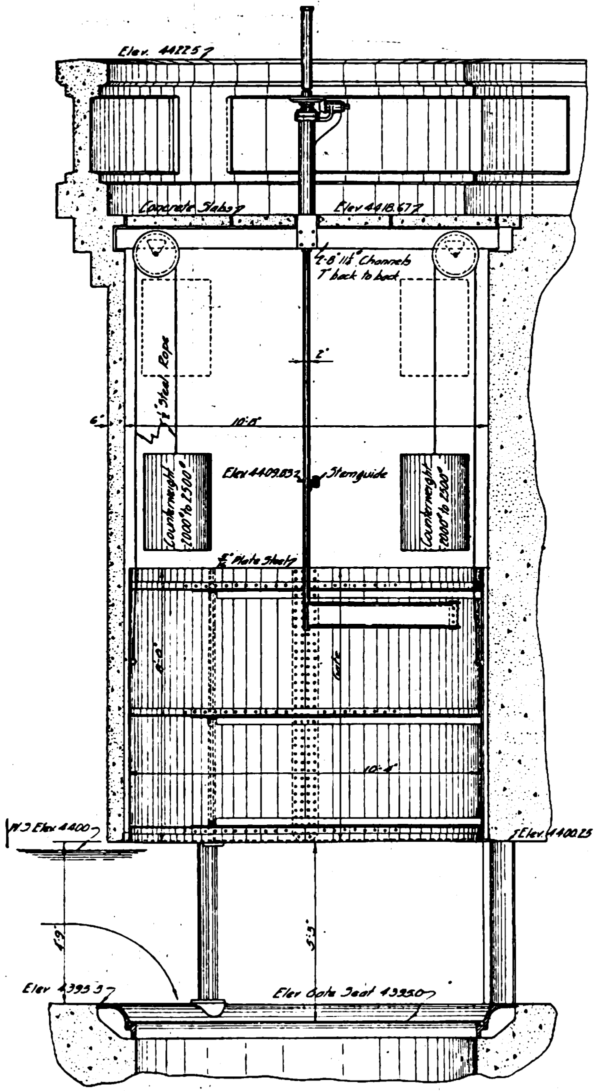


FIG. 20—Method of Eliminating Vibration in Stoney Gate, Interstate Public Service Co. of Indiana.

Fig. 20 shows the methods of venting two 20 x 30-ft. Stoney gates of the Interstate Public Service Company of Indiana, to eliminate vibration due to vacuum conditions. These gates have a flat, wooden member, 26 in. wide, which is attached to the bottom I-beam. This wood bottom seats against a thin steel sill embedded in the concrete of the spillway crest. At small gate openings violent vibration of the gate occurred, caused by the alternate making and breaking of the vacuum under the flat gate bottom. The vibration appeared to be concentrated at the center of the gate. To relieve the vacuum, vent holes on 24-in. centers were cut through the bottom I-beam and wood bottom and short lengths of 2½-in. pipes were welded into the holes. One of the gates was provided with 10 holes in the central portion, and later the other gate was provided with only 6 holes. This number proved to be sufficient, and no further trouble due to vibration has been experienced in either gate. It is suggested that trouble from vibration could be avoided by limiting the width of bottom to 12 in.

At another installation of the same company consisting of three 22 x 30-ft. Stoney gates, the sealing device was made up of 3-in. rubber tubing held loosely in the angle between the skin plate and the gate pier. The tubing was kept in place by clips loosely fitted and attached to the gate at 5-ft. centers. After about two years' service it was found that the tubing had stretched so that it buckled away from the joint and no longer served its purpose as a seal. Since the tubing was in good condition, a 2-in. iron pipe was inserted in it to prevent buckling. The pipe rested on a shoe at the bottom and was loosely held in place at the top. The modified seal was sufficiently flexible to serve its purpose.

Cylinder Gates—The Elephant Butte Dam spillway contains four cylinder gates for flood regulation (see Fig. 21). Each consists of a boiler-plate cylinder 10.3 ft. internal diameter and 8 ft. high mounted within a cylindrical concrete tower. Each cylinder is provided with two counterweights and is raised by means of a hand-operated hoist at roadway level. A single seat is provided at the bottom, and the clearance between the cylinder and the concrete is kept at a minimum to prevent leakage over the top of the cylinder in case of high water. The lower seat ring is an iron casting set in the concrete and carries three cast iron posts which help to support the concrete tower. Each gate discharges through a curved concrete draft tube leading under the spillway weir.



SECTION C-C

FIG. 21—CYLINDER GATE AND SPILLWAY, ELEPHANT BUTTE DAM, U. S. RECLAMATION BUREAU.

Siphon Spillways—The siphon spillway is a device for discharging water over a dam. It utilizes the available head to produce a higher velocity of flow than would be attained at an overflow weir, thus increasing the discharge. The siphon spillway has many advantages over any other type of spillway control apparatus up to a required capacity of 200 sec. ft. per ft. of crest length.

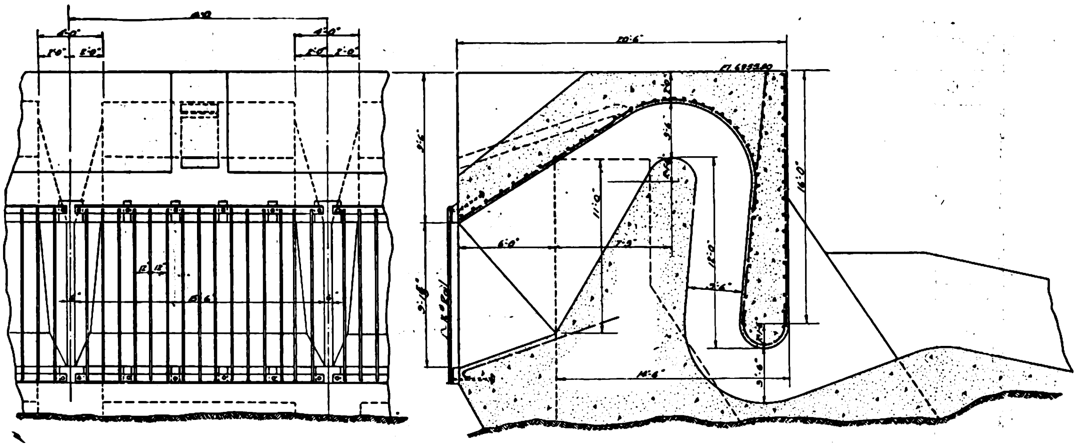
The evident advantages of this type of spillway are as follows: The action is entirely automatic. Priming takes place quickly so that the full capacity of the spillway is effective in an extremely short time, varying from 5 to 10 sec. to 2 or 3 min. for extremely large siphons.

The fluctuation of the water surface above the normal reservoir stage is restricted to a comparatively small range. The siphon type of spillway, owing to its close regulation of the reservoir level, allows the spillway crest to be raised considerably above what would be the case in a free overflow type of spillway and therefore makes available additional storage capacity at the top of the reservoir.

Under the limitations of discharge per lineal foot of crest length of spillway, as noted above, the siphon spillway can be built in approximately from one-half to two-thirds the area required for almost any other automatic or non-automatic type of spillway. In locations where freezing conditions obtain, consideration should be given to the possibility of the formation of ice in the siphon due to a small amount of water washing over the throat.

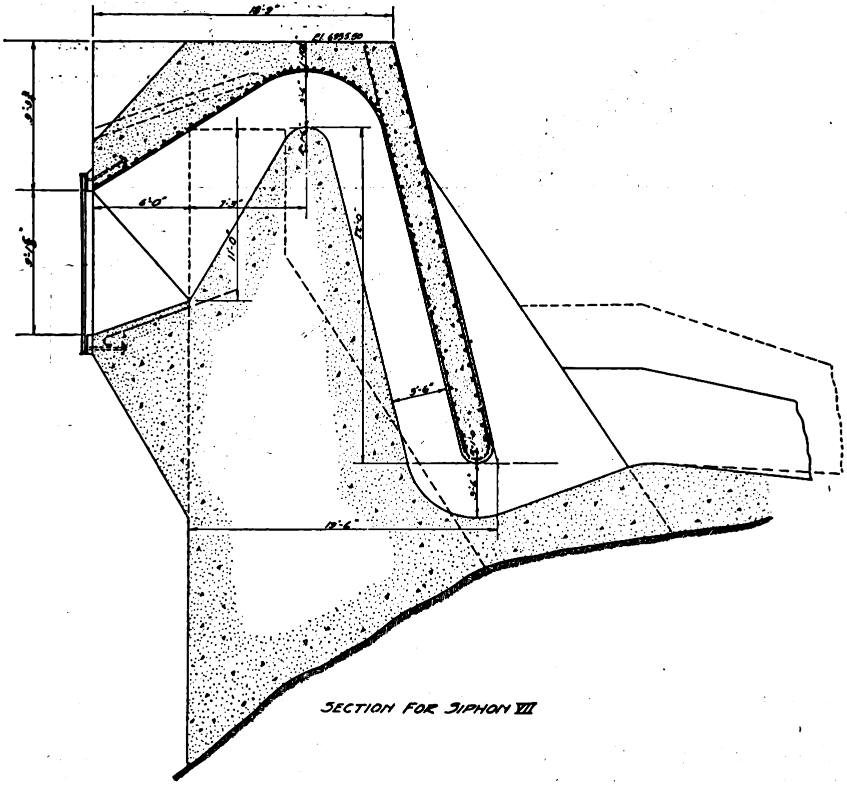
At Huntington Lake Dam the Southern California Edison Company provided a battery of seven siphon spillways (Fig. 22) which would prime at different elevations of the lake surface within the normal range of operating levels. Their combined capacity is 550 sec.-ft. The siphons are similar in construction, but the throat crests are at slightly different elevations and the downstream legs vary from 15 to 22 ft. The air-control passage running from the face of the dam to the upper throat of each siphon is controlled by a slide gate operated from the top of the dam. By varying the height of the gate the elevation at which the siphons prime is thereby adjusted. Priming is aided by a "back-pressure" control which allows the air in the top of the siphon to discharge quickly. The siphons are constructed of reinforced concrete.

Huntington Lake is kept near the normal operating level in order to keep the effective head on the Big Creek No. 1 power house as high as possible. Very little water is spilled from the reservoir because any surplus water can be diverted to Shaver Lake through



FRONT ELEVATION

SECTION FOR SIPHONS I-II & III.



SECTION FOR SIPHON VII

FIG. 22—SIPHON SPILLWAYS, DAM NO. 1, HUNTINGTON LAKE, SOUTHERN CALIFORNIA EDISON CO.

the Huntington-Shaver conduit, which was recently completed. In order to prevent waste of water and damage downstream by the spilled water, the siphon spillways have been modified to act as free-flow spillways by simply adding an air duct to prevent priming.

Measurements of the discharge of siphon spillways show a discharge coefficient of about 0.6.

Automatic Gates—Details of a counterweight automatic gate developed by the Pacific Gas & Electric Company are shown on Fig. 23. The original installation of this gate did not prove entirely satisfactory owing to the excessive momentum acquired when opening or closing. The dashpot control was then added to limit the rate of motion and operation has since been satisfactory. The cost of this gate is very low. A small increase in head is sufficient to cause the gate to drop.

The Stickney automatic gate, which was used on the New York State Barge Canal, consists of two leaves connected rigidly and at right angles to each other and hinged at the point where they join. When the gate is down it rests in a recess in the crest of the dam. Operation is similar to that of the drum gate.

At Baldwinsville, N. Y., on the Barge Canal there is a modified type of Tainter gate which operates automatically due to the water pressure in the pond.

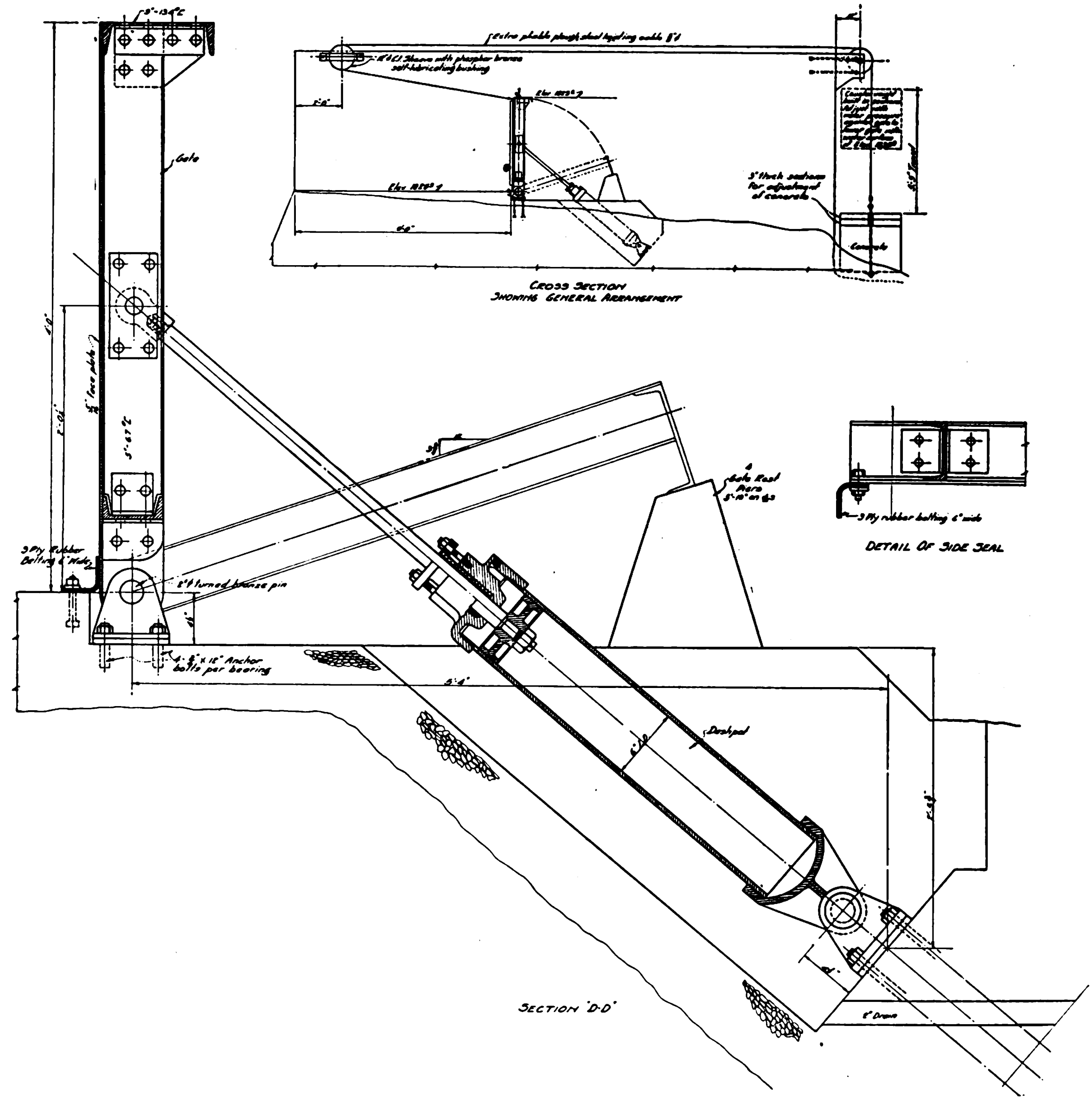


FIG. 23—ARRANGEMENT OF AUXILIARY AUTOMATIC FLOOD GATE, NEW YORK RESERVOIR.

Because of the lack of facilities for keeping the gate free from ice in winter, the automatic feature cannot be depended upon during this period of the year. In addition, back water on the downstream side of this gate interferes at times with its automatic operation (see Fig. 24).

Another type of automatic gate was installed at the Tallulah Falls development. It is pivoted at the bottom, and as it tilts, due to increased water pressure it causes a roller counterweight to move up an inclined plane. A similar type known as the Stauwerke gate uses a walking beam and counterweight. The degree of regulation of water surface for these two types is such that only several inches' rise will cause the gates to tilt. The gates return to their closed position when the water surface again becomes normal. The Stauwerke gates on the Wissota dam have been found to be lacking in sensitiveness, so that they sometimes open more than is necessary to take care of the increased flow, and therefore for a short time discharge considerably more water than is desired. In the same way they do not rise or close until after the head has dropped materially.

Automatic-control gates of California manufacture are being used widely. The gate is counterweighted and actuated by a float which may be governed by either the change in upstream or downstream water level.

The Pacific Gas & Electric Company has installed several of these gates, both for constant level upstream and for constant level downstream. These gates with one exception have operated successfully. The fault in the one case was in the setting of the pin bearing, which was easily remedied. Better results have been obtained with a rubber seal which crimps through an angle of 90 deg. and rubs on the

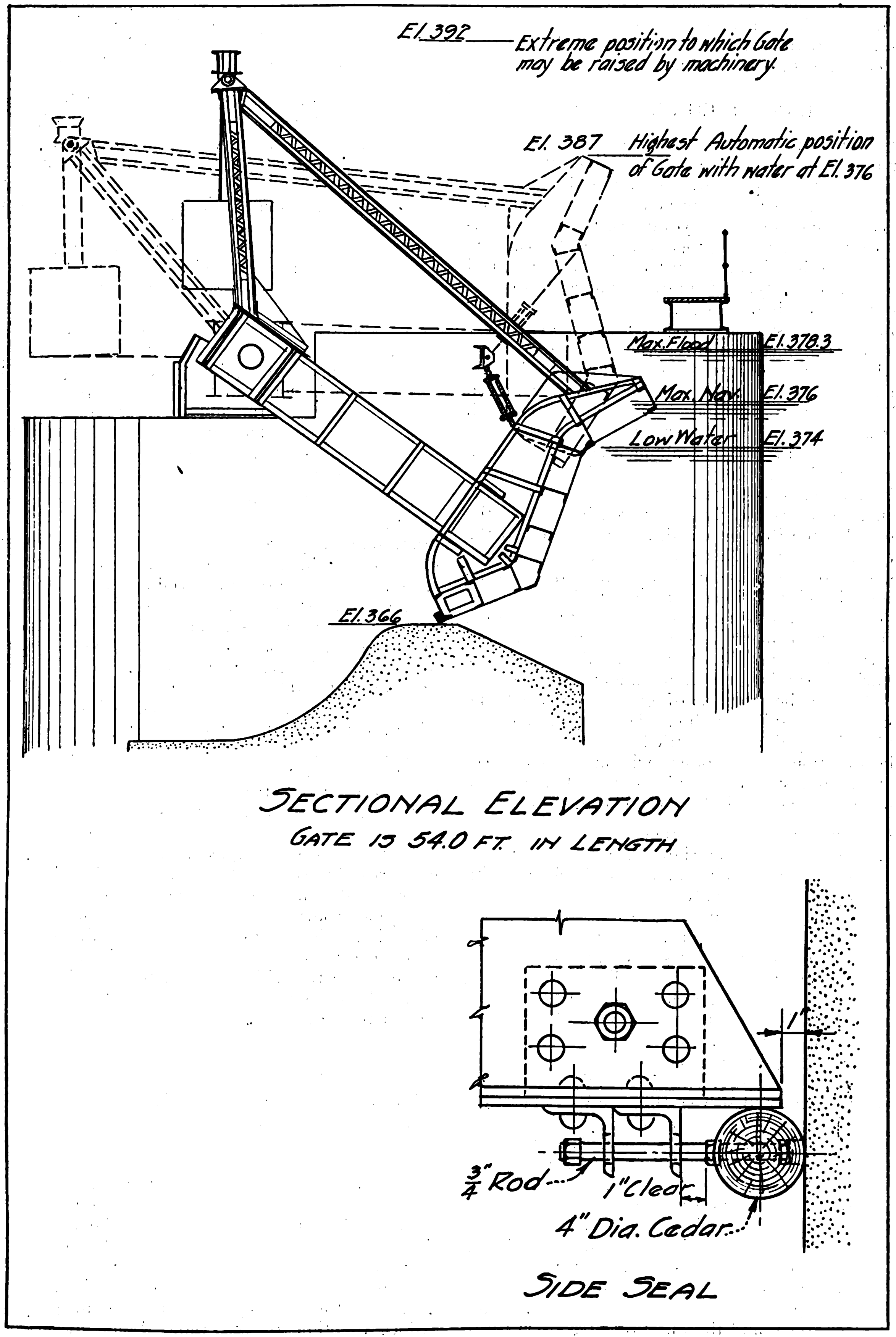

El. 392 Extreme position to which Gate may be raised by machinery
El. 387 Highest Automatic position of Gate with water at El. 376
Max. Flood El. 378.3
Max. Nav. El. 376
Low Water El. 374
El. 366
SECTIONAL ELEVATION
GATE IS 54.0 FT. IN LENGTH
1"
3/4" Rod
1" Clear
4" Dia. Cedar
SIDE SEAL

FIG. 24—AUTOMATIC GATE FOR BALDWINSVILLE DAM, NEW YORK STATE BARGE CANAL.

side walls rather than by providing a notch in the walls which permits the rubber belting to lie flat and parallel to the face of the gate.

GENERAL CONCLUSIONS

The conclusions drawn in a report of this character must necessarily be general. While the design and construction of spillways can and should be based on the fundamental principles of civil and mechanical engineering and hydraulics, the local influences of altitude, climate, topography, geological formation and other factors, must be carefully weighed in the selection of type of spillway gate, and in working out the details of design.

The size of spillway to provide is not strictly within the province of the report, but it would seem that the question of freeboard may properly be discussed. Freeboard should be defined and recognized as the amount of clearance beween maximum high water and the top of dam, or other structure under consideration. Properly speaking, the capacity of a spillway is limited by the permissible maximum depth of water on the crest. Any greater depth than this maximum is clearly an encroachment on the freeboard ostensibly provided, and a menace to the safety of the dam. Therefore, only in very special cases should the possible overtopping of gates be considered. If additional strength and ruggedness are desired, lower working stresses should be used, and the effect of impact provided for; but the desired strength should not be attained in the design by arbitrarily assuming a certain amount of overtopping. Before the problem of gates is attacked, the capacity of the spillway should be adequately determined and very definitely settled.

The question of economics will arise in connection with almost every spillway installation. The following factors should be given consideration:

(1) Value of gain in storage vs. cost of gates.
(2) Cost of flooding rights and clearing where higher reservoir surface will obtain with open type of spillway.
(3) Value of gain in storage due to the use of gates easily and quickly operated.
(4) Use of one type or size of gate on part of the crest suitable for ordinary regulation, and the use of another size or type for unusual flow conditions.
(5) Storage management with respect to the time and magnitude of peak floods.
(6) Investment cost and maintenance cost.
(7) Reliability of service and safety of operation.
(8) Relative costs of different types and locations of spillway on a given dam structure.
(9) The determination of the least total cost, which is the sum of the first cost plus the capitalized value of gain.
(10) Designs in anticipation of future changes and improvements, and designs of spillways for different stages of construction when dam is built in successive steps.
(11) The question of economy is again affected by policy and the question of conservatism. In general, government structures such as the Panama Canal are the most conservative of all, followed by government project structures of a semi-public nature, such as Reclamation Service projects. Public irrigation districts would be next on the list, followed by large, well-financed public utilities whose credit cannot afford to be impaired by the least possibility of failure of structures, and last in line smaller companies who cannot afford to spend any more in first cost than reasonably conservative engineering should require. These considerations must be borne in mind in reviewing the entire question of spillway gates and will not be the same for different companies.
(12) Insofar as policy and economy will permit, designs of spillways and spillway gates should conform as closely as possible with the structural and ornamental features of the main structure in order that the most pleasing and esthetic effect may be accomplished.

The materials of construction and stresses to be used for various types of spillway gates should not differ materially from those of other types of steel structures. The American Institute of Steel Construction specifications may well apply to gates made of structural steel. Gates of cast iron should not have tensional stresses greater than 2000 lb. per sq. in., nor compression greater than 12,000 lb. per sq. in. Cast steel stresses (Class B, Medium) should not exceed 14,000 lb. per sq. in. in either tension or compression; semi-steel when made with 25 per cent of scrap steel may have tensional stresses up to 3000 lb. per sq. in., and compression up to 12,000 lb. per sq. in. Steel forgings should permit stresses equal to those used for structural steel.

Bearing parts of most types of gates should be made of non-corrosive metal such as bronze or babbitt and be so designed that replacement may be made readily. Bronze screws for gate lifts have been recommended in some instances. The bearings of radial gate journals may be of steel if only the lifting effort is considered, as the leverage of lift is so great that a greatly increased friction in the journals will not increase the lifting load materially. The use of bronze bearings is to be recommended as an economical method of preventing undue wear at the bearings and consequent loss of true alignment of the gate.

The desirable speed of operation of most types of spillway gates varies over wide limits. Speeds greater than 2 or 3 ft. per minute are usually not necessary, and the greater speeds require relatively heavier operating mechanism. Where gates have rubber seals, faster speeds may result in excessive wear or possible binding. Norwegian practice has been based on a rate of opening of about 3 min. for the sector gates, 12 to 14 ft. high, and approximately 30 min. for the larger roller gates.

It is highly desirable to provide electric motor operation for spillway gates of any magnitude to reduce the time of operation. Some of the older types of hand-operated gates required hours to lift a single gate. The availability of electric power and expense necessary to bring electric power to remote localities has a great bearing on the problem. Remote or automatic control is desirable for gates of spillways of diversion dams to regulate the amount of water diverted into the conduit. Gates may be also supplemented by siphon spillways to advantage. Remote control of spillways of storage dams is not usually necessary.

The maintenance required for spillway gates is normally very inexpensive. Painting of gates in the original installation should be thoroughly investigated and some durable coating such as asphaltic enamels selected. The expense of maintenance painting then will be reduced to a nominal amount. The journals and operating mechanisms should be greased periodically and tested by partially raising and lowering the gates. This will insure that the gates are operative and break films of corrosion which may be forming.

The question of leakage and means to prevent it is important and has been discussed in connection with the several types of spillway gates.

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MANUFACTURERS' STATEMENTS

STATEMENT BY THE ALLIS-CHALMERS MANUFACTURING COMPANY

Among a number of interesting installations during the year 1928 two are worthy of special attention in the brief space allotted to this report. The first of these is another world record impulse turbine put into operation on the Pacific Coast, and the second is a group of turbines establishing a record in Japan.

In March, 1928, the Bureau of Power and Light of the city of Los Angeles, Cal., awarded a contract to this company for an impulse wheel unit to complete the quota of turbines at their San Francisquito No. 1 Plant. This last unit is rated 32,200 h.p., maximum, under a net effective operating head of 800 ft., and is double the capacity of each of the four units previously installed at that plant. This unit does not beat the world record as to capacity held by the 56,000-h.p. impulse wheels described in last year's report as being built by this company for the Big Creek 2-A Plant of the Southern California Edison Company. Neither does it beat the company's previous world record as to operating head under which the 45,000-h.p., 2400-ft. unit built for the Balch Plant of the San Joaquin Light & Power Corporation, mentioned in the 1926 report. It does, however, beat the previous world record, described in an earlier report, held by the company's Caribou units, built for the Great Western Power Company and which in itself had 11-in. diameter jets and an impulse diameter of 155 in. The new San Francisquito No. 1 unit is also of the double overhung impulse type, but its two jets are each 14 in. in diameter with wheel diameters of 176 in. Fig. 1 shows a shop view of one of the two 52-in. cast steel nozzle pipes with needle, which produces one of the 14-in. jets just mentioned. The speed of 143 revolutions, designed for 50-cycle operation, is the lowest speed of any hydro-electric impulse wheel unit of large capacity. The generator, which also was designed and built by the company, is, therefore, one of the largest of its kind ever built. It is of interest to note that, although this is the largest impulse wheel unit, as to physical dimensions, ever built, it was put into operation before the close of the year in spite of the fact that the order was not placed until March of the same year.

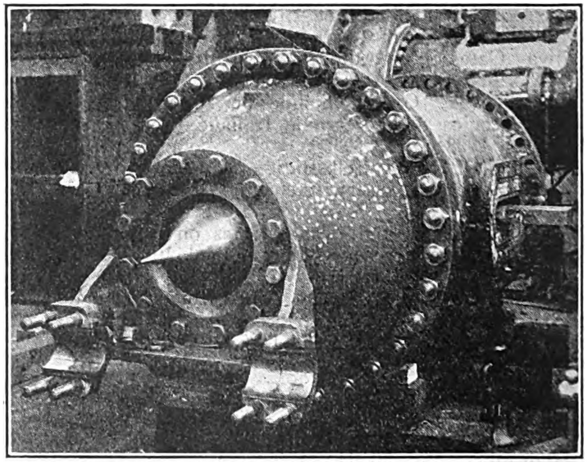

FIG. 1—NOZZLE PIPE AND NEEDLE FOR 32,000-H.P. ALLIS-CHALMERS IMPULSE TURBINE.

The year 1928 saw the complete manufacture and successful installation of three 36,000-h.p., single vertical plate steel spiral casing turbines built for the Saku Plant of the Kanto Suiryoku K. K. in Japan. These units established a record as to capacity of units previously installed in that country.

Fig. 2, in the foreground, shows the casing shop assembly of two of these units with their respective speed rings. These units operate under a normal net effective head of 390 ft., and, therefore, establish another world record in that they are the highest head plate steel spiral casing units ever built. The Allis-Chalmers patented plate steel spiral casings, which were used for this installation instead of the conventional cast steel casings, did much to eliminate

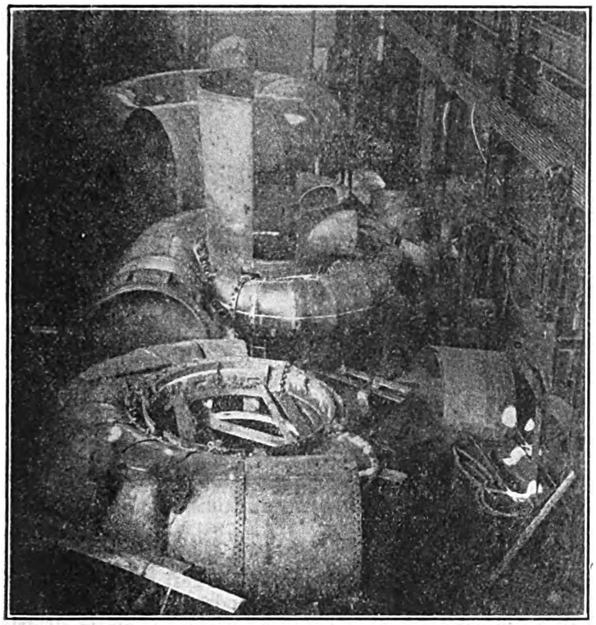

FIG. 2—PLATE STEEL SPIRAL CASING FOR 36,000-H.P. ALLIS-CHALMERS TURBINE.

transportation difficulties. Furthermore, in doing away with the handling of heavy cast steel casing parts with their difficult field assembly, the Allis-Chalmers plate steel spiral design did much to speed up the erection of these units, so that this plant went into operation ahead of the original estimated completion date. In addition to furnishing the three complete hydraulic turbines mentioned above, the company also furnished three 9-ft. diameter cast steel butterfly valves located at the spiral casing inlets, as well as three 11-ft. diameter cast steel butterfly valves placed at the upper ends of the respective turbine penstocks.

Fig. 3 shows two of these 11-ft. diameter butterfly valves in the foreground and one of the 9-ft. diameter butterfly valves in the background. All these are shown with their respective wickets, shafts and housings assembled together.

Among other installations of the past year, the six 5000-h.p. units built for the Chippewa Plant of the Northern States Power Company should be mentioned. These interesting units were designed for a normal operating head of 29.6 ft. and are of the high-speed propeller type, operating at 138½ r.p.m. In addition, the company has under design and construction—three 12,000-h.p., maximum, propeller type turbines for the Back River Development of the Montreal Island Power & Light Company. The runners, when built, will be 16 ft. in diameter for operation at a speed of 85 r.p.m. under a normal net effective head of 26 ft. When installed these units will establish a record on this continent as to physical dimensions.

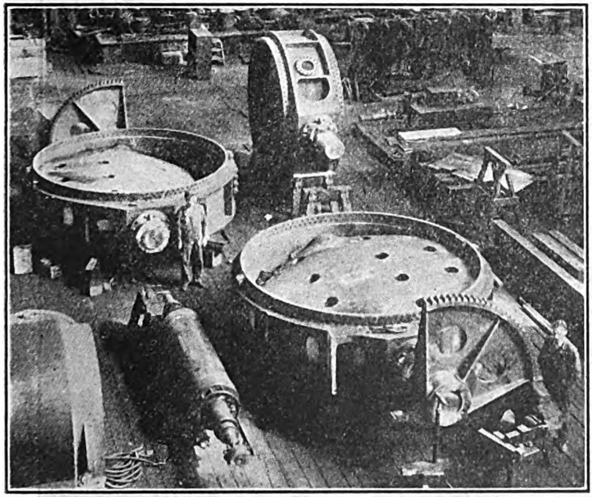

FIG. 3—SHOP ASSEMBLY OF THREE 11-FT. AND TWO 9-FT. ALLIS-CHALMERS BUTTERFLY VALVES.

Mention might also be made here of three 56,000-h.p. single vertical plate steel spiral casing turbines under construction, together with 16-ft. diameter butterfly valves, for the Calderwood development of the Knoxville Power Company. In the background of Fig. 2 also can be seen a 24,500-h.p. plate steel spiral casing turbine for operation under 112-ft. head, designed and built for the Bartlett's Ferry Development of the Columbus Electric & Power Company.

Space does not permit of mentioning numerous other smaller capacity units built or installed by the company during 1928.

STATEMENT BY JAMES LEFFEL & COMPANY

Although this company has been manufacturing water turbines since 1862, it has always specialized in what is termed "Low and Medium Head" field, not exceeding approximately 200 ft. head.

Also, although in 1920 this company erected and occupied an entirely new and thoroughly modern factory, with a view of equipping to build turbines of all sizes, it has always specialized in what are termed "Medium" and "Smaller" sizes.

Since there are four established, reputable manufacturers equipped for, and experienced in, the building of large turbines, this company has never felt it would be profitable to make the further investment in large tools necessary for building these large units, and thereby entering a new and highly competitive field. Its efforts, therefore, have been centered on the improvement of turbines within the field of head and sizes in which it specializes.

There has been considerable activity in recent months in the development of some extremely low heads, in comparatively high capacities. Some of these developments of special interest are the following:

West Missouri Power Company, Osceola Station: Two units, each operating under varying heads of 7 to 14 ft., at constant speed 120 r.p.m., each unit developing, under 14-ft. head, 1130 h.p.

These units are of high-speed type, designed with outside or exposed type gate operating mechanism. The penstocks are of decked, vacuum type, equipped with separate ejectors. The steady bearings are grease and water lubricated. The units are equipped with complete automatic remote control. These runners are approximately 112 in. in diameter.

Wisconsin Power & Light Co., Indian Ford Station: Two units operating at 90 r.p.m. Head varying from 4 to 6 ft. Capacity, each unit, at 6-ft. head, 281 h.p.

These units are of the submerged gate operating mechanism type, installed in decked, vacuum penstocks and equipped with complete, automatic remote control. These runners are approximately 102 in. in diameter.

Lake Superior District Power Company., Thornapple Plant: Two units operating at 120 r.p.m., under heads varying from 8 to 15 ft., each unit at 15-ft. head, developing 1170 h.p.

These turbines are installed in decked, vacuum type penstocks, with exposed type gate operating mechanism. The speed rings are cast solid. The turbine is fitted with automatic oil-lubricated steady bearings. These runners are approximately 112 in. in diameter.

City of Idaho Falls, Idaho: One unit, 21-ft. head, 1800 h.p., 150 r.p.m.

This unit is installed in a decked concrete penstock. The turbine has solid speed ring and exposed type gate operating mechanism, and self-lubricating oil steady bearing.

A very interesting development, which is in the nature of an experiment, is now being made by the Lowhead Water

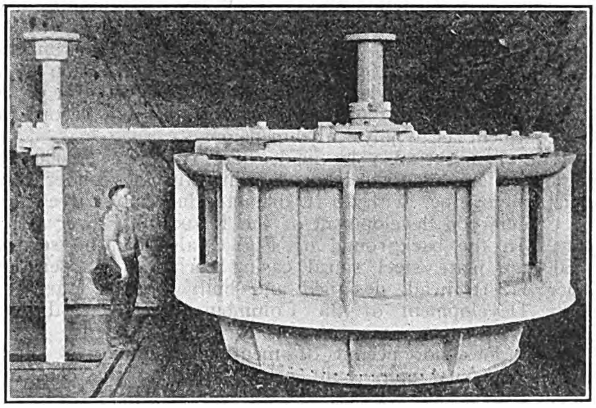

FIG. 4—LEFFEL TURBINE WITH SUBMERGED TYPE GATE MECHANISM AND ADJUSTABLE LIGNUM VITÆ BEARING.

Power Company, Beaufort, S. C., where they are installing one unit, 7-ft. head, 100 h.p., 164 r.p.m. This unit is operated by the rise and fall of the tide. There are a number of unique and interesting features in connection with it. If it proves entirely satisfactory, additional tide-water developments will be made.

Fig. 4 and 5 illustrate a typical vertical, direct-connected type of turbine with submerged type of gate operating mechanism, using lignum-vitæ steady bearing designed for adjustment in four directions.

Fig. 6 and 7 illustrate types of exposed or outside type of gate operating mechanism. The steady bearing shown on Fig. 7 uses six heavy, solid, lignum-vitæ bearing blocks, while in that shown in Fig. 6 self-lubricating oil steady bearings are used.

Almost all of these medium and low head plants are now equipped with complete remote control.

STATEMENT BY I. P. MORRIS & DE LA VERGNE, INC.

In March, 1928, several months ahead of schedule, the 54,000-h.p. Conowingo turbines were placed in successful commercial operation. From the start these turbines, which are outstanding in that they are the largest in overall physical dimensions of any turbines yet undertaken, have operated with an absence of any major difficulties. This is gratifying in view of the unprecedented size of the parts involved. The 27-ft. butterfly valves with rubber tube sealing devices have been most successful in saving water during the shutdown period of the turbines. These units now form a very important element in the generating capacity of the Philadelphia Electric Company's system. During low flow periods they are operated at peak load and during high flow periods continuously on base load.

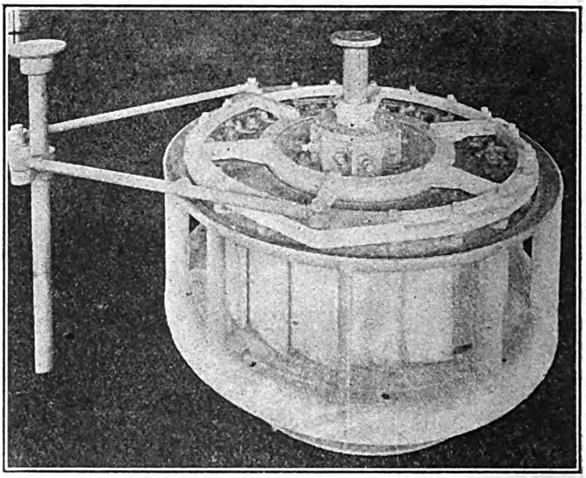

FIG. 5—LEFFEL TURBINE WITH SUBMERGED TYPE GATE MECHANISM AND ADJUSTABLE LIGNUM VITÆ BEARING.

Hydro-electric development in Canada continues at a very rapid pace, owing to the comparative absence of steam competition and to the large number of undeveloped water power sites: The principal contracts obtained by this company and by our licensees, the Dominion Engineering Works, Ltd., during the year 1928, are as follows:

One 43,000-h.p. turbine for the Shawinigan Engineering Company, for installation at Shawinigan Falls, Quebec. Head, 145 ft.

Two 31,000-h.p. turbines for the Great Falls Power

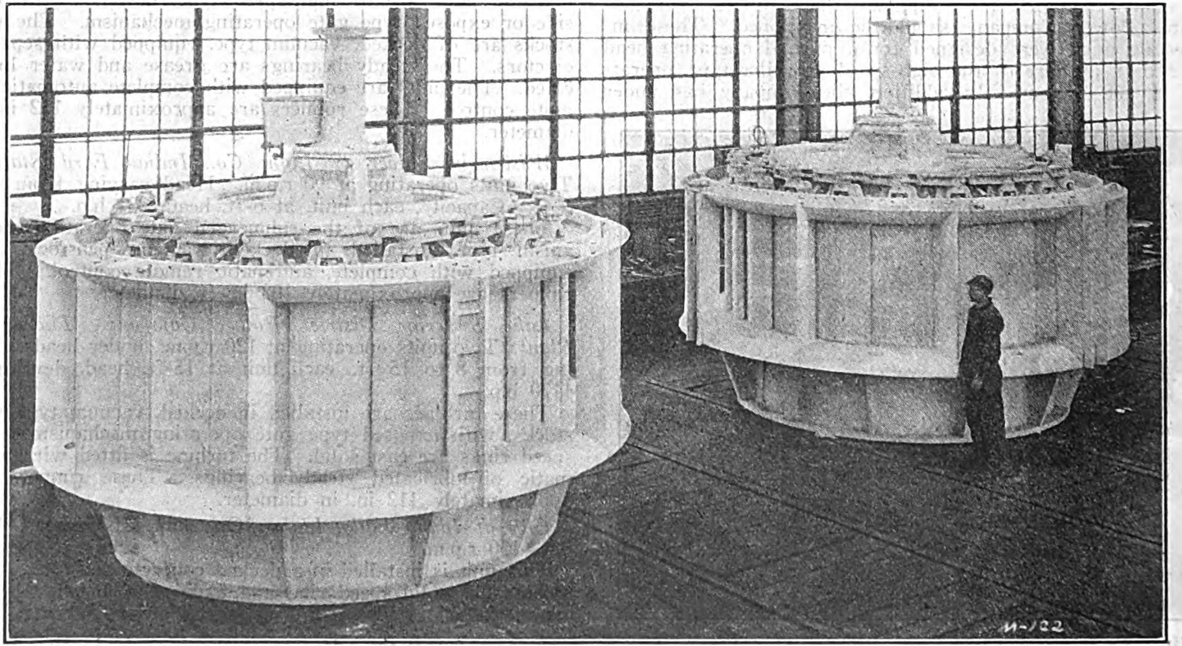

FIG. 6—LEFFEL TURBINE WITH OUTSIDE TYPE GATE MECHANISM AND SELF-LUBRICATING OIL STEADY BEARING.

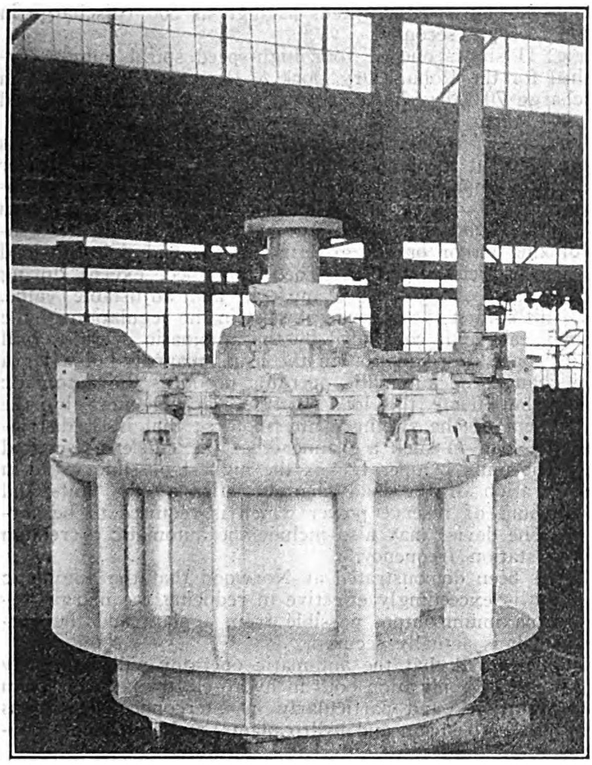

FIG. 7—LEFFEL TURBINE WITH OUTSIDE TYPE GATE MECHANISM AND LIGNUM VITÆ STEADY BEARING.

Company, Montana, Morony Development. Head, 82.5 ft.

Two 36,000-h.p. turbines for the Alabama Power Company, Lower Tallassee Development. Head, 88 ft.

Two 19,200-h.p. turbines and one 8550-h.p. turbine for the Turners Falls Power & Electric Company, Cobble Mountain Development. Head, 420 ft.

Two 18,000-h.p. turbines for Calgary Power Company, Ghost River Development. Head, 105 ft.

Two 12,000-h.p. turbines for the Corporation of the City of Winnipeg, Slave Falls Development. Head, 30 ft. Propeller type units.

One 15,700-h.p. turbine for St. Lawrence Valley Power Corporation, Colton Development. Head, 270 ft.

Three 14,000-h.p. turbines for Churchill River Power Company, Flin Flon Development. Head, 56 ft. Propeller type units.

Two 3000-h.p. turbines for Nova Scotia Power Commission, Upper Hooke Falls Development. Head, 31.5 ft. Propeller type units.

The aggregate capacity of propeller type units constructed by this company and the Dominion Engineering Works, Ltd., up to the end of 1928 totals 485,000 h.p.

The Morony turbines are duplicates of the 25,600-h.p. turbine which this company furnished for the Norwood Development of the Carolina Power & Light Company. In line with modern practice, the Cobble Mountain turbines will not be provided with relief valves, but are designed to take care of the pressure rise resulting when the governors close the gates at the maximum rate possible. This maximum rate will be fixed by non-removable diaphragms located in the governor piping.

The Alabama Power Company's Lower Tallassee turbines are equipped with rubber sealing strips set into the face of the upper and lower distributor plates in such a manner that when the movable guide vanes close these vanes are in contact with the strips. This reduces very effectively the amount of leakage through the turbine gates in the closed position, and this feature is coming to be of increasing importance in conjunction with the peak operation of turbines, which often necessitates the turbines being shut down with pressure in the casings during an extended period each day.

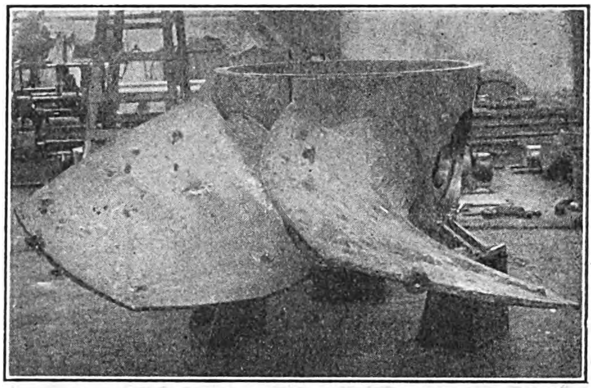

FIG. 8—I. P. MORRIS 8800-H.P. PROPELLER TYPE RUNNER.

The construction by the Dominion Engineering Works, Ltd., of the 8800-h.p. propeller type units for the Back River Development of the Montreal Island Power Company, Ltd., is of interest. The vanes of these runners will be manually adjustable. Fig. 8 and 9 show, respectively, the photograph of the runner during the assembly with the blades in the shops and a sectionalized aluminum model, showing the operating mechanism. In this mechanism the turbine of the runner vanes is accomplished by means of a lubricated sliding shoe without the use of gearing at this point, thus reducing materially the bearing pressure, lost motion and wear, which accompany the use of gears. These runners will have a diameter of about 15½ ft., and with the exception of the Lila-Edet turbines in Sweden, are believed to be the largest, in point of dimensions, of any adjustable blade propeller runners yet undertaken, and the largest in capacity, including the Lila-Edet units.

Fig. 10 represents a view of our new hydraulic laboratory for testing model turbine runners and pumps. The design is such that the same weir is used for the measurement of the water when a pump is being tested as when a turbine is being tested, this weir having been calibrated volumetrically.

A unique feature in connection with the laboratory is the

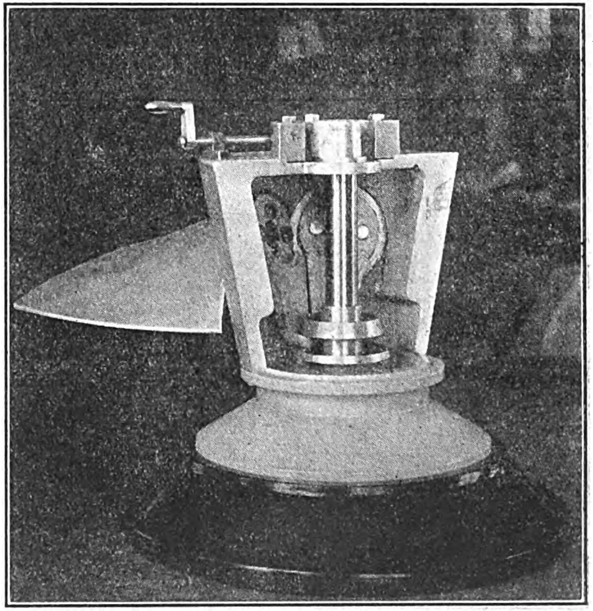

FIG. 9—SECTIONALIZED ALUMINUM MODEL OF RUNNER SHOWN IN FIG. 8.

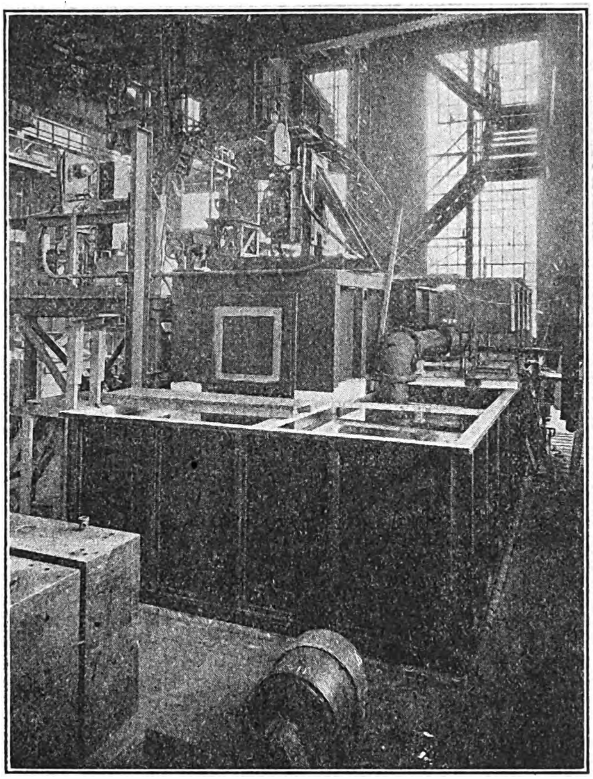

FIG. 10—HYDRAULIC TURBINE AND PUMP TESTING LABORATORY OF I. P. MORRIS & DE LA VERGNE, INC.

use of an electric dynamometer, which permits the accurate measurement of the power developed by the turbine and of the power required to drive the pump under test. As the stationary element of the dynamometer is mounted so that the torque being developed is measured by weighing scales, the efficiency of the dynamometer when operating as a motor or as a generator does not enter into the calculations. A very satisfactory control of speeds is possible.

The Moody spiral pump, which represents an application of the propeller type of runner for pumping, is experiencing broader application where the amount of water to be pumped is large and the head not higher than 40 to 50 ft. These conditions make high specific speed desirable, and these pumps develop specific speeds as high as 500 (discharge in cubic feet per second).

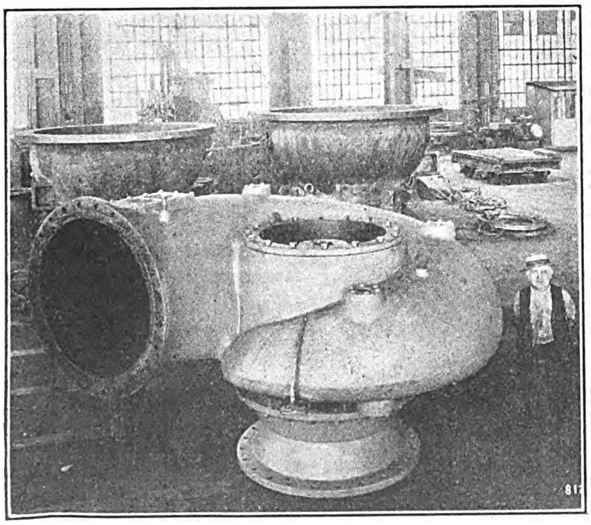

FIG. 11—HIGH SPEED SPIRAL PUMP, 70,000 G.P.M., 26-FT. HEAD, I. P. MORRIS & DE LA VERGNE, INC.

Fig. 11 shows one of four high-speed spiral pumps furnished for the Robins Dry Dock & Repair Company, which discharge 70,000 g.p.m. against a head of 26 ft. at a speed of 400 r.p.m.

The first installation of an automatic operator has taken place at the Norwood Station of the Carolina Power & Light Company and is now in successful commercial operation. This instrument has been devised for installation on the switchboard for the automatic operation of the synchronizing motor on the governor to the end that the load on any particular unit may be maintained, except during sudden load changes, at a uniform and adjustable value.

If this station is required to assist in the regulation of the system, each unit controlled by the automatic operator will do its share of regulation in the usual manner, but after a load change the automatic operator produces the automatic re-distribution of the load on the various units by the adjustment of the synchronizing motors; that is, it distributes the load in such a manner that the efficiency secured from the units in operation is the highest possible value in consideration of the load characteristics of the units and the amount of reserve power which is required to be carried. The device may also include the automatic correction of the station frequency.

It has been demonstrated at Norwood that the automatic operator is exceedingly effective in reducing the margin between maximum output possible from a plant and the output which is actually secured.

It is believed that the automatic operator will ultimately have a broad application both in hydro-electric and in steam power stations, and particularly in interconnected stations involving both steam and hydro plants, and in systems having stations subject to different conditions.

STATEMENT BY THE NEWPORT NEWS SHIPBUILDING & DRY DOCK COMPANY

Turbines

The following units are among those completed by this company and put into commercial operation during the past year:

(a) One 12,000-h.p., 75-ft. head, 133.3-r.p.m. vertical turbine for the Clarion River Power Company, Piney Station. This unit is of interest in that the built-in parts were already installed and were only designed for an 11,000-h.p. turbine whereas the unit gave an output of more than 12,500 h.p. on field test.

(b) Two 28,000-h.p., 90-ft. head, 120-r.p.m. vertical turbines for the Western Carolina Power Company, Oxford Station. These units have the Newport News type elbow draft tube (patented) described and illustrated in this company's last statement. These tubes have been found to function very satisfactorily and efficiently without vibration at any load condition and with a very satisfactory discharge appearance.

(c) One 10,000-h.p., 439-ft. head, 450-r.p.m. vertical turbine for the Braden Copper Company, Coya Station, Chile, S. A.

(d) One 3400-h.p., 65-ft. head, 240-r.p.m. vertical turbine for the U. S. Bureau of Reclamation, Gremsey Plant.

Two of the above installations have the Newport News type oil bearings (patented), illustrated in Fig. 12. This type of bearing was described in the last report and provides a positive separation of the oil in the sump below the bearing and any water leaking up around the shaft through the stuffing box, at the same time providing ready access for adjusting the packing gland while the unit is in operation, or renewing the packing without dismantling any portion of the bearing.

Two 4800-h.p., 32-ft. head, 150-r.p.m. and one 3400-h.p., 32-ft. head, 180-r.p.m. units, which were built during the past year for the West Florida Power Company, Jackson's

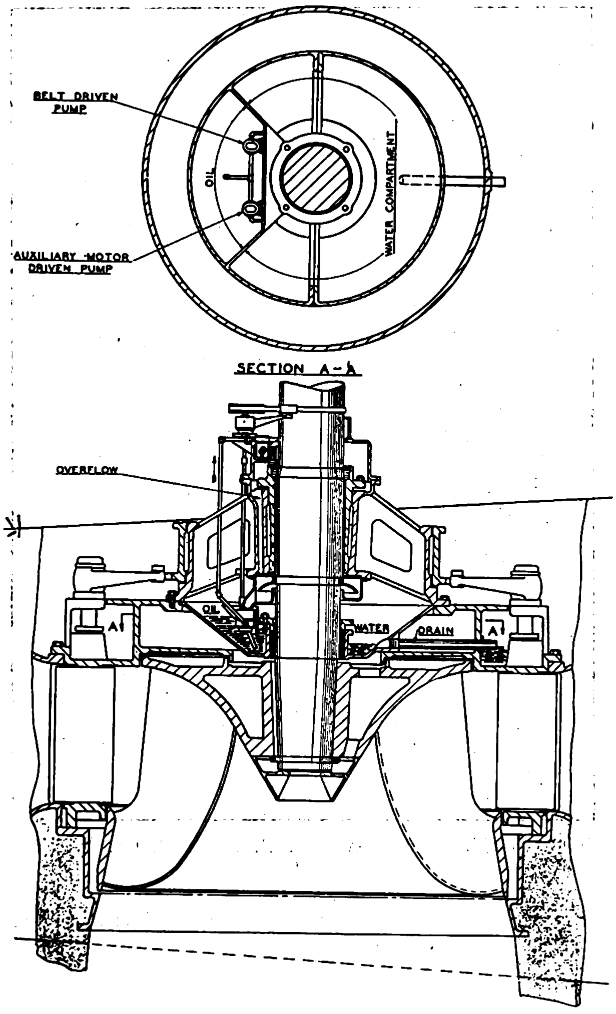

FIG. 12—PATENTED OIL BEARING, NEWPORT NEWS, S. B. & D. D. CO.

Bluff Station, are now being erected, and have runners of the propeller type. A 40-in. model of these runners showed a record performance of 92.2 per cent maximum efficiency on Holyoke Test and gave over 90 per cent efficiency over a range of specific speed from 115 to 180, which makes this type especially suitable for plants with large variations in head.

New contracts received during the past year include the following:

	No. Units	H.p. per Unit	Head in ft.	R.p.m.
Hydro-electric Power Commission of Crisp County, Ga.	1	6,000	30	100
Hydro-electric Power Commission of Crisp County, Ga.	1	3,600	30	100
City of Cookeville, Tenn.	1	1,600	230	720
South American Gold & Platinum Company	1	1,200	13	72

The units for Crisp County, Georgia, are of special interest in that the engineer selected a combination of Francis and propeller type runners of different capacities, so that an extremely high efficiency would be obtained throughout the power range of the plant.

The principal parts for the unit for South American Gold & Platinum Company were split up sufficiently so that no part would weigh over 6000 lb., in order to facilitate transportation to the power house.

A distinctly forward step was taken in runner construction in the successful building of a completely welded double runner to develop 15,000 h.p. under 250-ft. head at 360 r.p.m. This runner, shown in Fig. 13, was built for the Tennessee Electric Power Company to replace a cast-iron runner whose life had proved short on account of the unusually severe operating conditions. Separate steel castings were made for the hub and bands, and the water passage surfaces machined to the correct dimensions. The 19 vanes were pressed by dies from ⅝-in. boiler flange steel, one double vane being formed as a unit. The vanes were trimmed to templet and tack welded to the hub, then the bands put in place and tack welded, after which the vanes were completely welded to the hub and bands. The runner was annealed without scaling and finally finished the same as a solid cast runner. The resulting runner proved to be unusually strong, rigid and smooth.

Castings for double runners are very difficult in iron, besides not being susceptible to ready repair by welding when pitted or eroded, and are practically out of the question in solid cast steel. This partly accounts for manufacturers discontinuing the building of double runner units. It is possible that the use of welded runners will open up a new field in the use of double runners for relatively high heads. Double runners possess the advantage of being practically hydraulically balanced axially; they have less rotating surface in contact with water, which reduces the skin friction loss to a minimum; there is no leakage loss around the hub of the runner such as in the case with single runners; a higher rotating speed gives reduced generator cost, and the resulting turbine is somewhat less expensive than the equivalent single runner turbine. Obviously, it is only applicable to horizontal machines, but, as there seems to be some tendency toward a return to horizontal machines for relatively high heads, this does not appear to be a disadvantage.

Mechanical Rack Rakes.

Thirteen installations were contracted for during 1928, bringing the total number of installations to sixty-one and involving the use of ninety-eight rakes.

This type of rack rake has become so standardized, so simple in its construction and operation, and its economy so well known that very little new of interest can be said about it. However, a somewhat special installation is shown in Fig. 14. This installation was made at the York Haven Station on the Susquehanna River. The space for the

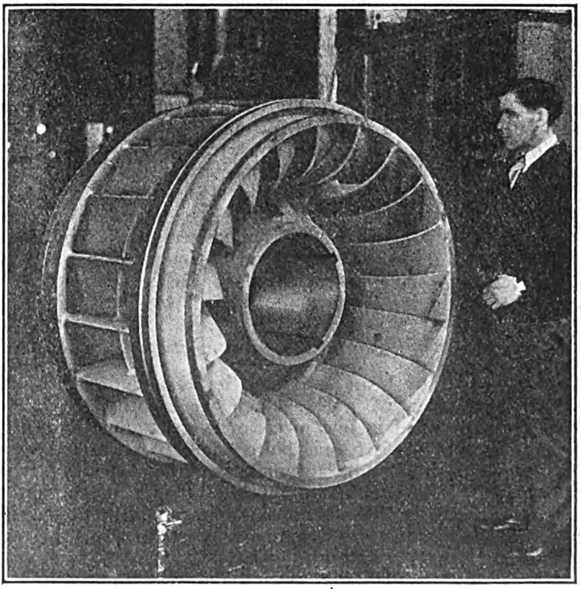

FIG. 13—15,000-H.P. WELDED DOUBLE RUNNER, NEWPORT NEWS, S. B. & D. D. CO.

Turbines

The problem of developing hydro power in the West is generally co-existant, to a minor or major degree, with that of irrigation and domestic water supply. Two developments where this situation existed to a major degree were prosecuted during 1928. The Coolidge Dam and reservoir just completed, on the Gila River in Arizona, by the U. S. Indian Irrigation Service is primarily for irrigation service, and provides a storage of approximately 1,200,000 acre ft. The power to be developed, however, renders this undertaking economically satisfactory and this company have under construction in its San Francisco Works, two vertical Pelton, reaction turbines complete with governors, oil pressure sets and accessory hydraulic equipment for the Coolidge Dam power house. Each unit will develop 9200 h.p. under 220-ft. effective head at 300 r.p.m. The design is such as to provide maximum efficiencies under variable head, the range being from 140 ft. to 220 ft.

The East Bay Municipal Utility District is completing its main storage reservoir on the Mokelumne River at Pardee Dam, where 20,000 h.p. will be developed as a by-product of the domestic water supply for the cities on the eastern shore of San Francisco Bay. The power house will include two 10,000-h.p. vertical Pelton reaction turbines, operating under a normal effective head of 300 ft.—the range of head being 125 ft. These turbines will be complete with Pelton governors, oil pressure sets and accessory equipment.

Among the notable Pelton installations in 1928, in the reaction turbine field, the No. 2 Unit of the Big Creek No. 8 Plant of the Southern California Edison Company, illustrated in Fig. 16, may be mentioned. The shop assembly, as illustrated, was subjected to a hydrostatic test of 700 lb. per sq. in. which was maintained continuously for 24 hr. while the stresses and strains at critical points were checked at intervals with a strain gage which indicated them to be well within design limits. This turbine has a rating of 44,000 h.p. under a static head of 715 ft. at 375 r.p.m.—a record capacity in the West for a unit operating under such a high head.

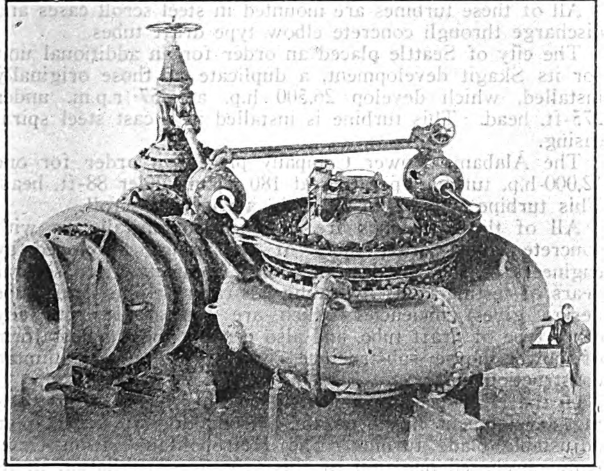

FIG. 16—44,000-H.P. PELTON TURBINE, 715-FT. HEAD.

Important progress has been made in the field of automatic hydro plants, an outstanding example being the Spaulding No. 3 Unit of the Pacific Gas & Electric Company. Here all of the principal operating functions of the turbine and auxiliaries are performed hydraulically, using the water pressure direct from the penstock, with electrical control. A novel improvement is the hydraulic controller which replaces the oil pressure governor and which performs all of the functions of starting, loading and shutdown, for block load plants, without requiring any oil pressure system and its attendant complications. A complete description of the automatic features of this plant has been published in the May 15, 1928, issue of *Electrical West* in a report of the Hydraulic Power Committee, P. C. E. A., and will again appear in the serial report of the Hydraulic Power Committee, N. E. L. A., in due course.

The successful operation of automatic hydro-electric plants has conclusively demonstrated their reliability and economic advantages over manual control, with a result that many existing equipments are being converted to automatic operation. Since the principles of operation are practically independent of the size of equipment, there is no doubt that automatic control and operation will be applied to large capacity equipment in the future.

Impulse Wheels

Among the notable Pelton impulse installations placed in service during the year 1928 may be mentioned the Big Creek 2-A Unit of the Southern California Edison Company, shown in Fig. 17. This is a characteristic double overhung, single nozzle assembly with governor operated, straightflow power nozzles with individual auxiliary relief needle pressure regulating nozzles. Shortly after being placed in service, this unit was called upon for outputs of 70,000 h.p. and over, which it carried continuously in a very satisfactory manner; a record performance with impulse equipment.

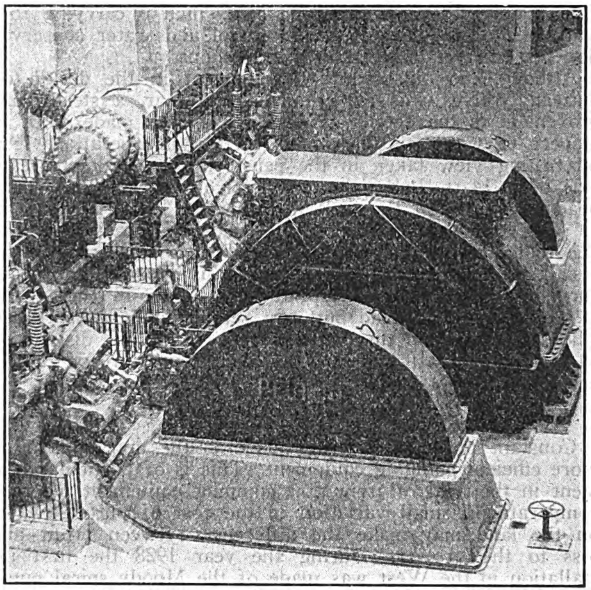

FIG. 17—70,000-H.P. PELTON DOUBLE OVERHUNG IMPULSE WHEEL.

The Bucks Creek Plant of the Feather River Power Company, illustrated in Fig. 18, containing two horizontal,

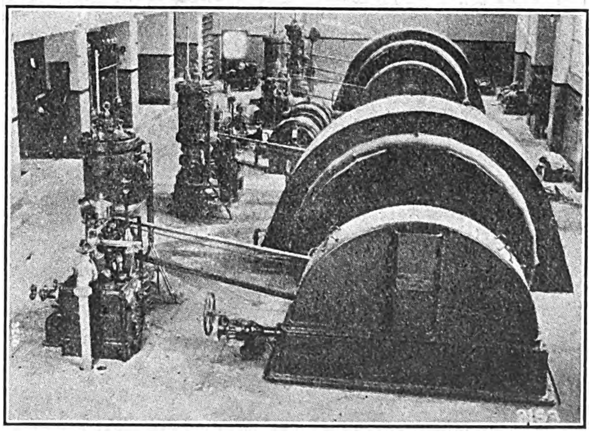

FIG. 18—35,000-H.P. PELTON DOUBLE OVERHUNG IMPULSE WHEEL, 2562-FT. HEAD.

double overhung, single nozzle units each furnishing 35,000 h.p. at 450 r.p.m., was placed in successful service under a record static head of 2562 ft. The acceptance test for efficiency of the hydraulic equipment, with water quantity measured by the Allen salt velocity method, disclosed a maximum efficiency of 85.5 per cent at the normal operating point with efficiencies in excess of 85 per cent over a wide range of load.

Valves

The use of Larner Johnson free discharge valves for water flow regulation in storage dams for irrigation and water supply service is being constantly extended. The size and height of such dams has been increased to a remarkable extent during the past few years, and the higher heads thus produced necessitate the use of this type of valve for discharge regulation. A number of these valves were installed during 1928, several being furnished to the Los Angeles Flood Control District which is carrying forward one of the largest flood control and water conservation projects yet undertaken in this country.

Although no outstanding development in the design of butterfly valves was made during the year, a steady improvement in the details of design has been made, both in respect to water tightness and facility in operation. An interesting view taken in the penstock on the downstream side of a 14-ft. Pelton butterfly valve with the full static head of 45 ft. on the disk is shown in Fig. 19. As can be seen from the illustration, the leakage is practically zero due to the adjustable, sectionalized bronze seat ring on the disk. Another interesting valve of this type is that being furnished for the 44,000-h.p. turbine shown in Fig. 1. It is the largest high head butterfly yet installed in the West. The static head on this valve is 720 ft. and the disk is of 84 in. diameter. It was shop tested at a pressure of 725 lb. per sq. in.

Pumping Equipment

Constant progress is being made in the development of more efficient pumping equipment. This is of particular moment in the field of irrigation pumping equipment where a comparatively small variation in the cost of putting water on the land may make the difference between profit and loss to the grower. During the year 1928 the first installation in the West was made of the Moody spiral pump —a high-speed, low-lift pump of high efficiency manufactured by this company at the San Francisco Works. Seventeen of these pumps, each of 20,000 g.p.m. capacity, are being installed by the West Stanislaus Irrigation District in Central California.

Another notable installation of this type of pumping equipment is being made by the Patterson Water Co. at Patterson, Cal., to whom this company is furnishing 25 of these units to replace obsolete pumping equipment. The economic analysis as made by the engineers of the water company indicates that a saving of $17,000 per year in operating costs will be effected.

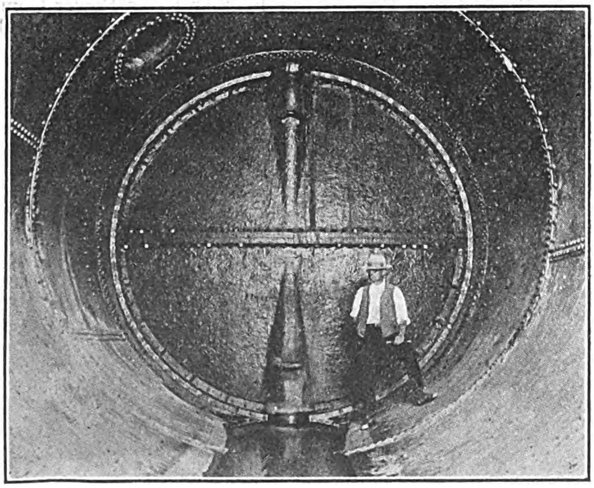

FIG. 19—14-FT. PELTON BUTTERFLY VALVE.

STATEMENT BY S. MORGAN SMITH CO.

During 1928, a year marked by many important activities in the field of hydraulic power development, this company was awarded a number of large contracts for turbines, some of which involved features of much importance. The total power involved in these contracts, including the orders placed with the company's Canadian associates, the S. Morgan Smith-Inglis Company, amounts to more than 1,000,000 h.p.

The largest turbines ordered during this period were four vertical shaft units set in 17-ft. diameter steel spiral casings for the Alcoa Power Company at its Chute-a-Caron development. These turbines, the runners of which are made of cast steel, are designed to develop 75,600 h.p. each, at 120 r.p.m. under 165-ft. head. This company also was awarded the contract for four units for the Saluda development of the Lexington Water Power Company in South Carolina. These units will each develop 55,650 h.p. under 180-ft. head, operating at a speed of 138½ r.p.m. Four units of the same size and type also are being built for the Lower Fifteen Mile Falls development of the New England Power Construction Company. These units will be rated at 53,100 h.p. at 138½ r.p.m. under 175-ft. head. The Brazilian Hydro-Electric Company awarded this company the order for the third unit for its Parahyba plant, this unit being designed to develop 40,000 h.p. at 125 r.p.m. under a head of 104 ft. The James Maclaren Paper Company of Buckingham, P. Q., has ordered three 30,000-h.p. vertical units operating at 180 r.p.m. under 180-ft. head.

All of these turbines are mounted in steel scroll cases and discharge through concrete elbow type draft tubes.

The city of Seattle placed an order for an additional unit for its Skagit development, a duplicate of those originally installed, which develop 26,500 h.p. at 257 r.p.m. under 275-ft. head. This turbine is installed in a cast steel spiral casing.

The Alabama Power Company placed an order for one 12,000-h.p. turbine operating at 180 r.p.m. under 88-ft. head. This turbine will be installed in a concrete scroll.

All of these turbines are designed for installation with concrete elbow draft tubes of the design developed by engineers of the S. Morgan Smith Company after several years of testing in its hydraulic laboratory. This draft tube design gives efficiencies which are comparable with any other type of draft tube, and also permits the simplest form of power house substructure, which results in minimum construction costs.

In the high-speed turbine field possibly the most interesting development has been the introduction of the Kaplan adjustable blade turbine. The Metropolitan Edison Company purchased one unit of this type for installation in its York Haven plant. This unit has manually adjustable runner vanes. The turbine is installed in an old flume which is very greatly restricted, and which necessitated special design for conducting the water to the runner. The draft tube is of the concrete elbow type. This unit is rated at 2750 h.p. under 26-ft. head at 200 r.p.m. It has been in satisfactory operation for some time, but as yet efficiency tests have not been completed.

The first automatically controlled adjustable blade Kaplan turbine was ordered by the Central Power & Light Company for its Devils River No. 9 development in Texas. This unit (Fig. 20) is of the 4-blade type with the blades automatically controlled by an oil pressure governor. The unit is rated at 1900 h.p. under 33-ft. head at 300 r.p.m. Due to the very flat efficiency curve of the Kaplan turbine, and also to its ability to take overloads of up to 20 per cent beyond the point of best efficiency with only a very slight loss in efficiency, it is expected that the yearly output will be greatly increased. During the past year orders for three similar automatically adjustable blade units were received from the Nova Scotia Power Commission for its Tusket Falls development, these units being rated at 1052 h.p. at 225 r.p.m. under 27-ft. head, and from the Wisconsin Power & Light Company for one unit for its

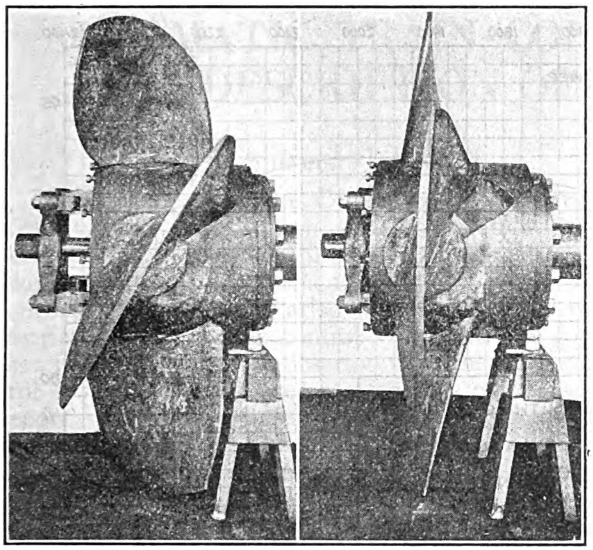

FIG. 20—AUTOMATICALLY ADJUSTABLE BLADE, KAPLAN RUNNER, S. MORGAN SMITH CO.

Rockton development, which will develop 750 h.p. at 100 r.p.m. under 10½-ft. head. The two illustrations show the Kaplan automatically adjustable blade runner with the blades in the fully opened and fully closed positions.

During the year efficiency tests were conducted at a number of plants, and some of these results are shown by the accompanying curves. The test curve for the Santeetlah development of the Tallassee Power Company (Fig. 21) shows the results of a high head type unit. This turbine was designed to operate over a range from 500 to 660-ft. head, with the point of best efficiency at about 560 ft. Conditions were such that the test had to be run with a head of 660 ft., and it is expected that at 560 ft. 1½ per cent higher efficiency could be obtained at the best point. The draft tube used with this turbine was of a special type designed by the Hydraulic Engineer of the Aluminum Company. An interesting test of a small capacity unit is that of the station service unit built for the Conowingo plant of the Philadelphia Electric Company. This turbine was tested by both the Allen salt velocity and by the Gibson methods, which differed only 0.3 of 1 per cent in efficiency at the peak. The test for the Alabama Power Company's Jordan Dam development was made by the Allen salt velocity method, and the results are as shown on the curve illustrated by Fig. 23.

In addition to the turbines described above, a great many units of various sizes were built both in the Francis and high-speed Kaplan types.

The Dow disk-arm butterfly valve continues to be popular, and orders were received for a number of these valves in very large sizes.

Interest has continued in the company's hydraulic testing laboratory, and a number of power companies have conducted tests there covering new and reconstruction work in order to determine definitely what results will be obtained under conditions and structures that otherwise would leave considerable room for doubt as to the ultimate results.

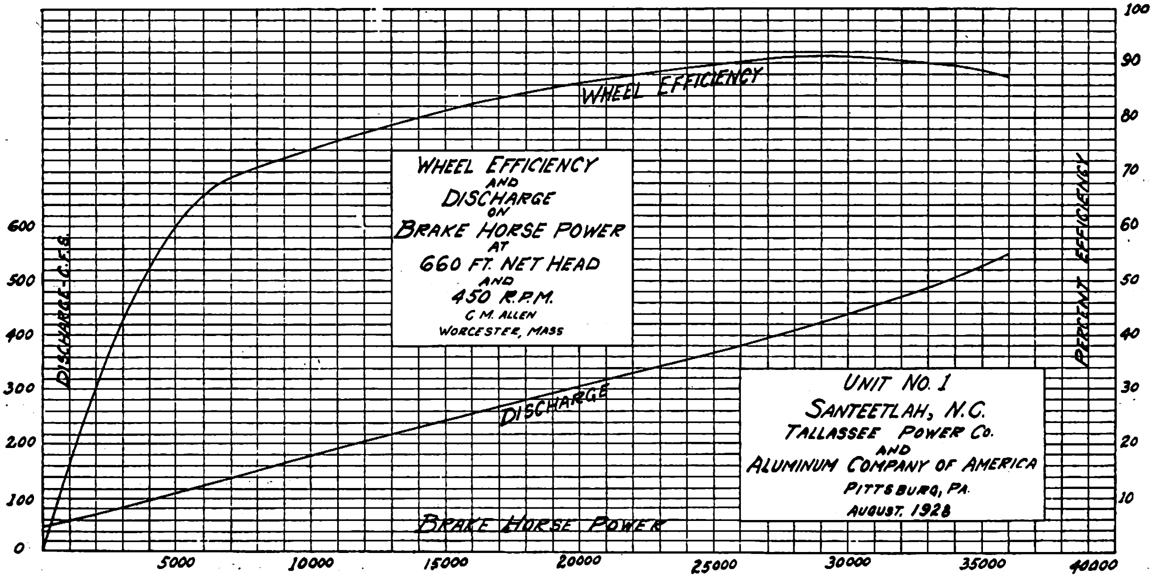

FIG. 21—TEST CURVES, SANTEETLAH TURBINES, 36,000 H.P.

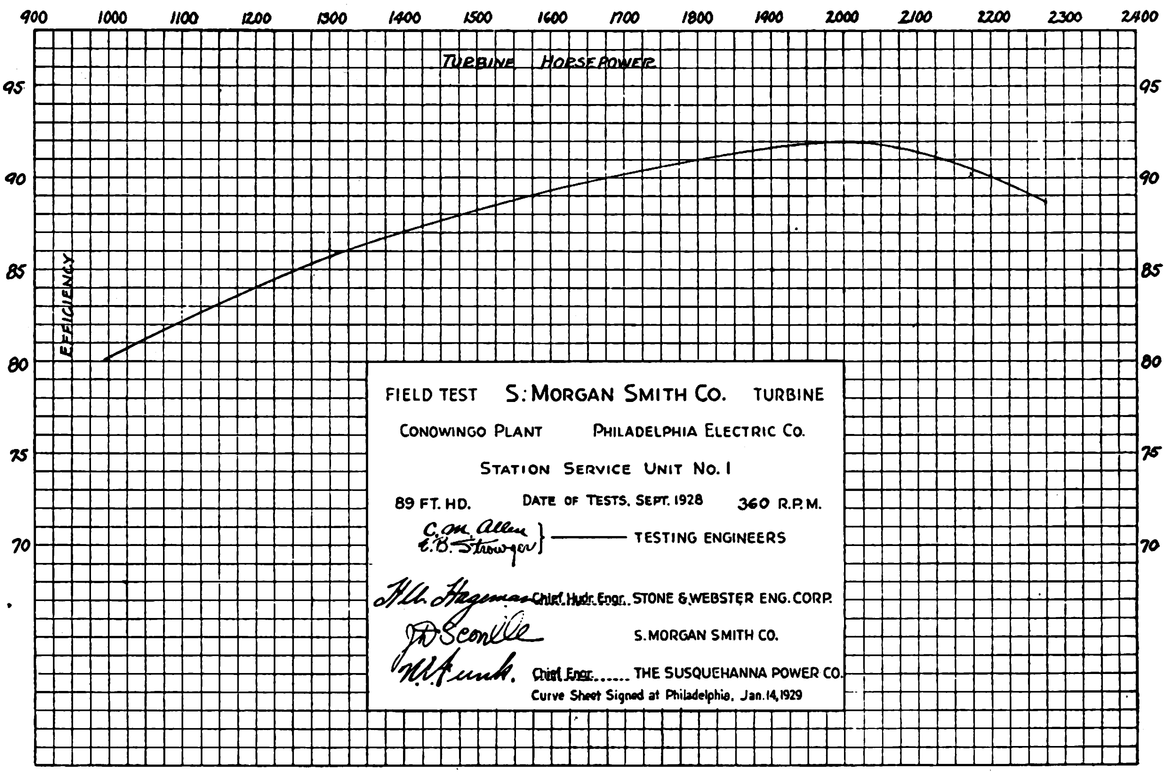

FIG. 22—TEST CURVES, CONOWINGO SERVICE TURBINE, 2250 H.P.

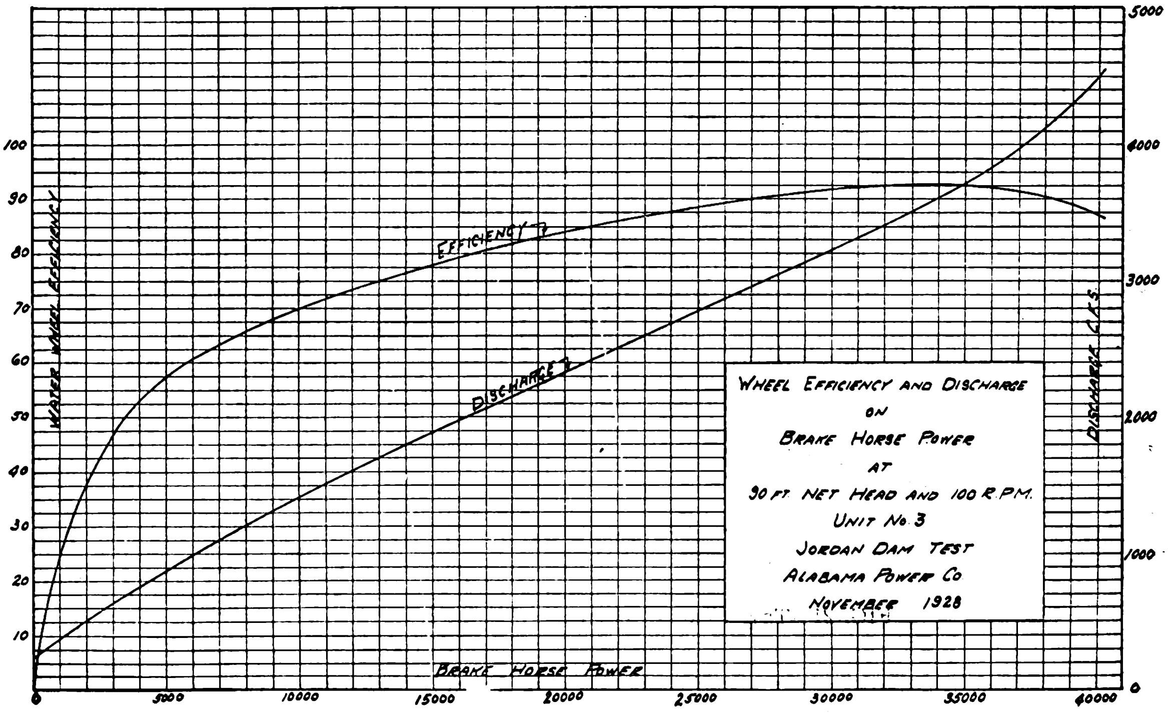

FIG. 23—TEST CURVES, JORDAN DAM TURBINE, 40,000 H.P.

AUTOMATIC TRAIN CONTROL INSTALLATIONS AND DESCRIPTION OF THE CODE SYSTEM*

Summary

The first report of the Committee on Automatic Train Control, dated March, 1927, called attention to the fact that problems of inductive coordination between train control systems and adjacent power and lighting circuits might arise particularly in urban districts when the train control system utilized commercial frequencies. A description of the train control systems then in use was made a part of the report. Since the publication of this report the installations of train control systems called for under the first and second orders of the I. C. C.* have been completed. In addition, several railroad systems have extended their control installations beyond that demanded by the orders of the Commission.

There has also been a pronounced trend toward the utilization of those systems of train control that are inherently either immune or less susceptible to interference from adjacent power line installations. This movement has been seen in the development of new apparatus and the utilization of frequencies of the order of 100 cycles for the operation of the train control system. In some cases power at this frequency is also used for the operation of the wayside signals. This obviates the necessity of one distribution system for the supply of energy to these signals and another for the train control system. Also, train control apparatus has, by changes in design, been made less susceptible to interference from adjacent power systems. This has been made possible by better design and arrangement of the pickup coils and bar mounted on the locomotive and by a more sharply tuned circuit in the amplifying equipment between the pickup coils and the relays which actuate the signals in the locomotive cab.

The I. C. C. has recently announced that "Without minimizing the need for automatic train control it is more imperative that grade crossings be abolished." It is probable, therefore, that no new mandatory orders, calling for additional train control installations, will be issued but that instead the Commission will depend upon the carriers to amplify and extend their present systems of train control as they may deem most advisable. This marks a change in the attitude of the Commission regarding train control.

In order to summarize the present status of train control installations, together with a description of the code system which has been introduced since the publication of the first serial report of this subcommittee, the following report has been prepared. It summarizes the installations made following the first and second orders of the I. C. C. and also those installations made voluntarily. The report includes a description of the new code system of continuous inductive train control as developed by the U. S. & S. Co. The report also includes a discussion of the present aspect of the inductive coordination problem between the railway utilizing train control systems and the electric light and power companies. In conclusion, a very condensed digest of the hearings this year on the subject before the I. C. C. is given.

The greater part of the work of preparation of the material in this resumé, as well as the description of the new code system, has been done by Frank F. Fowle. The Subcommittee on Automatic Train Control wishes to acknowledge at this time the very great assistance of Mr. Fowle in the preparation of this report.

Status of Train Control

Summary of Installations

The statistics on train control installations as of March, 1928, are summarized in the nine attached tables, which are next explained. The I. C. C. has issued no further general orders calling for installations or extensions, since the so-called second order, but there are several railroads which have made voluntary installations in addition to those ordered by the I. C. C. The installations under the first two orders are now practically complete, as of July, 1928, but voluntary installations are still in progress, and very probably this class will increase as time goes on.

Grand Summary

Table I shows the grand summary of installations as of March, 1928, for which details are available. This table shows the 49 roads cited in the I. C. C. orders, of which five are exempted, leaving 44 required to comply. The table shows the installations under the first order and the second order, those made voluntarily, and the grand total which embraces 19,765 miles of track and 8142 locomotives.

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[*] List of abbreviations used in this report given in Appendix A.

Publication No. 289-95 Serial Report, Inductive Coordination Committee.

TABLE I

GRAND SUMMARY OF TRACK MILEAGE AND LOCOMOTIVES EQUIPPED AND TO BE EQUIPPED UNDER FIRST AND SECOND ORDERS OF THE I. C. C. AND TRACK MILEAGE AND LOCOMOTIVES EQUIPPED VOLUNTARILY—STATUS AS OF MARCH, 1928

Ref. No.	Name of Railroad	First Order		Second Order		Voluntary		Grand Total	
		Track Miles	Locomotives	Track Miles	Locomotives	Track Miles	Locomotives	Track Miles	Number of Locomotives
1	A. T. & S. F. (a)	203.97	87	145.8	...			349.77	87
2	A. C. L.	233.34	135	344.2	...			577.54	135
3	B. & O.	73.6	136	185.0	94			258.6	230
4	B. & A.	235.08	238	250.74	...			485.82	238
5	B. & M.	203.9	137	xx	xx			203.9	137
6	B. R. & P.	x	x	x	x			x	x
7	C. R. R. of N J.	65.6	49	104.8	75			170.4	124
8	C. & O.	70.0	63	55.0	...			125.0	63
9	C. & A.	203.5	46	xx	xx			203.5	46
10	C. & E. I.	210.8	147	77.4	...			288.2	147
11	C. & E.	x	x	x	x	.....	...	x	x
12	C. & N. W.	298.0	122	414.0	70	338.0	173	1,050.0	365
13	C. B. & Q.	139.8	58	104.4	44	.....	...	244.2	102
14	C. I. & L.	67.7	32	93.3	18	.....	...	161.0	50
15	C. M. St. P. & P.	216.2	59	206.1	38	.....	...	422.3	97
16	C. R. I. & P.	330.8	95	233.7	58			564.5	153
17	C. St. P. M. & O.	x	x	x	x			x	x
18	C. N. O. & T. P.	235.0	179	257.7	...			492.7	179
19	C. C. C. & St. L.	195.8	100	181.1	...			376.9	100
20	D. & H.	120.85	66	154.0	95			274.85	161
21	D. L. & W.	282.0	71	262.86	130			544.86	201
22	Erie	204.0	97	279.4	60			483.4	157
23	Gt. Nor.	142.57	38	113.3	24			255.87	62
24	I. C. (a)	243.6	60	97.5	46			341.1	106
25	K. C. S.	x	x	x	x			x	x
26	L. V.	175.02	150	484.58	175	.....	...	659.60	325
27	L. I. (b)	32.8	104	55.2	160	.....	...	88.0	264
28	L. & N.	162.0	49	139.0	44	.....	...	301.0	93
29	M. C.	149.0	245	229.92	...	156.94	...	535.86	245
30	Mo. Pac.	50.0	39	xx	xx	.....	...	50.0	39
31	N. Y. C.	553.11	633	704.1	511	1,809.45	...	3,066.66	1,144
32	N. Y. C. & St. L.	154.85	45	xx	xx			154.85	45
33	N. Y. N. H. & H.	119.6	60	212.0	178			331.6	238
34	N. & W.	106.1	41	132.6	44			238.7	85
35	No. Pac.	109.6	35	106.0	8			215.6	43
36	O.-W. R. R. & N. Co.	86.1	33	x	x			86.1	33
37	Penna.	163.0	131	490.2	354			653.2	485
38	P. M.	62.4	73	86.2	...			148.6	73
39	P. C. C. & St. L.	351.5	131	374.77	300			726.27	431
40	P. & L. E.	232.3	116	x	x			232.3	116
41	Reading	113.0	50	91.6	80			204.6	130
42	R. F. & P.	208.86	75	.....	...			208.86	75
43	St. L.-S. F.	44.4	39	71.0	69			115.4	108
44	So. Pac.	100.1	137	125.4	75			225.5	212
45	Southern	304.22	107	303.82	...	2,311.3	586	2,919.34	693
46	T. & N. O.	50.23	40	119.91	21			170.14	61
47	U. P.	204.0	99	246.0	31			450.0	130
48	W. J. & S.	112.4	134	.....	...			112.4	134
49	W. Md.	x	x	x	x			x	x
	Totals	7,620.70	4,581	7,532.60	2,802	4,615.69	759	19,764.99	8,142

x Exempt. xx Suspended.
(a) Operated without permissive roadside signals.
(b) Multiple-unit cars are counted as locomotives.

TABLE I(A)

	Road Miles	Track Miles	Number of Locomotives
First Order	4,313.94	7,620.70	4,581
Second Order	4,073.12	7,532.60	2,802
Voluntary	3,444.09	6,425.14	759
Total	11,831.15	21,578.44	8,142

Average miles of road equipped per locomotive equipped: 1.4
Average miles of track equipped per locomotive equipped: 2.6

Table I(A) shows the total reported mileage, including certain voluntary installations for which details are not available. This table shows totals of 11,831 road miles, 21,578 track miles and 8142 locomotives. These figures are understood to be complete except for 284 locomotives of tenant roads operating over some of the installations shown in Table I.

Groups by Mileage

Under the I. C. C. orders it was generally the case that any given installation covered one engine division. It is interesting to observe the range of aggregate mileage of different railroad systems and this has been developed in Table II, where the first column shows the mileage on individual railroads comprising the system, and the installations by entire systems have been divided into those of 1000 total track miles or less and those of more than 1000 miles. This shows that there are 11 individual railroads which form parts of complete systems having aggregate track mileage of installations exceeding 1000 miles per system.

TABLE II

SUMMARY OF INSTALLATIONS GROUPED ACCORDING TO TOTAL TRACK MILEAGE IN ANY COMPLETED RAILROAD SYSTEM

Track Miles on Individual Railroads (See Table I)	Installations Grouped by Aggregate System Mileage on Two or More Railroads		All Systems
	1,000 Miles or Less	Over 1,000 Miles	
0 to 100 miles	3	..	3
101 to 200 miles	7	1	8
201 to 300 miles	12	1	13
301 to 400 miles	4	1	5
401 to 500 miles	3	2	5
501 to 600 miles	3	1	4
601 to 700 miles	1	1	2
701 to 800 miles	..	1	1
801 to 900 miles	..	..	..
901 to 1000 miles	..	..	..
Over 1000 miles	..	3	3
Total Above	33	*11	44
Add Roads Exempt	..	..	5
Total Accounted for	..	..	49

* See details for these roads on Table III.

TABLE III

SUMMARY OF RAILROAD SYSTEMS HAVING INSTALLATIONS AGGREGATING 1000 TRACK MILES OR MORE

Name of Railroad	Track Miles	Locomotives
New York Central Lines:		
B. & A.	485.82	238
C. C. C. & St. L.	376.9	100
M. C.	535.86	245
N. Y. C.	3,066.66	1,144
P. & L. E.	232.3	116
Total	4,697.54	1,843
Southern Railway System:		
C. N. O. & T. P.	492.7	179
Southern	2,919.34	693
Total	3,412.04	872
Pennsylvania System:		
Penna.	653.2	485
P. C. C. & St. L.	726.27	431
W. J. & S.	112.4	134
Total	1,491.87	1,050
Chicago & Northwestern System:		
C. & N. W.	1,050.0	365
C. St. P. M. & O.	(Exempt)	(Exempt)
Total	1,050.0	365
Total Above	10,651.45	4,130
Percentage of All Installations	53.9%	50.7%

Table III shows the details for these 11 railroads and the four systems to which they belong. At the present time (July, 1928) the Penna. System mileage is somewhat larger than here shown, by reason of additional voluntary installations. These four systems, the N. Y. C., Southern, Penna. and the C. & N. W., of course are the outstanding examples of the use of automatic train control today, representing 54 per cent of the total track mileage and 51 per cent of the locomotives equipped in the whole country as of March, 1928.

Average Installation

The average size of installation is shown in Table IV. For all installations the average is about 450 miles of track and 185 locomotives. Excluding the four systems having more than 1000 miles, the average is about 277 miles of track and 122 locomotives.

Status of I. C. C. Orders

Only five railroads have installations not completed in pursuance of both I. C. C. orders, but these are in progress. The details appear in Table V. It appears likely that all work will be 100 per cent complete by the close of 1928, and thereafter the new construction will be wholly voluntary unless, or until, the I. C. C. orders further installations.

TABLE IV

AVERAGE TRACK MILES AND AVERAGE NUMBER OF LOCOMOTIVES PER INSTALLATION

Number of Individual Railroads	Classification of Track Mileage in Any Complete Railroad System	Average Installation	
		Track Mileage	Number of Locomotives
33	1,000 Miles or Less	276.5	121.6
11	Over 1,000 Miles	968.3	375.5
44	All	449.2	185.0

Average miles of track equipped per locomotive equipped............2.43

Road Miles Equipped

Table VI shows the road miles equipped, under I. C. C. orders, with 1-track, 2-track, 3-track, 4-track, 5-track and 6-track installations. Double-track represents 57 per cent and single-track 35 per cent of the total road mileage, leaving only about 8 per cent with three or more tracks equipped.

Locations and Types of Installations

The location and the type of each installation made both pursuant to I. C. C. orders and voluntarily, are shown in Table VII. In compiling this table the installations are listed, in all cases, in the order corresponding to the first and second I. C. C. orders, followed by the voluntary installations, if any.

These installations are summarized by manufacturers and devices in Table VIII, arranged in the order of each manufacturer's aggregate track mileage equipped, with the greatest mileage at the top. The G. R. S. installations comprise about 58 per cent of the total track miles, the U. S. & S. Co. is represented by about 30 per cent, and the four remaining manufacturers comprise the balance of 12 per cent. No other manufacturers have any installations in road service, although a few are working with experimental installations, later mentioned.

TABLE V

STATUS OF INSTALLATIONS UNDER FIRST AND SECOND I. C. C. ORDERS

	First Order	Second Order
Railroads Installing Train Control.......	44	36
Railroads Exempted....................	4	6
Railroads Having Completion Date Suspended............................	1	5
	49	47
Railroads Having Installations Completed............................	43	32
Railroads Having Installations Uncompleted............................	1	4
	44	36
Percentage of Total Miles Completed....	97.0%	91.1%
Percent. of Total Locomotives Equipped..	99.0%	83.4%
Final I. C. C. Inspections Completed....	38	24

Installations Incomplete:
First Order—C. & A.
Second Order—C. R. R. of N. J.
D. L. & W.
N. Y. N. H. & H.
Reading

Tenant Roads

There are 19 tenant roads or lessees of track rights operating over roads equipped with automatic train control, with road distances ranging from about 3 miles up to 144 miles. These 19 tenant roads have 284 locomotives equipped for such operation. In one instance (C. & E. I.) there are 30 locomotives equipped with two different devices, Miller ramp and G. R. S. auto-manual. These 284 locomotives are not included in Table I, or any of the tables showing the details of Table I (II to IX, inclusive).

Types of Devices

Table IX shows a summary of all installations, grouped according to types of functions and types of devices. It appears very noteworthy that automatic train stops comprise about 83 per cent of the total mileage, of which 67 per cent is intermittent and 16 per cent is continuous inductive. The new code system of continuous inductive train stop, which is immune to foreign current or inductive interference, already comprises about 8.6 per cent of the total track mileage installed within the last two years. That is to say, slightly more than half of the present track mileage of continuous inductive train stop is equipped with the new code system and the remainder with the earlier type using steady 60-cycle rail current (with two exceptions) in the track circuit. Evidently from the latest reports the mileage of the code system is increasing, whereas the earlier type is not.

Automatic speed-control installations comprise about 17 per cent of the total track mileage, all of which was equipped under I. C. C. orders, except in one instance. Two-speed control includes 13 per cent and three-speed includes only 4 per cent of the total track mileage. Three-speed control, which is quite susceptible inductively, is still confined to the four roads which adopted it initially, namely the A., T & S. F., C. R. R. of N. J., N. & W., and Reading.

Installations made voluntarily have been equipped with the G. R. S. auto-manual (intermittent inductive) system of train stop, G. R. S. two-speed continuous inductive control (60 cycle), and the U. S. & S. Co. code system of continuous inductive train stop (100 cycle, interrupted). The G. R. S. installations of auto-manual comprise the largest mileage, the code system comes next, and the G. R. S. two-speed continuous control comes last with only one installation.

Future voluntary installations seem more likely to be made with the G. R. S. auto-manual and the U. S. & S. Co. code system than any of the other types; both are immune to foreign current interference.

TABLE VI

SUMMARY OF ROAD AND TRACK MILEAGE EQUIPPED AND TO BE EQUIPPED UNDER FIRST AND SECOND I. C. C. ORDERS

(Upper figures are for first order and lower figures for second)

Ref. No.	Railroad	Road Miles Equipped						Total Road Miles	Total Track Miles
		1-Track	2-Track	3-Track	4-Track	5-Track	6-Track		
1	A. T. & S. F.	.37	101.8 72.9					102.17 72.9	203.97 145.8
2	A. C. L.	6.6	113.37 172.1					119.97 172.1	233.34 344.2
3	B. & O.		32.4 92.5					32.4 92.5	73.6 185.0
4	B. & A.	.68 .85	68.21 60.01	32.66 15.53	.... 20.82			101.55 97.21	235.08 250.74
5	B. & M.		94.6	4.9				99.5	203.9 ....
6	B. R. & P.							x	x
7	C. R. R. of N. J.	65.6	.... 48.4		.... 2.0			65.6 50.2	65.6 104.8
8	C. & O.	70.0 55.0						70.0 55.0	70.0 55.0
9	C. & A.	24.1	89.7					113.8	203.5 ....
10	C. & E. I.		105.4 38.7					105.4 38.7	210.8 77.4
11	C. & E.							x	x
12	C. & N. W.		149.0 207.0					149.0 207.0	298.0 414.0
13	C. B. & Q.	24.4 56.2	57.7 24.1					82.1 80.3	139.8 104.4
14	C. I. & L.	67.7 93.3						67.7 93.3	67.7 93.3
15	C. M. St. P. & P.	.... 2.7	108.1 101.7					108.1 104.4	216.2 206.1
16	C. R. I. & P.	.... 109.9	165.4 61.9					165.4 171.8	330.8 233.7
17	C. St. P. M. & O.							x	x
18	C. N. O. & T. P.	78.0 92.3	78.5 82.7					156.5 175.0	235.0 257.7
19	C. C. C. & St. L.	55.6 37.7	70.1 71.7					125.7 109.4	195.8 181.1
20	D. & H.	11.65	4.6 77.0					116.25 77.0	120.88 154.0
21	D. L. & W.		141.0 92.39	.... 14.52	.... 8.62			141.0 115.54	282.0 262.86
22	Erie		102.0 139.7					102.0 139.7	204.0 279.4
23	Great Northern	98.07 104.52	22.25 4.39					120.32 108.91	142.57 113.3
24	I. C.	.... 97.5	121.8					121.8 97.5	243.6 97.5
25	K. C. S.							x	x
26	L. V.	0.92 11.09	32.34 161.77	19.94 17.45	12.40 24.4			65.60 214.71	175.02 484.58

x Exempt.

TABLE VI—(*Concluded*)

SUMMARY OF ROAD AND TRACK MILEAGE EQUIPPED AND TO BE EQUIPPED UNDER FIRST AND SECOND I. C. C. ORDERS

(Upper figures are for first order and lower figures for second)

Ref. No.	Railroad	Road Miles Equipped						Total Road Miles	Total Track Miles
		1-Track	2-Track	3-Track	4-Track	5-Track	6-Track		
27	L. I.	8.8	12.0					20.8	32.8
			27.6					27.6	55.2
28	L. & N.	162.0						162.0	162.0
		139.0						139.0	139.0
29	M. C.		74.5					74.5	149.0
			114.96					114.96	229.92
30	Mo. Pac.	50.0						50.0	50.0
31	N. Y. C.		18.23		118.0	8.93		139.86	553.11
		0.21	8.19	3.32	168.33	.03	.68	180.76	704.1
32	N. Y. C. & St. L.	123.25	15.8					139.05	154.85
33	N. Y. N. H. & H.		59.8					59.8	119.6
			106.0					106.0	212.0
34	N. & W.	106.1						106.1	106.1
		132.6						132.6	132.6
35	No. Pac.	109.6						109.6	109.6
		106.0						106.0	106.0
36	O.-W. R. R. & N.	81.1	2.5					83.6	86.1
37	Penna.		81.5					81.5	163.0
			12.3	6.8	111.3			130.4	490.2
38	P. M.	59.2	1.6					60.8	62.4
		63.0	11.6					74.6	86.2
39	P. C. C. & St. L.	46.5	116.5	24.0				187.0	351.5
			112.49	25.89	18.03			156.41	374.77
40	P. & L. E. (No second order)		11.9	.7	51.6			64.2	232.3
41	Reading		52.6	2.6				55.2	113.0
			45.8					45.8	91.6
42	R. F. & P.			104.43				104.43	208.86
43	St. L.-S. F.	35.6	4.4					40.0	44.4
		61.2	4.9					66.1	71.0
44	So. Pacific	51.1	24.5					75.6	100.1
		125.4						125.4	125.4
45	Southern		152.11					152.11	304.22
			151.91					151.91	303.82
46	T. & N. O.	50.23						50.23	50.23
		119.91						119.91	119.91
47	U. P.		102.0					102.0	204.0
			123.0					123.0	246.0
48	W. J. & S.		56.2					56.2	112.4
49	W. Md.							x	x
	Total First Order	1,487.17	2,548.84	84.80	184.20	8.93		4,313.94	7,620.70
	Total Second Order	1,408.38	2,227.71	83.51	353.51	.03	.68	4,073.12	7,532.60
	Total	2,895.55	4,776.55	168.31	537.71	8.96	.68	8,387.06	15,153.30

x Exempt.

TABLE VII

DETAILS OF INSTALLATIONS MADE UNDER FIRST AND SECOND ORDERS AND MADE VOLUNTARILY

Ref. No.	Railroad	Terminals of Installation	Class of Device	Manufacturer	Track Miles
1	A. T. & S. F.	Chillicothe, Ill. to Fort Madison, Ia. Pequot to Chillicothe, Ill.	Cont. Ind. 3-Speed Cont. Ind. 3-Speed	Union Union	203.97 145.8
2	A. C. L.	Rocky Mount, N. C. to Acca Wye, Va. So. Rocky Mt. N. C. to Florence, S. C.	Intermittent Ind. Intermittent Ind.	General General	233.34 344.2
3	B. & O.	Baltimore, Md. to Washington, D. C. Baltimore, Md. to Philadelphia, Pa.	Intermittent Ind. Intermittent Ind.	General General	73.6 185.0
4	B. & A.	Springfield, Mass. to Rensselaer, N. Y. Springfield, Mass. to Boston, Mass.	Intermittent Ind. Intermittent Ind.	General General	235.08 250.74
5	B. & M.	West Cambridge to East Deerfield, Mass. (None)	Cont. Ind. Stop	Union	203.9 ...
7	C. R. R. of N. J.	Red Bank to Winslow Jct., N. J. Elizabeth to Bay Head, N. J. *	Cont. Ind. 3-Speed Cont. Ind. Stop (Code)	Union Union	65.6 104.8
8	C. & O.	Orange to Staunton, Va. Staunton to Clifton Forge, Va.	Intermittent Ind. Intermittent Ind.	Union Union	70.0 55.0
9	C. & A.	Glen to Bloomington, Ill. *	Intermittent Ind.	National	203.5 ...
10	C. & E. I.	Chicago-Danville, Ill. Danville, Ill. to Clinton, Ind.	Intermittent Contact Intermittent Contact	Miller Miller	210.8 77.4
12	C. & N. W.	Boone to Council Bluffs, Ia. Clinton to Boone, Ia. Chicago to Clinton, Ia.	Cont. Ind. 2-Speed Cont. Ind. 2-Speed Cont. Ind. 2-Speed	General General General	298.0 414.0 338.0
13	C. B. & Q.	Creston to Pacific Jct., Ia. Pacific Jct., Ia. to Lincoln, Neb.	Intermittent Ind. Intermittent Ind.	Sprague Sprague	139.8 104.4
14	C. I. & L.	Hammond to Monon, Ind. Monon to Indianapolis, Ind.	Intermittent Ind. Intermittent Ind.	Miller Miller	67.7 93.3
15	C. M. St. P. & P.	Bridge Switch to Hastings, Minn. LaCrosse to Portage, Wis.	Cont. Ind. Stop Cont. Ind. Stop	Union Union	216.2 206.1
16	C. R. I. & P.	Blue Island to Rock Island, Ill. Davenport to Des Moines, Ia.	Intermittent Contact Intermittent Contact	Regan Regan	330.8 233.7
18	C. N. O. & T. P.	Ludlow to Somerset, Ky. Somerset, Ky. to Chattanooga, Tenn.	Intermittent Induc. Intermittent Induc.	General General	235.0 257.7
19	C. C. C. & St. L.	Indianapolis, Ind. to Mattoon, Ill. Mattoon to Lenox, Ill.	Intermittent Induc. Intermittent Induc.	General General	195.8 181.1
20	D. & H.	Whitehall to Rouses Point, N. Y. Albany to Whitehall, N. Y.	Intermittent Induc. Intermittent Induc.	General General	120.85 154.0
21	D. L. & W.	Elmira to East Buffalo, N. Y. Elmira to Scranton, Pa. *	Cont. Ind. 2-Speed Cont. Ind. 2-Speed	Union Union	282.0 262.86
22	Erie	Port Jervis, N. Y. to Susquehanna, Pa. Susquehanna to Hornell, N. Y.	Intermittent Ind. Intermittent Ind.	General General	204.0 279.4
23	Gt. Nor.	Minot to Williston, N. D. New Rockford to Minot, N. D.	Intermittent Ind. Intermittent Ind.	Sprague Sprague	142.57 113.3
24	I. C.	Champaign to Branch Jct., Ill. Waterloo to Fort Dodge, Ia.	Cont. Ind. Stop Cont. Ind. Stop	Union Union	243.6 97.5
26	L. V.	Newark, N. J. to Easton, Pa. Easton to Sayre, Pa.	Intermittent Ind. Intermittent Ind.	General General	175.02 484.58
27	L. I.	Winfield Jct. to Whitestone Jct., L. I. Jamaica to Babylon, L. I.	Cont. Ind. Stop Cont. Ind. Stop (Code)	Union Union	32.8 55.2
28	L. & N.	Corbin, Ky. to Etowah, Tenn. Mobile, Ala. to New Orleans, La.	Cont. Ind. 2-Speed Cont. Ind. Stop	Union Union	162.0 139.0
29	N. C.	Detroit to Jackson, Mich. Jackson to Niles, Mich. Niles, Mich. to Kensington, Ill.	Intermittent Ind. Intermittent Ind. Intermittent Ind.	General General General	149.0 229.92 156.94

*Installation under construction.

TABLE VII—(*Concluded*)

DETAILS OF INSTALLATIONS MADE UNDER FIRST AND SECOND ORDERS AND MADE VOLUNTARILY

Ref. No.	Railroad	Terminals of Installation	Class of Device	Manufacturer	Track Miles
30	No. Pac.	Leeds, Mo. to Osawatomie, Kan.	Intermittent Ind.	National	50.0
		....	....	....	...
31	N. Y. C.	Albany to Syracuse, N. Y.	Intermittent Ind.	General	553.11
		Cleveland, O. to Buffalo, N. Y.	Intermittent Ind.	General	704.1
		Poughkeepsie to Rensselaer, N. Y.	Intermittent Ind.	General	195.02
		Syracuse to Buffalo, N. Y.	Intermittent Ind.	General	579.79
		Cleveland, O. to Englewood, Ill.	Intermittent Ind.	General	1,034.64
32	N. Y. C. & St. L. W	Ft. Wayne, Ind. to Stony Island Ave., Ill.	Intermittent Ind.	Union	154.85
		....	....	....	....
33	N. Y. N. H. & H.	Air Line Jct. to Springfield, Mass.	Cont. Ind. Stop	Gen. & Union	119.6
		New Haven, Conn. to Providence, R. I. *	Cont. Ind. Stop (Code)	Union	212.0
34	N. & W.	Hagerstown to Shenandoah, Va.	Cont. Ind. 3-Speed	Union	106.1
		Roanoke to Shenandoah, Va.	Cont. Ind. 3-Speed	Union	132.6
35	No. Pac.	Mandan to Dickinson, N. D.	Intermittent Ind.	Sprague	109.6
		Dickinson, N. D. to Glendive, Mont.	Intermittent Ind.	Sprague	106.0
36	O.-W. R. R. & N.	Portland to The Dalles, Ore.	Cont. Ind. 2-Speed	Union	86.1
		....	....	....	....
37	Penna.	Baltimore, Md. to Harrisburg, Pa.	Cont. Ind. Stop	Union	163.0
		Harrisburg to Altoona, Pa.	Cont. Ind. Stop (Code)	Union	490.2
38	P. M.	Seymour to North Lansing, Mich.	Intermittent Ind.	General	62.4
		Lansing to Detroit, Mich.	Intermittent Ind.	General	86.2
39	P. C. C. & St. L.	Columbus, O. to Indianapolis, Ind.	Cont. Ind. Stop (Code)	Union	351.5
		Pittsburgh, Pa. to Newark, O.	Cont. Ind. Stop (Code)	Union	374.77
40	F. & L. E.	Pittsburgh, Pa. to Youngstown, O.	Intermittent Ind.	Union	232.3
		....	....	....	....
41	Reading	Camden to Atlantic City, N. J.	Cont. Ind. 3-Speed	Union	113.0
		Bethlehem to Jenkintown, Pa. *	Cont. 2-Speed (Code)	Union	91.6
42	R. F. & P.	Richmond to "AF" Block Station, Va.	Cont. Ind. 2-Speed	Union	203.2
		Acca Wye, Va. to James Riv., Branch, Va.	Intermittent Ind.	General	5.66
		....	....	....	....
43	St. L.-S.F.	Nichols to Monett, Mo.	Intermittent Ind.	National	44.4
		Monett, Mo. to Afton, Okla.	Intermittent Ind.	National	71.0
44	So. Pac.	Oakland to Tracy, Cal.	Intermittent Ind.	National	100.1
		Tracy to Fresno, Cal.	Intermittent Ind.	National	125.4
45	Southern	Spencer, N. C. to Greenville, S. C.	Intermittent Ind.	General	304.22
		Greenville, S. C. to Atlanta, Ga.	Intermittent Ind.	General	303.82
		Salisbury to Asheville, N. C.	Intermittent Ind.	General	147.2
		Asheville to Morristown, N. C.	Intermittent Ind.	General	93.0
		Biltmore to Hayne, N. C.	Intermittent Ind.	General	69.0
		Charlotte, N. C. to Columbia, S. C.	Intermittent Ind.	General	109.0
		Bristol, Tenn. to Morristown, N. C.	Intermittent Ind.	General	89.0
		Morristown, N. C. to Knoxville, Tenn.	Intermittent Ind.	General	84.0
		Knoxville to Coltewah, Tenn.	Intermittent Ind.	General	98.0
		Chattanooga, Tenn. to Atlanta, Ga.	Intermittent Ind.	General	179.0
		Atlanta to Macon, Ga.	Intermittent Ind.	General	91.0
		Macon, Ga. to Jacksonville, Fla.	Intermittent Ind.	General	266.8
		Chattanooga to Memphis, Tenn.	Intermittent Ind.	General	282.0
		Chattanooga to Meridian, Miss.	Intermittent Ind.	General	393.0
		Meridian, Miss. to New Orleans, La.	Intermittent Ind.	General	208.0
		Lot to Holton, Ky.	Intermittent Ind.	General	4.6
		Austel, Ga. to Birmingham, Ala.	Intermittent Ind.	General	157.4
		Haleyville to Jasper, Ala.	Intermittent Ind.	General	40.3
46	T. & N. C.	Rosenberg to Glidden, Tex.	Intermittent Ind.	National	50.23
		Glidden to San Antonio, Tex.	Intermittent Ind.	National	119.91
47	U. P.	Sidney, Neb. to Cheyenne, Wyo.	Cont. Ind. 2-Speed	Union	204.0
		North Platte to Sidney, Neb.	Cont. Ind. 2-Speed	Union	246.0
48	W. J. & S.	Camden to Atlantic City, N. J.	Cont. Ind. Stop (Code)	Union	112.4
		....	....	....	....
				Total	19,764.99

* Installation under construction.

TABLE VIII

SUMMARY OF DEVICES INSTALLED UNDER BOTH I. C. C. ORDERS AND INSTALLED VOLUNTARILY

Manufacturers and Devices	First I. C. C. Order			Second I. C. C. Order			Voluntary			Total		
	Railroads	Track Miles	Locomotives	Railroads	Track Miles	Locomotives	Railroads	Track Miles	Locomotives	Railroads	Track Miles	Locomotives
General Railway Signal Co.:												
Auto-Manual	13	2,547.08	2,159	12	3,460.76	935	3	4,277.69	586	13	10,285.53	3,680
Miller Intermittent Inductive	1	67.7	32	1	93.3	18	..	......	...	1	161.0	50
Two-Speed Continuous Inductive	1	298.00	122	1	414.0	70	1	338.0	173	1	1,050.00	365
Continuous Train Stop	1	......	30	..	......	...	..	......	...	1	....	30
Total	16	2,912.78	2,343	14	3,968.06	1,023	4	4,615.69	759	16	11,496.53	4,125
Union Switch & Signal Co.:												
Intermittent Inductive	3	467.15	224	1	55.0	...	..	......	......	3	522.15	224
Two-Speed Continuous Inductive	5	937.30	327	3	600.46	241	..	......	......	6	1,537.76	568
Three-Speed Continuous Inductive	4	488.67	227	2	278.4	44	..	......	......	4	767.07	271
Continuous Train Stop	8	1,443.0	786	8	1,679.57	1,195	..	......	......	13	3,122.57	1,981
Total	20	3,336.12	1,564	14	2,613.43	1,480	..	......	......	26	5,949.55	3,044
*National Safety Appliance Co.	5	448.23	301	3	316 31	165	..	......	......	5	764.54	466
*Sprague Safety Control & Signal Corp.	3	391.97	131	3	323.7	76	..	......	......	3	715.67	207
*Regan Safety Devices Co., Inc.	1	330.8	95	1	233.7	58	..	......	......	1	564.5	153
*Miller Train Control Corp.	1	210.8	147	1	77.4	...	..	......	......	1	288.2	147
Grand Total	44	7,630.70	4,581	36	7,532.60	2,802	4	4,615.69	759	44	19,764.99	8,142

*The National and Sprague systems are intermittent and inductive; the Regan and Miller systems are intermittent ramp.

Train Control Without Block Signals

Table X shows the railroads (two) at present operating installations of automatic train control without permissive wayside signals, more often termed automatic block signals. Both roads depend on continuous-type cab signals under continuous inductive control. Another road which has lately adopted this practice is the C. & N. W. This type of signal practice is novel and at present somewhat experimental. It represents only 8.8 per cent or less of the total track mileage equipped with automatic train control.

TABLE IX

SUMMARY OF TYPES OF DEVICES

Type of Function	Type of Device	Railroads	Track Miles	Locomotives
Automatic Train Stop	Intermittent Inductive	25	12,438.89	4,627
	Intermittent Ramp	2	852 7	300
	Continuous Inductive:			
	Steady A. C. Type	7	1,421.7	679
	Code System	6	1,700.87	1,332
	Continuous Inductive:			
Automatic Speed Control	2-Speed	7	2,587.76	933
	3-Speed	4	767.07	271
		44	19,764.99	8,142

Total Track Miles

Automatic Train Stop, Intermittent	67.%	
Automatic Train Stop, Continuous	16.%	83.%
Automatic Speed Control		17.%
		100 %

TABLE X

INSTALLATIONS IN SERVICE WITHOUT PERMISSIVE WAYSIDE (AUTOMATIC BLOCK) SIGNALS

Railroad	Type of Control	Track Miles	Number of Locomotives
A. T. & S. F.	Continuous Inductive, 3-Speed	349.77	87
I. C.	Continuous Inductive, Train Stop	341.1	106
Total		690.87	193
Percentage of all Installations		3.5%	2.4%

Experimental Installations

Three installations have been in service experimentally, for test purposes, on the following railroads.

M. C.

The Continuous Train Control Corp. has been experimenting with the Clark System on 10 miles of one track between Jackson and Rives Junction, Mich., with one equipped locomotive. This system employs high-frequency current imposed on the existing signal circuits, for continuous control. It is understood to be somewhat similar to the carrier system, but no detailed technical information has been obtainable.

N. Y. C.

The Miller Train Control Corp. has an installation for development purposes on a division of the N. Y. C. between Detroit and Toledo. This company also has installations of two of its devices in regular service, the Miller ramp on the C. & E. I. and the Miller intermittent inductive system on the C. I. & L.

Mo. Pac.

The Automatic Electric Inc., manufacturer of Strowger automatic telephone equipment, in Chicago, has been testing the Hudd system on a short section of the Mo. Pac. Railway. The equipped engine has been temporarily dismantled.

The Hudd device is an intermittent inductive system. It is arranged to display three different conditions, namely, high, medium and low speeds, with cab signals, and can be applied as a train stop or as speed control. The present plans are to equip the Mo. Pac. between Omaha and Kansas City, some six months hence. As regards inductive susceptibility, it appears to be in the same class as other systems of the intermittent type.

Discussion of Inductive Susceptibility

There was a discussion of this subject in the Serial Report of the Inductive Coordination Committee on "Automatic Train Control," dated March, 1927 (Publication No. 267-21). That report covered the status of installations and devices as of August, 1925, or about four years ago at this time. The outstanding development since that date is the U. S. & S. Co. code system, which is a continuous inductive device, operating with 100-cycle current, coded by means of periodic interruptions of very much lower frequency.

As far back as three years ago it was already established that the continuous inductive three-speed 60-cycle system (U. S. & S. Co.) was very susceptible and actually experienced interference from 60-cycle commercial power systems adjacent to such an installation. Tests made on the Reading and the A. T. & S. F. established the cause of the susceptibility, and both the manufacturers and the railroads were cooperatively advised of the fact. Fortunately there have been no voluntary extensions of this system, but the situation with respect to the four roads now using this system, namely the A. T. & S. F., C. R. R. of N. J., N. & W. and Reading (see Table VII), are not substantially changed, except that the manufacturer made certain improvements in the loop receiver bar which helped matters to some extent.

The continuous inductive two-speed 60-cycle system of the U. S. & S. Co. and similar equipment used only as a continuous train stop is not very susceptible, but neither is it entirely immune. There is a potential type of danger, or false-clear failure, if a train should enter an occupied block, as under some conditions of inductive exposure the following (or rear) train might receive an erroneous high-speed or clear indication. Such a possibility was verified, experimentally, on a road installation. This difficulty appears to be inherent, and there is no apparent remedy except to adopt some different frequency of operating current, such as 100 cycles. No actual trouble in service has been reported from the installations now in operation, but we understand that at least one railroad is planning to change from 60 cycles to 100 cycles to avoid such possible failures.

The continuous inductive two-speed 60-cycle installations (G. R. S.) on the C. & N. W. from Chicago to Council Bluffs, Iowa, 1050 track miles, are claimed to be immune, and experience to date bears out the claim. There are numerous parallels with 60-cycle power lines on all three engine divisions, directly adjacent to the railroad. The Code system of two-speed 100-cycle continuous control on the Reading, 92 track miles, is claimed to be immune, and there is ample reason to accept the claim as true, although the operating experience to date is comparatively brief. These two roads, C. & N. W. and Reading, make an aggregate installation of 1142 track miles of two-speed continuous control, which appears to be immune to interference. The remainder of 1446 track miles of installations of two-speed control should be classed as doubtful, for reasons already stated. The latter installations are shown in Table VII and embrace the following five railroads:

D. L. & W.
L. & N.
O.-W. R. R. & N.
R. F. & P.
U. P.

Continuous inductive train stops embrace three kinds of devices, namely, the new Code system of the U. S. & S. Co., the devices using special frequencies, and those using 60 cycles. The installations of the Code system (on six roads) shown in Table VII embrace 1701 track miles, and this is being somewhat increased by recent voluntary installations. The 100-cycle system on the L. I. embraces 33 miles, and the 140-cycle system on the N. Y., N. H. & H. embraces 119 track miles, or together 152 track miles. These three systems can be classed as immune to interference, but the remainder of 1269 track miles of 60-cycle installations should be classed as doubtful, for the same reasons which apply in the case of two-speed 60-cycle continuous control. These installations of doubtful class are listed in Table VII, on the following five railroads:

B. & M.
C. M. St. P. & P.
I. C.
L. & N.
Penna.

The automatic train stops of the intermittent type, both inductive and ramp, appear to be wholly immune to any interference from adjacent power systems. Theory and experience seem to confirm this conclusion quite definitely

TABLE XI

TOTAL TRACK MILEAGE OF INSTALLATIONS CLASSIFIED BY INDUCTIVE SUSCEPTIBILITY

(As of March, 1928)

Type of Function	Type of Device	Classified by Inductive Susceptibility		
		Immune	Doubt-ful	Very Sus-ceptible
Automatic Train Stop	Intermittent Inductive	12,439	....	...
	Intermittent Ramp	853	....	...
	Continuous Inductive:			
	60-Cycle Systems	.....	1,269	...
	100 or 140 Cyc. Systems	152	....	...
	Code System, 100 Cycls.	1,701	....	...
Automatic Speed Control	Continuous Inductive:			
	2-Speed	1,142	1,446	...
	3-Speed	.....	....	767
Totals (Per	Cent of Grand Total)	82%	14%	4%

The status of all types of installations as to inductive susceptibility is summarized in Table XI This shows 82 per cent of the total track mileage as immune, 14 per cent doubtful, and 4 per cent very susceptible. It seems to be now recognized that the use of 60-cycle rail current is attended with certain hazardous possibilities from a railroad standpoint.

In this connection it is interesting to note that the second installation of three-speed 60-cycle continuous control on the A. T. & S. F., projected from Chillicothe, Ill., to McCook, Ill. (12.7 miles from Chicago), has been brought eastward only as far as Pequot, Ill. The unequipped section from Pequot to McCook, 44.5 road miles, traverses a region rather highly developed with power lines, including the Joliet-Chicago industrial district, a large steam generating station and switching station directly adjacent to the railroad near Joliet, and a very close parallel with the 44-kv. lines of the Chicago Sanitary District. It seems very questionable whether the three-speed 60-cycle train control can ever be made a safe and reliable device under such conditions as those just mentioned. The new Code system offers a very attractive remedy for such a situation, especially as it can be operated without permissive wayside signals, in accordance with A. T. & S. F. signal practice in the district already equipped.

Description of Code System

The so-called Code system of continuous inductive control was developed very recently by the U. S. & S. Co. in order to meet the requirements of both steam and electric propulsion, a-c. or d-c., and to overcome the effects of any kind of foreign current interference.

The Code system operates fundamentally with 100-cycle a-c. track circuits and tuned selective receivers on the locomotives. It can be adapted for use as a continuous train stop or for continuous speed control, with color-light cab signals. The system in use on the Penna. is a four indication automatic stop with the following indications:

1. Clear block (green signal, full speed).
2. Approach at restrictive speed (in a clear block, advancing toward a yellow signal).
3. Approach prepared to stop (in a yellow block, advancing toward a red signal).
4. Proceed with caution at low speed (in a red block, with train ahead in same block).

The 100-cycle current supplied to the track circuits is periodically interrupted, according to the following code, for the four preceding indications:

1. 180 interruptions per minute.
2. 120 interruptions per minute.
3. 80 interruptions per minute.
4. Steady 100-cycle current, or no current at all.

The cab signals change almost instantaneously with changes in track-circuit current, governed by the location and movements of the next train ahead. The locomotive equipment consists of a receiver bar just in advance of the front pair of truck wheels, electrical filter, 2-stage 2-tube amplifier, decoding transformer and master relay to amplify the coded impulses of low frequencies, and selective decoding relays which respond only to the low-frequency coded impulses. These relays control the color-light cab signals and the pneumatic brake application. Forestalling is provided for, if the engineman is alert and makes proper acknowledgment at each restrictive signal. The roadside apparatus includes a motor-driven interrupter, which supplies the coded 100-cycle current fed to the track circuit; there is one such interrupter at each point of track feed. Uncoded or steady 100-cycle current, or the absence of any such current, will both impose the low-speed condition on the receiver.

The 100-cycle track current can also be used for controlling the automatic block signals on the wayside, thus requiring but one source of power supply for both purposes, which can be supplied from a special 100-cycle transmission line located along the right-of-way. This has the further advantage that it tends to eliminate foreign-current interference with the block signal system. In order to obtain a clear understanding of the Code system, it will be of help to understand the fundamental principle of the a-c. track circuit for the automatic block signals, inasmuch as this track circuit serves a double purpose, namely. for both the block signals and the train control.

A-C. Block Signal Circuits

Whether or not wayside signals are employed in the automatic block system with superimposed train control, all other features of the block system must be employed in any event. The fundamental principle of the a-c. track circuit is, therefore, always employed, and it will facilitate the explanation of the train control to consider it first.

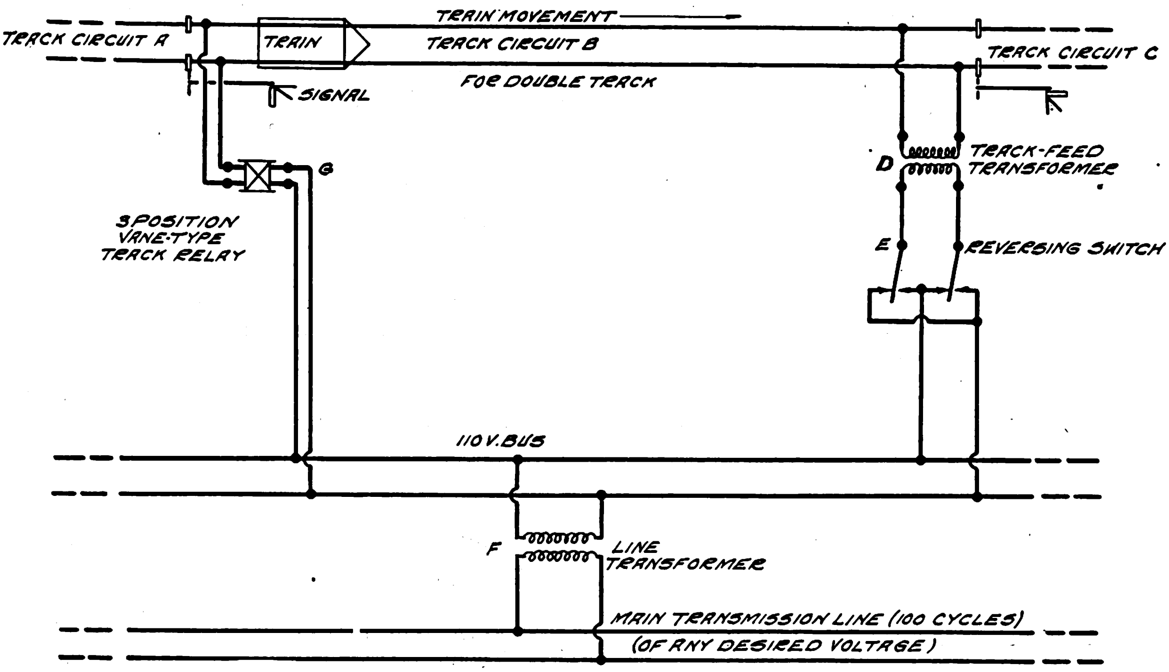

FIG. 1—Simplified Diagram of A-c. Wayside Circuits for Automatic Block Signals.

A simplified diagram of the a-c. track circuit is shown in Fig. 1, as applied to one track of a double-track road. Only one complete track circuit (B) is shown on the drawing, with a train moving in the normal direction of traffic. Assuming first that no train is present in block *B* or in block *C*, the conditions are as follows: The track transformer *D* is feeding the far end of track circuit *B*, so that energy will flow along the track against the direction of a normal train movement, thus energizing one of the windings of the track relay *G* at the entering (or approach) end of block *B*. The track relay G is a vane-type three-position relay, with its other winding normally energized from the 110-volt bus. When thus energized, the relay will cause the block signal at the entrance to block *B* to display green or clear. The reversing-switch *E* is controlled by the track relay of block *C*, as later explained. The line transformer *F* serves the 110-volt bus which extends along the right-of-way to feed the track circuits and the signal apparatus and lamps.

When a train is approaching in block *A*, a clear signal will be displayed at the entrance to block *B*. When the train enters block *B*, the axles will short the track circuit and de-energize one winding of the track relay *G*, which in turn will release and cause the signal at the entrance to *B* to turn red, and remain so until the train passes into block *C*. As the train enters *C*, the track relay in that block will be released, not only displaying a red signal at the entrance to *C*, but reversing the switch *E* and thus reversing the phase of the current in track circuit *B*. The latter will cause track-relay *G* to reverse, and thus display a yellow or restrictive signal at the entrance to block *B*, until the train passes beyond block *C*. When the train clears *C*, the track relay in *C* will pick up, thus restoring the reversing-switch *E* to normal, and changing the signal protecting *B* from yellow to green. At the same time the signal protecting *C* will change from red to yellow, as already explained.

Ordinarily the engineman must depend on the wayside signals of the automatic block system. However, when continuous inductive control is employed, with cab signals corresponding in color and indication to the wayside signals, the engineman will be instantly aware of any change in the signals, wherever he may be in a block, because the cab signals will change simultaneously. For example, assume a train in block *C*, and a train following, about to enter block *B* under a yellow or restrictive signal. When the second train advances say 1000 ft. in block *B*, assume that the leading train clears block *C*. Then the signal protecting *B* would change from yellow to green, if it were not for the rear train in *B*, but nevertheless the cab signal in the rear train will change instantly from yellow to green, allowing the engineman to increase speed without waiting until he has moved, say, 3000 ft. farther to the next wayside signal, and thus saving time.

Code System Track Circuits

In the Code system the track circuits are the same in principle as just explained, except that at each point of a-c. current feed to the track circuits there is a small motor-driven interrupter equipped to supply three different frequencies, namely, 180 interruptions per minute, 120 per minute and 80 per minute. This motor is started by a contact on the track relay at the entrance to the block, which closes when the track relay releases. This, of course, requires a control wire extending the whole length of the block. Thus the motor starts when a train enters the block and stops again when the train leaves it. The interrupter contacts are connected in series with the 110-volt supply to the reversing switch in such a way as to code the track current at the desired frequency, depending upon the signal indication at that location.

Fig. 2 shows the theory of the roadside circuits at a signal location on double track, for one track only. In tracing out the circuits, the contacts of each relay will be observed directly below the legend for the relay coils. The diagram, as shown, indicates the circuit conditions when no trains are present. When a train enters block *A*, the track relay releases and one of its center contacts (like the lower contact of *G* in the drawing) closes a circuit over a control wire which energizes relay *L*. This relay in turn starts the motor of the interrupter *M* and connects the latter with the 110-volt supply; it also clears the back contacts connecting the track-feed transformer *T* with the auto-transformer, for normal current supply to the track circuit, and impresses 110 volts on the transformer. By this means the 100-cycle a-c. current supplied to *T* is coded at 180 interruptions per minute, which conveys a clear or full-speed indication to the locomotive advancing in block *A*.

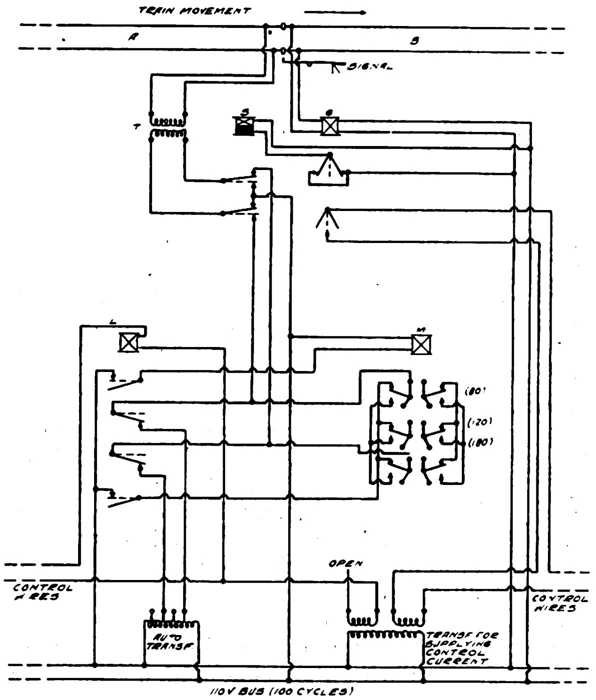

FIG. 2—SIMPLIFIED DIAGRAM OF A-C. WAYSIDE CIRCUITS FOR CODE SYSTEM OF TRAIN CONTROL

Now if block *B* were occupied by a train while another train is approaching in block *A*, the relay *G* would be released. This in turn would release the slow-acting relay *S*, thus reversing the phase of the track-circuit feed, and also impressing a periodicity of 80 interruptions per minute on the track circuit. The latter periodicity would impose the "approach prepared to stop" indication on the approaching train in block *A*.

When the train clears block *A*, the track relay of that block will pick up, but in reversed position, thus displaying a yellow signal. This will open the circuit of relay *L*, stop the interrupter *M*, disconnect the 110-volt supply to *M*, and restore the auto-transformer supply to *T*. Relays *G* and *S* will be released, and the interrupter in block *B* will be supplying coded track current at such frequency as the next signal, at the end of block *B*, may impose.

When the train clears block *B*, track relay *G* will pick up in reversed position, displaying a yellow signal; the contacts of *G* will re-energize *S*, and restore normal polarity to track circuit *A*, thus changing the signal at the entrance to *A* from yellow to green. When the train clears the next block beyond *B*, the signal from *B* will change from yellow to green.

The motor-driven interrupter is in operation only when a train is in the block to which it supplies track current, thus economizing in energy required.

If there is a train in block *B* and a second train follows it into this block, the second locomotive will receive no inductive pick-up and hence will have the low speed condition imposed on it. As soon as the leading train clears the block, the second locomotive will receive the "approach prepared to stop" indication, warning of a red signal at the next block.

When the feature of approach at restrictive speed is desired, as when the signals are less than braking distance apart, it can be provided very readily by adding another control relay and making use of the 120-per minute interruptions. This additional relay would be energized by relay *G* when in reversed position and would impose 120 interruptions per minute on *T*. The latter would impose the "approach at restrictive speed" indication on the locomotive advancing in block *A*, warning of a yellow signal at block *B*.

Code System Locomotive Circuits

The receiver bar on the locomotive is the same as that used in the 2-speed system of continuous inductive control, operated at 60 cycles. It is mounted just behind the pilot, but ahead of the front pair of truck wheels. The receiver coils constitute the moving secondary member of a loosely coupled transformer, of which the primary is the track circuit. The two receiver coils are so connected that their induced voltage is additive when current is flowing in opposite directions in the two rails of the track circuit; obviously no voltage would be induced by equal currents flowing in the same direction in the rails.

The locomotive circuits and electrical equipment are shown in Fig. 3. The induced receiver current passes through the filter, which excludes all frequencies more than 5 per cent above or below 100 cycles, and thence to the two-stage amplifier. Then the amplified current passes through the transformer primary, and the secondary current actuates the master relay, which is a d-c. polarized type and responds only to the frequency supplied by the wayside code transmitter, 180, 120 or 80 interruptions per minute. If the wayside current supplied to the

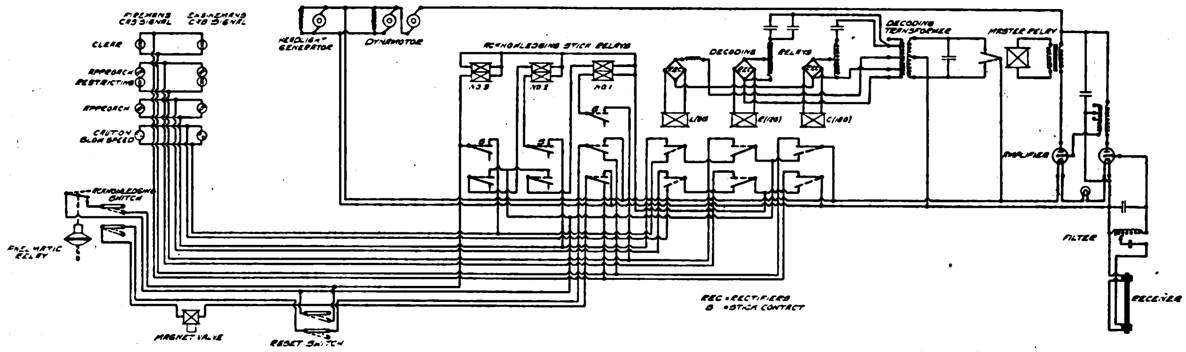

FIG. 3—SIMPLIFIED DIAGRAM OF LOCOMOTIVE CIRCUITS FOR CODE SYSTEM OF TRAIN CONTROL.

track circuit is steady 100-cycle current (not coded), or if there is no current in the track circuit, the master relay makes no response. The master relay is responsive to the increase and decrease in plate current from the amplifier, caused by the interrupted current induced in the receiver coil and in turn applied to the grid. Plate voltage is supplied from a dynamotor operated from the 32-volt headlight generator, which also supplies d-c. current for operating the train-control relays and associated apparatus.

The master relay impresses reversals of d-c. on the primary of the decoding transformer at the code frequency, and the secondary supplies a-c. at the code frequency to the rectifiers associated with the decoding relays. Selective operation of relay *C* is accomplished by means of a circuit tuned to 180 cycles per minute, with a low-voltage tap on the reactor. Relay *R* is similarly tuned for 120 cycles per minute. Relay *L* is not tuned, but has a reactor in series with the rectifier to cut down the current at the two higher frequencies. Thus at 180 cycles per minute, *C* and *L* will respond; at 120 cycles, *R* and *L* will respond; at 80 cycles, only *L* will respond; and at zero cycles all three relays will release.

All relays in Fig. 3 are shown in the position of responsiveness for 180 cycles per minute; the cab signals for "clear" are displayed, and there is a holding circuit through the two lower back-contacts of stick relay No. 1, the reset switch, the magnet valve, and the acknowledging switch.

When the coded track current changes from 180 to 120 interruptions per minute, relay *C* will release, relay *R* will be energized, and *L* will not change. This will extinguish the "clear" cab signal and display the "approach restricting" signal. If the engineman made no acknowledgment of the restrictive change in signals, the magnet valve would be deenergized and cause a service application of the brakes. Actuation of the acknowledgment switch will operate stick relays No. 3, No. 2 and No. 1 in cascade or sequence; No. 1 will close its own stick circuit and also close the circuit through the magnet valve, thus preventing a brake application, while No. 2 and No. 3 will release when the acknowledgment valve is released. This is termed forestalling a brake application.

When the coded track current changes from 120 to 80 interruptions per minute, relays *C* and *R* will be released, but *L* will not change. This will extinguish the "approach restricting" signal and display the "approach" signal. The stick circuit of stick relay No. 1 will be broken, and thus cause a brake application, but the actuation of the acknowledging switch will energize all of the stick relays as before, closing the stick circuit of No. 2, which in turn will hold No. 1 closed, and thus prevent a brake application.

When the track current is not coded, or if it is absent altogether, relays *C*, *R* and *L* will all be released. This will extinguish the "approach" signal and display the "slow speed" signal. It will also break the stick circuit of No. 2, but the actuation of the acknowledging switch will energize all of the stick relays as before, and the stick circuit of No. 3 will hold them all closed.

When the speed restrictions are removed in the reverse order, the stick circuits will be held automatically, and actuation of the acknowledging switch is unnecessary.

If an automatic brake application occurs, the pneumatic relay will open the circuit of the acknowledging switch, and it cannot be reclosed except by actuating the reset switch, which the engineman can reach only from the ground. This insures that an automatic application (which is not forestalled) will always perform its intended function and bring a train to a full stop.

The system above described is a four-indication automatic stop, but the number of indications may be only three, or even two, where the signal conditions will permit. It is also unnecessary, with cab signals, to retain the wayside signals, but this will leave a train without signal indications to regulate its movements if the cab signals should fail. The principles and equipment already described can be applied to speed control, but this introduces the necessity for an axle-drive contrifuge and imposes certain added complications in the locomotive equipment.

Code System Power Supply

Reliable central-station power, usually, at 60 cycles, may be obtained in nearly all parts of the country, but in unusually isolated locations self-starting, oil-electric generating sets may be employed. In order to obtain 100-cycle current without the complications incident to generator excitation with d-c., use is being made of induction-type frequency changers. The motor is a three-phase 60-cycle squirrel-cage unit, direct-connected to the wound rotor of the frequency changer, driving it in the direction of rotation which is opposite to the magnetic rotation of the stator field excited with three-phase 60-cycle current. The output frequency is the sum of the frequency of excitation and the frequency of rotation. The power input is partly electrical and partly mechanical, or approximately in the ratio of the component frequencies contributed by these two means. Thus a 10-kw. frequency changer excited with 60-cycle current requires only a 4 kw. motor to drive its rotor, from which the electrical output is delivered. The N. Y., N. H. & H. R. R. is using frequency-changer sets designed for a rated output of 5 kv-a., 4.5 kw., 0.9 power factor and 1200 r.p.m.

Where more power is required, as in the installations on the P. C. C. & St. L. Ry., where a-c. signals are employed, use is being made of motor-generator sets consisting of a 75-h.p., 2200-volt, 3-phase, 60-cycle squirrel cage motor, direct-connected to a 60-kv-a., 0.80-power factor, 220-volt, single-phase, 100-cycle generator with a direct-connected exciter.

It is necessary to provide a 100-cycle transmission line along the railroad right-of-way to supply the track circuits and associated control circuits; in some cases it may also supply a-c. signals, as on the Penna. road. Customary line voltages are 550, 2200, 4400 and 6600 volts. Power sources are usually located every 20 to 25 miles, where small automatic substations are installed, sometimes with a reserve source for emergency. The line is sectionalized between substations, so that it can be fed from either end, or cut through, and automatic features are provided for throw-over in the event of the failure of any individual source of supply. Close regulation of voltage and frequency is necessary for the proper operation of the train control.

Installations

In Table VII there are listed six installations of the Code system of train stop, on the C. R. R. of N. J., L. I., N. Y., N. H. & H., Penna., P. C. C. & St. L. and W. J. & S.; also one installation Code system of 2-speed control on the Reading. In addition the Penna. installation from Baltimore to Harrisburg in order to be interchangeable with the others, is being changed to the Code system. The aggregate installations (five) on the entire Penna. system will comprise 611.5 road miles, 1491.8 track miles and 1159 locomotives. These installations will be interchangeable with those on the C. R. R. of N. J., L. I., N. Y., N. H. & H. and Reading.

I. C. C. Hearings on Automatic Train Control

Division 6 of the I. C. C. held hearings on automatic train control and block signals in Washington, D. C., on Feb. 27-29 and April 23-30, 1928, and some of the testimony presented is of interest. The reports of these hearings are very briefly abstracted in what follows, by railroads (taken from "Railway Signaling").

C. & E. I. Miller ramp. No accidents. Sleet on ramps has caused some undesirable stops. They consider their present installation sufficient, under existing conditions.

B. & O. G. R. S. intermittent inductive. No accidents. Still have too many unnecessary stops, due to various faults, but these are being reduced. Stops are sometimes caused by metal masses on the roadway. Reading locomotives with U. S. & S. control also operate on B. & O. tracks with G. R. S. control. Are positively opposed to cab signals. Regard automatic train control wholly unnecessary.

Southern. G. R. S. intermittent inductive. Few undesired stops. Two accidents. System is satisfactory. Have made voluntary installations on 17 engine divisions.

C. & N. W. G. R. S. 2-speed continuous inductive. Use cab signals and have removed roadside block signals. No trouble from foreign currents and few undesired stops. Have had one false-clear operation. Equipped one engine division voluntarily.

I. C. U. S. & S. Co. continuous inductive stop. Use cab signals but no wayside signals. Tried speed control, but was rejected because too complicated. No accidents. Seven false-clear operations, but not chargeable to the system. Their enginemen greatly favor the cab signals.

A. T. & S. F. U. S. & S. Co. 3-speed continuous inductive. Use cab signals but no wayside signals. The Union system was adopted after considering the first trial of it on the Lewistown branch of the Penna. Enginemen like the system. Management would prefer to spend money for block signals instead of train control. Are extending the block signals.

Mo. Pac. National intermittent inductive. No false-clear operations and few undesirable stops. Has deferred need for second track. Need more block signals rather than train control.

C. R. I. & P. Regan ramp. No more trouble from ice and snow than with semaphores. Have had five false-clear failures, but none recently. Have economized by eliminating unnecessary stoppage of trains at signals.

N. Y. C. G. R. S. intermittent inductive. Have very large mileage now equipped, including numerous voluntary installations. No light signals are used in the cabs, and enginemen prefer not to have them. One false-clear indication. Electric division from New York to Harmon is yet to be equipped. Penna. and C. & E. I. locomotives are operated over N. Y. C. tracks with no trouble. N. Y. C. considers it has made a great improvement.

C. B. & Q. Sprague intermittent inductive. General results are very good. No false-clear failures. Need uniformity or interchangeability as between different roads. No sweeping order should be issued by I. C. C.

Penna. Operated U. S. & S. Co. 3-speed continuous inductive on Lewistown branch from July, 1923, until January, 1926, with cab signals but no wayside signals. Next installed U. S. & S. Co. continuous inductive stop from Baltimore to Harrisburg, but are now changing it to the Code system, 100-cycle interrupted current, with four-indication cab signals. The Code system is now in service on four other divisions, and the installations are not only identical with each other, but with the L. I., C. R. R. of N. J., Reading and N. Y., N. H. & H., so that locomotives will be interchangeable.

Code system was developed to overcome effects of a-c. or d-c. propulsion of trains and a-c. or d-c. track circuits for signals. Analysis of their accidents show that cab signals would have prevented the most serious accidents. Their enginemen are greatly in favor of visual (color-light) cab signals. Will install Code system on New York division this year, with two four-indication cab signals on each locomotive, one for the engineman and one for the fireman. Will also equip other main-line divisions with similar equipment as rapidly as their finances will permit, without orders from the I. C. C. Have had a few false-clear failures, mostly not chargeable to the system. Do not approve of eliminating roadside block signals on a busy road.

Central of Georgia. No passenger killed in 12 years in any accident preventable by automatic train control. Highway grade-crossing protection requires large expenditures. Train control not justified at this time.

C. I. & L. Miller intermittent inductive. No passenger killed in a collision since 1897 and none injured since 1915. Do not need any more automatic train control.

C. M. St. P. & P. U. S. & S. Co. continuous inductive stop. Report satisfactory results. No trouble from stray currents. Use the cab signal and favor it. Consider that the experimental stage is not yet past.

C. G. W. Has no train control. It makes expenditures for extension of its automatic block signals.

D. L. & W. U. S. & S. Co. 2-speed continuous inductive. Automatic roadside signals are reasonably adequate and far more economical than automatic train control. Accident records for seven years show possible saving of $14,000 by automatic train control.

D. & R. G. W. This road is mountainous and crooked. Overheated wheels offer more danger than collisions. Have made large expenditures for block signals, including the appropriation for this year.

C. & O. U. S. & S. Co. intermittent inductive. Have experimented with automatic train control since 1916. Present system is satisfactory. They make large expenditures for grade crossing elimination and for signals. Present need for additional automatic wayside signals is so important that no order should be issued at this time for more train control.

Erie. G. R. S. intermittent inductive. In 16 years past there was no death in a train collision which could have been prevented by automatic train control.

Gt. Nor. Sprague intermittent inductive. Have never killed a passenger in a train accident in automatic block signal territory. Make large expenditures for signals.

Gr. Trunk Western. Are installing automatic block signals this year, at a large expenditure, on 50 miles of double track.

St. L.-S. F. National intermittent inductive. They do not believe the results of their installation justify its cost. Will install automatic block signals on 120 miles this year.

M. K. T. Asked to be relieved from any order of the I. C. C. as not justified at present. Will continue to make large expenditures for automatic block signals.

N. Y., N. H. & H. U. S. & S. Co. general continuous inductive stop and Union Code System. Not opposed to train control, but think that equivalent expenditures for other purposes will provide greater safety. Have no record that train control has prevented an accident. No passengers killed in train accidents since 1916.

Nor. Pac. Sprague intermittent inductive. Have large investment in automatic block signals, but additional train control would not be justified.

St. L.-S. W. Has not reached a stage of development where train control is required or justified.

S. A. L. Now has 500 miles of automatic block signals. Better to extend signals than install train control, but cannot get money to do both. Asks to be exempted from I. C. C. orders.

So. Pac. National intermittent inductive. Has the largest road mileage of automatic block signals of any road in the country, and it is being extended. Has no traffic conditions which justify automatic train control.

Tex. & Pac. Already has extensive block signal system, which is being extended. Asks that the I. C. C. impose no order upon it.

L. & N. U. S. & S. Co. 2-speed continuous inductive and Union continuous inductive stop. Have made large expenditures for block signals and other safety devices, and will continue to extend block system. Train control is neither necessary nor desirable at this time.

U. P. U. S. & S. Co. 2-speed continuous inductive. Has large installation of automatic block signals covering all main lines, which will be extended to secondary lines. Their present installations of train control are not needed, but are supplying valuable experience. When traffic conditions justify it, they are ready to go ahead with voluntary installations.

N. & W. U. S. & S. Co. 3-speed continuous inductive. Have 90 per cent of their passenger track mileage and 72 per cent of mileage now equipped with automatic block signals. They desire to be permitted to exercise their best judgment as to expenditures.

Reading. U. S. & S. Co. 3-speed continuous inductive and Code system. They urge the postponement of any further I. C. C. requirements until more experience has been had with the various types as to interchangeability, which affects them rather seriously.

Summary of Hearings

Railroad safety is on the increase for both passengers and employes. Last year's safety record was excellent and far above the previous year. Highway grade crossings present a serious problem. Train control installations have already cost the railroads $22,395,000 under I. C. C. orders. Some of the railroads regard train control as still in the experimental stage; others stress the need for uniformity and interchangeability in types of installations. Railroads oppose any additional formal orders by the I. C. C. for automatic train control or other safety devices at this time and desire freedom of judgment in making expenditures to secure the best and most satisfactory results. This was substantiated by most of the representatives of 168 respondent railroads at the hearing and by the official spokesman for the A. R. A.

TABLE OF ABBREVIATIONS

I. C. C.	Interstate Commerce Commission
	Manufacturing Companies
G. R. S.	General Railway Signal Co.
Miller	Miller Train Control Corp.
National	National Safety Appliance Co.
Regan	Regan Safety Devices Co., Inc.
Sprague	Sprague Safety Control & Signal Corp.
U. S. & S. Co.	Union Switch & Signal Co.
	Railroads
A. T. & S. F.	Atchison, Topeka & Santa Fe Ry.
A. C. L.	Atlantic Coast Line R. R.
B. & O.	Baltimore & Ohio R. R.
B. & A.	Boston & Albany R. R.
B. & M.	Boston & Maine R. R.
B. R. & P.	Buffalo, Rochester & Pittsburgh Ry.
C. R. R. of N. J.	Central Railroad of New Jersey
C. & O.	Chesapeake & Ohio Ry.
C. & A.	Chicago & Alton R. R.
C. & E. I.	Chicago & Eastern Illinois Ry.
C. & E.	Chicago & Erie R. R.
C. & N. W.	Chicago & Northwestern Ry.
C. B. & Q.	Chicago, Burlington & Quincy R. R.
C. I. & L.	Chicago, Indianapolis & Louisville Ry.
C. M. St. P. & P.	Chicago, Milwaukee, St. Paul & Pacific R. R.
C. R. I. & P.	Chicago, Rock Island & Pacific Ry.
C. St. P. M. & O.	Chicago, St. Paul, Minneapolis & Omaha Ry.
C. N. O. & T. P.	Cincinnati, New Orleans & Texas Pacific Ry.
C. C. C. & St. L.	Cleveland, Cincinnati, Chicago & St. Louis Ry.
D. & H.	Delaware & Hudson Co.
D. L. & W.	Delaware, Lackawanna & Western R. R.
Erie	Erie R. R.
Gt. Nor.	Great Northern Ry.
I. C.	Illinois Central R. R.
K. C. S.	Kansas City Southern Ry.
L. V.	Lehigh Valley R. R.
L. I.	Long Island R. R.
L. & N.	Louisville & Nashville R. R.
M. C.	Michigan Central R. R.
Mo. Pac.	Missouri Pacific R. R.
N. Y. C.	New York Central R. R.
N. Y. C. & St. L.	New York, Chicago & St. Louis R. R.
N. Y., N. H. & H.	New York, New Haven & Hartford R. R.
N. & W.	Norfolk & Western Ry.
No. Pac.	Northern Pacific Ry.
O-W. R. R. & N.	Oregon-Washington R. R. & Navigation Co.
Penna.	Pennsylvania R. R.
P. M.	Pere Marquette Ry.
P. C. C. & St. L.	Pittsburgh, Cincinnati, Chicago & St. Louis Ry.
P. & L. E.	Pittsburgh & Lake Erie R. R.
Reading	Reading Ry.
R. F. & P.	Richmond, Fredericksburg & Potomac R. R.
St. L.-S. F.	St. Louis-San Francisco Ry.
So. Pac.	Southern Pacific Co.
Southern	Southern Ry.
T. & N. O.	Texas & New Orleans R. R.
U. P.	Union Pacific R. R.
W. J. & S.	West Jersey & Seashore R. R.
W. Md.	Western Maryland Ry.

STATE LAWS RELATING TO THEFT OF ELECTRIC CURRENT

As a result of frequent requests for information concerning State laws relating to the theft of electric current, the Meter Committee, Engineering National Section, N. E. L. A., has, through its Contact and General Procedure Subcommittee, had compiled by the General Counsel for the Association the following State laws covering the subject.

In the following pages is set forth the text of the current laws of each State (and the District of Columbia), together with pertinent comment from court and commission decisions in leading cases. Although the Committee's primary interest is in laws relating to the theft of electric current, enactments and opinions concerning the theft of other public utility services have been included.

STATES THAT HAVE LAWS COVERING ILLEGAL USE OF ELECTRICITY, GAS, WATER, ETC.

1. Alabama—Gas, Steam and Electricity.
2. Arizona—Gas, Water and Electricity.
3. Arkansas—Gas and Electricity.
4. California—Gas and Electricity.
5. Colorado—Gas and Electricity.
6. Connecticut—Gas and Electricity.
7. Delaware—Electricity and Gas.
8. District of Columbia—Electricity only.
9. Florida—Electricity, Gas and Water.
10. Georgia—Gas and Electricity.
11. Idaho—Electricity and Gas.
12. Illinois—Gas, Water and Electricity.
13. Indiana—Gas and Electricity.
14. Iowa—Electricity, Water, Steam Heating and Gas.
15. Kansas—Gas, Electricity and Oil.
16. Kentucky—Electricity only.
17. Louisiana—Gas, Electricity and Water.
18. Maine—Gas, Electricity and Water.
19. Maryland—Gas and Electricity.
20. Massachusetts—Gas and Electricity.
21. Michigan—Water, Steam, Electricity and Gas.
22. Minnesota—Electricity only, but refers to prepay meters and pay telephones.
23. Mississippi—Electricity, Water and Gas.
24. Missouri—Gas and Electricity.
25. Montana—Gas and Electricity.
26. Nebraska—Electricity, Gas and Water.
27. Nevada—Water, Gas, Electricity or Power.
28. New Hampshire—Electricity only.
29. New Jersey—Gas and Electricity; Water.
30. New Mexico—Electric Transmission Lines, or leakage or loss in any manner therefrom.
31. New York—Gas, Electricity, Telephone or Telegraph.
32. North Carolina—Gas and Electricity.
33. North Dakota—Gas and Electricity.
34. Ohio—Gas and Electricity.
35. Oklahoma—Gas only.
36. Oregon—Gas and Electricity.
37. Pennsylvania—Electricity, Heat, Power, Gas and Water.
38. Rhode Island—Gas, Water and Electricity.
39. South Carolina—Light, Heat, Power and Gas.
40. South Dakota—Gas, Water and Electricity.
41. Tennessee—Gas, Electricity, Telephone and Telegraph Wires, and current used in connection with Light and Power.
42. Texas—Electricity, Gas and Water.
43. Utah—Gas and Electricity.
44. Vermont—Gas, Electricity and Water; Heat and Power
45. Virginia—Gas and Electricity.
46. Washington—Gas, Electricity, Steam and Water.
47. West Virginia—Gas, Electricity and Water.
48. Wisconsin—Gas, Electricity, Water and Steam.
49. Wyoming—Gas and Electricity.

CRIMINAL CODE—REVISED STATUTES, SUMMARIZED

Alabama

Ten Sections—covering all offenses concerning Gas, Steam and Electricity. Penalty: Fine not less than $10.00 nor more than $500.00, or imprisonment in the county jail at hard labor not less than ten days nor more than six months.

Arizona

Four Sections—covering Gas, Water and Electricity. Penalty not exceeding six months; fine not exceeding $300.00, or both.

Arkansas

Four Sections—covering Gas and Electricity. Penalty: Fine not less than $5.00 nor more than $100.00, or by imprisonment not exceeding one year, or both.

California

Three Sections—covering Gas and Electricity. Penalty: Fine not exceeding $500.00 or imprisonment in jail not exceeding six months, or both.

Colorado

Twelve Sections giving in great detail various methods of detection of Gas and Electricity, and what constitutes prima facie evidence. Penalty: thirty to ninety days or $50.00-$300.00, or both. Section covers tampering with electric wires in any manner.

Connecticut

Two Sections—covering Gas and Electricity. Penalty: Fine not more than $50.00 or imprisonment not more than ninety days, or both.

Delaware

Two Sections—covering Electricity and Gas. Penalty: Not exceeding $50.00 or three months' imprisonment, or both.

District of Columbia

One Section—Electricity only. Penalty not exceeding $1,000.00 or imprisonment not exceeding one year, or both.

Publication No. 289-7, Serial Report, Meter Committee.

Florida

Two Sections—covering Electricity, Gas and Water. Penalty not exceeding $500.00 or imprisonment not exceeding one year.

Georgia

Three Sections—Gas and Electricity. Penalty: Female, not exceeding twelve months or fine not exceeding $1,000.00. Male, imprisonment; convict work on public roads not more than twelve months; fine not exceeding $1,000.00. Punishment seems to be discretionary with judge as to whether a sentence shall be to the penitentiary or to the State Farm.

Idaho

Six Sections. Principal and anyone assisting or abetting equal guilt. Penalty: Not exceeding $300.00; imprisonment not exceeding six months, or both. Covers Electricity and Gas.[1]

Illinois

One Section—covering Gas, Water and Electric Current. Penalty: Not exceeding three months or fine not exceeding $250.00, or both.[2]

Indiana

Five Sections—Gas and Electricity. Fine not exceeding $100.00; imprisonment not exceeding one year, or both. The Indiana law seems to have been tested on more than one occasion by appeal to the Supreme Court, who appears to have upheld the Act in every particular.

Iowa

Three Sections—Electricity, Water, Steam Heating and Gas. Penalty: When property stolen exceeds $20.00, imprisonment in penitentiary not more than five years, nor in the county jail not more than one year; nor fined not more than $1,000.00, or both. Where value stolen does not exceed $20.00, fine not exceeding $100.00 and imprisonment in county jail not exceeding thirty days.

Kansas

Three Sections—Gas, Electricity and Oil. These Sections are general and cover tampering with telephone, telegraph, electric transmission lines, wires and cables, pipes on surface or in ground, etc. Penalty under Section No. 17, fine not exceeding $500.00 and imprisonment in county jail not exceeding one year, or both. Under Section No. 55-109, which appears to refer particularly to Oil and Gas, fine not less than $25.00, nor more than $100.00.

Kentucky

Five Sections—covering Electricity. Penalty: $5.00 to $500.00 or imprisonment ten days to one year, or both.

Louisiana

Electricity and Gas. Four Acts, consisting of twenty sections, defining evidence. Making tampering or diversion a misdemeanor. Penalty varies from ten days to six months imprisonment in Parish Prison. Sentence may be applied to principal and those convicted of assisting in act.

Maine

One Section—Gas, Electricity and Water. Penalty: Fine not exceeding $100.00, imprisonment not more than one year, or both.

Maryland

Three Sections—covers Gas and Electricity. Penalty: Imprisonment not exceeding six months; fine not exceeding $500.00, or both.

Massachusetts

General Laws of 1921—Two Sections—covers Gas and Electricity. Penalty not more than $100.00 fine or imprisonment not more than one year, or both.

Michigan

Three Sections—covers Water, Steam, Electricity and Gas. Penalty: Where value stolen does not exceed more than $25.00, fine not exceeding $100.00 or imprisonment not more than ninety days, or both. If value of commodity stolen exceeds $25.00, fine is not to exceed $1,000.00 and imprisonment in the State penitentiary for not less than three months nor more than three years, or both. The provision is written in the law which states that criminal prosecution does not impair the right of the company full compensation in damages by a civil suit; also defines what constitutes prima facie evidence as to control and occupancy of the premises where offence was committed.

Minnesota

One Section—covers Electricity only, but refers to prepayment; electric prepay meters and pay telephones fraudulently obtaining the use of either. Penalty not exceeding three months in jail; fine not exceeding $100.00.[3]

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[1] Idaho has a special section known as "CH-208—Idaho Session Laws 1921," section No. 2 of which permits any corporation selling illuminating gas who shall have probable cause to believe that any person, etc., is violating the provisions of their meter cheating act, shall, upon making affidavit required in, and complying with all the provisions of Chapter No. 332, of Title No. 61, of the Compiled Statutes, be entitled to have a search warrant issued to it and served in the manner provided in Chapter No. 332, of Title No. 61.

This provision will prove of value in detecting meter cheating. Many good and sufficient reasons can be given as "probable cause" when application is made for a search warrant. In Louisiana today, unless permission is granted by the owner to enter a house, it is impossible for company inspectors to gain admission thereto without a long tedious process of law, and by the time the suspected person is summoned into court to show cause why a search warrant should not be issued, all evidence of guilt, of course, is removed.

[2] In the interesting case of Woods vs. The People, 222 Ill. 293-298, the amount of gas stolen, the jury found, exceeded $15.00 in value and the defendant was sentenced to the penitentiary for an indeterminate period. On a writ of error, the case was appealed to the Supreme Court, who affirmed the judgment of the jury.

[3] In examining the Digest of the Minnesota Law, Section No. 8946 particularly refers to Electricity, but reference is made to the case of the State of Minnesota vs. Wellman, 34 Minn. 221, 222, in which defendant was charged with larceny of 500 feet of illuminating gas, valued at $12.50. He was found guilty of larceny and sentenced accordingly.

Reference is made to this case, as Section No. 8946 apparently only refers to Electricity, so we can assume that the Minnesota law covers both Gas and Electric meter cheaters.

Mississippi

General laws of 1922. One Section—covers Electricity, Water and Gas. Penalty: Fine $10.00 to $100.00; imprisonment three months, or both.

Missouri

Three Sections—covers Gas and Electricity. Penalty: Fine not less than $50.00, nor more than $500.00; imprisonment not less than three months, nor more than twelve months, or both; defines in detail what constitutes prima facie evidence and intent to defraud.

Montana

Two Sections—covers Gas and Electricity. Penalty: Fine not exceeding $500.00 or imprisonment not exceeding six months, or both.

Nebraska

Six Sections—covers Electricity, Gas and Water. Penalty: Fine not less than $50.00 nor more than $300.00; imprisonment not less than thirty days nor more than ninety days; defines prima facie evidence of guilt.

Nevada

One Section No. 6733 with four divisions; defines tampering with the purveyance of flumes, ditches, conduits, reservoirs, wires or any other apparatus used in connection with Water, Gas, Electricity or Power, or destroys or detaches or disconnects or damages in any manner any apparatus that purveys above commodities; fine not exceeding $500.00; imprisonment not to exceed six months, or both.

New Hampshire

One Section—Electricity only. Penalty: Not to exceed $300.00 in a criminal case and in a civil case to pay treble damages should an action be taken to recover under a civil action.

New Jersey

Three Sections—covers Gas, Electricity and Water. Penalty: Fine not exceeding $1,000.00, imprisonment with or without labor not exceeding three years, or both; reserve right to recover damages by civil action.

New Mexico

One Section—covers Electric Transmission lines, or leakage or loss in any manner therefrom. Penalty: Not exceeding $100.00 or imprisonment not exceeding thirty days, or both.

New York

Three Sections and Subdivisions thereof—covers tampering with any meters, automatic vending machines, slot machines, coin box telephones, telephone machines or any other machine used in connection with the purveyance of Gas, Electric Current, Telephone or Telegraph. Penalty: Fine not more than $250.00 or imprisonment not more than six months, or both; gas or electric current or steam; imprisonment in county jail or penitentiary not more than one year and fine not more than $500.00, or both.

North Carolina

Three Sections with Subdivisions—covers Gas and Electricity. Penalty: Imprisonment for not less than four months, not more than ten years; fine (amount not stated).

North Dakota

Three Sections—covers Gas and Electricity. Penalty: Not exceeding one year in jail and fine not exceeding $500.00, or both.

Ohio

Four Sections—covers Gas and Electricity. Penalty: Not less than $25.00 nor more than $300.00; imprisonment not more than thirty days, or both.

Oklahoma

Two Sections—covers gas. Penalty: Not exceeding one year or fine not exceeding $500.00, or both. These sections cover larceny of Gas only; Electricity is not mentioned.

Oregon

One Section with nine Subdivisions—covers Gas and Electricity, and any person that aids and abets and assists. Penalty: Fine not less than $50.00 nor more than $500.00, or imprisonment in jail not less than thirty days, nor more than one year, or both.

Pennsylvania

Four Sections—covers Electric Light, Heat, Power, Gas and Water. Penalty: Imprisonment not exceeding one year nor fine not exceeding $1,000, or both, for electricity, light, heat and power. For gas and water fine not exceeding $300.00 or imprisonment not exceeding three months, or both.

Rhode Island

Three Sections—covers Gas, Water and Electricity. Penalty: Not exceeding thirty days; fine not exceeding $100.00.

South Carolina

Four Sections—covers Light, Heat, Power and Gas. Penalty: Fine not exceeding $100.00 and imprisonment not exceeding thirty days, or both.

South Dakota

Three Sections—covers Gas, Water and Electricity. Penalty: Fine not exceeding $100.00, imprisonment not exceeding sixty days, or both.[4]

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[4] The South Dakota Revised Code of 1912, Section No. 4398, provides that any person employed to read meters who knowingly reports to his employer that any consumer of Gas, Water, or Electricity has used a greater amount of Gas, Water or Electricity than the amount actually used by said consumer, shall be sentenced in the County Jail not exceeding three months or by fine not exceeding $250.00, or both. Any person who knowingly collects from a consumer a greater amount than is actually used shall be punished by a fine not exceeding $500.00. This provision is unique as it does not appear in any other laws so far examined.

Tennessee

Four Sections—covers Gas, Electricity, Telephone and Telegraph Wires and Current used in connection with Light and Power. Penalty not less than $5.00 nor more than $50.00, or imprisonment in the county workhouse or jail not less than ten days nor more than twelve months, or both.

Texas

One Section—covers Electricity, Gas and Water. Penalty: Fine not less than $25.00 nor more than $100.00, and defines what constitutes prima facie evidence.

Utah

Three Sections—Gas and Electricity. Penalty: Imprisonment in jail not exceeding six months or by fine not less than $300.00, or both; but in case a corporation is convicted of any offense, such corporation is punishable by a fine not exceeding $1,000.00.

Vermont

Three Sections—covers Gas and Electricity. Penalty: For Gas, Electricity and Water, not more than $100.00, or imprisonment not more than one year, or both. Penalty for interfering with Electric Light, Heat or Power, or obstructing its use in any way, imprisonment not more than two years, or be fined not more than $300.00, or both; recovery is made in an action of tort for breaking into, damaging or interfering with a meter properly registering, or appliances attached to or connected with wires, pipes, mains, etc., shall be imprisoned not more than three months or pay more than $100.00, or both.

Virginia

Two Sections—covers Gas and Electricity. Penalty: Fine not exceeding $500.00, or imprisonment in jail not exceeding twelve months, or both.

Washington

Two Sections with numerous Subdivisions—covers Gas, Electricity, Steam and Water. Penalty: Imprisonment not more than ninety days, nor fine not more than $250.00.

West Virginia

Two Sections—covers Gas, Electricity and Water. Penalty: Not exceeding twelve months in jail, or by fine not exceeding $1,000.00, or both.

Wisconsin

One Section—covers Gas, Electricity, Water and Steam. Penalty: Fine not exceeding $500.00, or imprisonment in the county jail not more than one year, or both. In the event the amount stolen does not exceed $20.00, punishment shall be by imprisonment in jail for not more than three months, or by fine not exceeding $100.00.

Wyoming

Eight Sections—covers Gas and Electricity. Penalty: Not less than $50.00 nor more than $300.00, or by imprisonment in jail for not less than thirty nor more than ninety days, or by both.

STATUTES AND COURT AND COMMISSION DECISIONS

Alabama Criminal Code of 1923

Offenses Concerning Gas, Steam or Electricity

Sec. 4294.—No person shall connect a tube, pipe, wire or other instrument or contrivance with a pipe or wire used for the conducting or supplying of illuminating gas, fuel gas, electricity or steam, in such a manner as to supply such gas or electricity or steam to any burner, orifice, lamp, motor or pipe where the same is or can be burned or used, without passing through the meter or instrument provided for registering the quantity consumed.

Sec. 4295.—No person shall destroy, alter or prevent the action of a meter or other instrument used to measure or register the quantity of illuminating gas, fuel gas, electricity or steam, consumed in a house or apartment, or at an orifice, burner, lamp, motor or pipe, or by a consumer or other person, or detach or disconnect such meter or other instrument.

Sec. 4296.—No person shall, in any manner whatever, change, extend, or alter any service or other pipe, wire or attachment of any kind, connecting or through which artificial gas, electricity or steam is furnished from the gas mains or pipes or wires or source of supply, of any person, company or corporation.

Sec. 4297.—No person shall make any connections or reconnections with the gas mains, service pipes or wires of any person, company or corporation furnishing to consumers artificial gas, electricity or steam, or turn on or off in any manner, or in any manner interfere with any valve or stopcock or other appliance belonging to such person, company or corporation and connected with its gas mains, service or other pipes or wires.

Sec. 4298.—No person shall retain possession of or refuse to deliver any meter or meters, lamp or lamps, or other appliances which may be or may have been loaned or rented by any person, company or corporation for the purpose of furnishing gas, electricity or steam through the same, nor sell, loan or in any manner dispose of the same to any person or persons other than the said person, company or corporation entitled to the possession of the same.

Sec. 4299.—No person shall set on fire any gas escaping from broken or leaking mains, pipes, valves or other appliances used by any person, company or corporation in conveying gas to consumers, or interfere in any manner with the pipes, mains, gate boxes, valves, stopcocks, wires, cables, conduits or any other appliances, machinery or property of any person, company or corporation engaged in furnishing gas, electricity or steam.

Sec. 4300.—Any person who shall maliciously, or with intent to injure or defraud, do or commit, or shall aid or abet in the commission of any of the acts forbidden in this chapter, shall be guilty of a misdemeanor, and upon conviction shall be fined not less than $10 nor more than $500, and may also be imprisoned in the county jail, or at hard labor for the county, for not less than ten days nor more than six months, one or both at the discretion of the judge or jury trying the case.

Sec. 4301.—Proof that any of the acts specified in this chapter was done on the premises in the possession of the accused, or that the accused received the benefit of any such act or acts, shall be prima facie evidence that the accused committed such act, or aided or abetted in the commission thereof maliciously, or with intent to injure or defraud.

Sec. 4302.—Every person, company or corporation now engaged or hereafter engaging in the business of furnishing natural or artificial gas for heating, illuminating or other purposes, to be used and paid for by patrons by meter measure, shall furnish to each and every patron a meter properly tested and in good order, and shall arrange such meters so that the patrons can, at any time, see the meter dial and ascertain how much gas he is consuming, and how much he is liable to pay for.

Sec. 4303.—Whoever knowingly constructs, or uses, or furnishes to gas consumers to be used, any false meter provided for measuring and registering the quantity of gas consumed by any person under a contract with any gas company, shall, on conviction, be fined not less than $10 nor more than $100.

Arizona Revised Statutes 1913 (Penal Code)

Larceny

Sec. 495.—Every person who, with intent to injure or defraud, makes or causes to be made, any pipe, tube or other instrument, and connects the same, or causes it to be connected, with any main, service pipe or other pipe for conducting or supplying illuminating gas, in such manner as to supply illuminating gas to any burner or orifice, by, or at which illuminating gas is consumed, around or without passing through the meter provided for the measuring and registering the quantity consumed, or in any other manner so as to evade payment therefor, and every person who, with like intent, injures or alters any gas meter or obstructs its action, is guilty of a misdemeanor.

Sec. 496.—Every person who, with intent to injure or defraud, connects or causes to be connected, any pipe, tube or other instrument, with any main, service pipe or other pipe, or conduit, or flume for conducting water, for the purpose of taking water from such main, service pipe, conduit or flume, without the knowledge of the owner thereof, and with intent to evade payment therefor, is guilty of a misdemeanor.

Sec. 497.—Every person who, with intent to injure or defraud, makes or causes to be made by wire, or otherwise, any connection with any main or service line for conducting or supplying electricity in such manner as to procure electricity without its passing through the meter provided for the measuring and registering of the quantity consumed or in any other manner so as to avoid payment therefor, or any person who, with like intent, injures or alters any electric meter or obstructs its action, is guilty of a misdemeanor.

Sec. 19.—Except in cases where a different punishment is prescribed by this code, every offense declared to be a misdemeanor is punishable by imprisonment in a county jail not exceeding six months, or by a fine not exceeding $300, or by both.

Arkansas (Crawford & Moses) Digest of Statutes 1921

Criminal Law

Sec. 2480.—It is hereby declared to be unlawful for any person or persons to set on fire any gas escaping from wells or from broken or leaking mains, pipes, valves or other appliances, used by any person, company or corporation in conveying gas to consumers, or to tap any pipe or main for the purpose of taking and stealing gas therefrom, or to interfere in any manner with wells, pipes, mains, gate boxes, valves, stopcocks or other appliances, machinery or other property of any person, company or corporation engaged in furnishing gas to consumers, unless employed by, and acting under the authority and direction of, such person, company or corporation furnishing gas to consumers. Act, May 6, 1905, p. 635, sec. 1.

Sec. 2481.—It is hereby declared to be unlawful for any person in any manner whatever, to change, extend or alter, or to cause to be changed, extended, or altered, any service or other pipe or attachment of any kind, by or through which natural or artificial gas is furnished from the gas mains or pipes of any person, company or corporation without first securing from said persons, company or corporation written permission to make such change, extension or alteration. Id. sec. 2.

Sec. 2482.—Any person violating any provision of secs. 2480 and 2481 of this act shall, upon conviction, be fined in any sum not less than $5 nor more than $100 for such offense. Id. sec. 3.

Sec. 2517.—Whoever unlawfully and intentionally injures or destroys or permits to be injured or destroyed any meter, pipe, conduit, wire, line, pole, lamp or other apparatus belonging to any person, firm or corporation engaged in the manufacture or sale of electricity for light, heat, power or other purpose, or unlawfully and intentionally prevents an electric meter from duly registering the quantity of electricity supplied, or in any way interferes with its proper action or just registration, or without the consent of such person, firm or corporation unlawfully and intentionally diverts any electric current from any wire of such persons, firm or corporation, or otherwise unlawfully and intentionally uses or causes to be used, without the consent of such person, firm or corporation, any electricity manufactured or distributed by such person, firm or corporation, shall be deemed guilty of a misdemeanor and shall for every such offense be punished by a fine not exceeding one hundred dollars, or imprisonment not exceeding one year, or by both fine and imprisonment. Act, March 29, 1923, p. 1015.

Carson vs. Fort Smith Light & Traction Co., 108 Ark. 452, dealt with the right of a consumer of gas upon placing money in a meter. The court said (pp. 456-457):

> In any event, it cannot be questioned that appellants had the right upon putting the quarter into the meter to consume the amount of gas for which it paid, and when it was so deposited and the gas turned into the meter, it was delivered to them and became their property with the right to consume it at their convenience, so long as the terms of the contract were not violated in so doing. Chouteau v. St. L. Gas Light Co., 47 No. Appeals, 326; Schmeer v. Gas Light Co., 147 N. Y. 529; 42 N. E. 202; 30 L. R. A. 653; Blondell v. Gas Co., 89 Md. 732; 43 Atl. 817; 46 L. R. A. 187.
>
> It may be true that the gas company had the right under its contract to shut off the supply of gas to appellants to compel the payments of amounts already due for gas consumed, or furnished, but it could not do so until after giving notice in accordance with the terms of the contract, and certainly with the slot meter in use and the money deposited therein for the payment of 1000 cu. ft. of gas according to the old price, and of that much upon the price of 1000 ft. according to the last rate fixed, it had no right to turn the gas already delivered to appellants out of the meter. If, according to the usage they are entitled to continue to consume 1000 ft. of gas for each quarter deposited in the meter until the meter could be changed to register in accordance with the advanced price, which we do not decide, the gas in the meter was already paid for, and if it can be said they should be held to the payment of the advance price for all the gas consumed since they were notified it should go into effect, then they would only have owed for the difference in the price, which would have been collected on the first of the succeeding month and could not have warranted their agent in turning the gas already delivered in the meter out. It

was as much a wrongful act as if he had taken or destroyed any other of the personal property or effects of these appellants in their homes.

It was a tort, pure and simple, committed without justification or excuse, and for which the gas company should be held answerable for all damages directly traceable to the wrong done and arising without an intervening agency and from no fault of the persons injured. Cov. v. Indianapolis Gas Co., 146 Ind. 665; 46 N. E. 17; 36 L. R. A. 535; Indiana Gas Co. v. Anthony, 26 Ind. App. 307; 58 N. E. 868; Thornton Oil & Gas, sec. 534.

California Penal Code 1923

Larceny

Sec. 498.—Every person who shall willfully, with intent to injure, or defraud, make or cause to be made, or uses or causes to be used, any pipe, tube or other instrument or conduit in connection with any main, service pipe or other pipe or conduit owned or controlled by any other person for conducting or supplying illuminating or fuel gas in such manner as to supply such or any illuminating or fuel gas to any burner, or outlet by or at which illuminating or fuel gas is consumed or otherwise used or wasted without passing through any meter provided for the measuring and registering the quantity of gas passing through such pipes, tubes or other conduits, or willfully acts in any other manner so as to evade, or cause the evasion of payment therefor, and every person who, with like intent, injures or alters any gas meter or register, or obstructs its action, is guilty of a misdemeanor. (Amendment approved 1909; Stats. 1909, p. 329.)

Sec. 499 a.—Every person who shall willfully and knowingly, with intent to injure or defraud, make or cause to be made any connection in any manner whatsoever with any electric wire or electric appliance of any character whatsoever operated by any person, persons or corporation authorized to generate, transmit and sell electric current, or who shall so willfully and knowingly with intent to injure or defraud, use or cause to be used any such connection in such manner as to supply any electric current for heat or light or power to any electric lamp, or apparatus or device, by or at which electric current for heat or light or power is consumed or otherwise used or wasted, without passing through a meter for the measuring and registering of the quantity passing through such electric wire or apparatus, or who shall knowingly and with like intent injure, alter or procure to be injured or altered any electric meter, or obstruct its working, or procure the same to be tampered with or injured, or use or cause to be used any electric meter, or appliance so tampered with or injured, shall be deemed guilty of a misdemeanor. (Amendment approved April 20, 1917; Stats. 1917, p. 150.)

Sec. 19.—Except in cases where a different punishment is prescribed by this code, every offense declared to be a misdemeanor is punishable by imprisonment in a county jail not exceeding six months, or by a fine not exceeding $500, or by both.

Colorado Compiled Laws 1921

Tapping Gas and Electrical Conduits

Sec. 6753.—Any person who connects any pipe, tube, stopcock or other instrument, device or contrivance with any main, service pipe or other pipe conducting or supplying, or intended to conduct or supply gas to any house, store or building, without the knowledge and consent of the person or corporation owning said pipe, in such manner that any portion of such gas may be conducted or supplied to any burner, orifice, heating apparatus or other instrument by or at which gas is consumed shall be deemed guilty of a misdemeanor and punished as provided in section five (5) hereof. (L. '09, p. 395, sec. 1.)

Sec. 6754.—Any person who connects any pipe, tube, stopcock or other instrument, device or contrivance with any main, service pipe or other pipe conducting or supplying or intended to conduct or supply gas to any house, store or other building without the knowledge and consent of the person or corporation owning said pipe, in such manner as to conduct or supply any such gas to any pipe, tube, burner, orifice, heating apparatus or other instrument by or at which gas is consumed, around or without passing through the meter provided for measuring or registering the amount or quantity of gas passing through it, shall be deemed guilty of a misdemeanor and punished as provided in section five (5) hereof. (L. '09, p. 395, sec. 2.)

Sec. 6755.—Any person who willfully injures, alters or by any instrument, device or contrivance in any manner interferes with or obstructs the action or operation of any meter made or provided for measuring or registering the amount or quantity of gas passing through it, without the knowledge and consent of the person or corporation owning said meter, shall be deemed guilty of a misdemeanor and punished as provided in section five (5) hereof. (L. '09, p. 396, sec. 3.)

Sec. 6756.—Proof of the existence of any pipe connection, or of any injury, alteration or obstruction of a meter, as in this act provided, shall be taken as prima facie evidence of the guilt of the person in possession of the premises where such connection, injury, alteration or obstruction is proved to exist. (L. '09, p. 396, sec. 4.)

Sec. 6757.—Any person convicted of a violation of any of the provisions of this act shall be punished for each offense by a fine of not less than fifty dollars ($50) nor more than three hundred dollars ($300), or by imprisonment in the county jail for a period of not less than thirty (30) days nor more than ninety (90) days, or both such fine and imprisonment. (L. '09, p. 396, sec. 5.)

Sec. 6758.—Any person who connects or changes any wire, cord, socket, motor or other instrument, device or contrivance, with any wire transmitting or supplying, or intended to transmit or supply electricity to any house, store or other building, without the knowledge and consent of the person or corporation owning said wire, in such manner that any portion of such electricity may be transmitted or supplied to any globe, lamp, heating apparatus or other instrument by or at which electricity is consumed, shall be deemed guilty of a misdemeanor and punished as provided in section five (5) hereof. (L. '09, p. 364, sec. 1.)

Sec. 6759.—Any person who connects or changes any wire, cord, socket, meter or other instrument, device or contrivance with any wire, transmitting or supplying or intended to transmit or supply electricity to any house, store or other building, without the knowledge and consent of the person or corporation owning said wire, in such manner as to transmit or supply any such electricity to any globe, lamp, heating apparatus or other instrument by or at which electricity is consumed, around or without passing through the meter provided for measuring or registering the amount or quantity of electricity passing through it, shall be deemed guilty of a misdemeanor and punished as provided in section five (5) hereof. (L. '09, p. 365, sec. 2.)

Sec. 6760.—Any person who willfully injures, alters or by any instrument, device or contrivance in any manner interferes with or obstructs the action or operation of any meter made or provided for measuring or registering the amount or quantity of electricity passing through it, without the knowledge and consent of the person or corporation owning said meter, shall be deemed guilty of a misdemeanor and punished as provided in section five (5) hereof. (L. '09, p. 365, sec. 3.)

Sec. 6761.—Proof of the existence of any wire connection, or of any injury, alteration or obstruction of a meter, as in this act provided, shall be taken as prima facie evidence of the guilt of the person in possession of the premises where such connection, injury, alteration or obstruction is proved to exist. (L. '09, p. 365, sec. 4.)

Sec. 6762.—Any person convicted of a violation of any of the provisions of this act shall be punished for each offense by a fine of not less than fifty dollars ($50) nor more than three hundred dollars ($300), or by imprisonment in the county jail for a period of not less than thirty (30) days nor more than ninety (90) days, or by both such fine and imprisonment. (L. '09, p. 365, sec. 5.)

Sec. 6763—Any person or persons who shall change, tap or connect with any electrical or gas apparatus, such as converters, meters, motors or other appliances, or with any electric light wire or gas pipe for the purpose of obtaining an electric current or gas for light, power or heat or for any other purpose whatever, without the knowledge and consent of the owner thereof or the person or persons or corporation, as the case may be, operating such apparatus, appliances, pipes and wires or who shall maliciously tamper with or injure any such apparatus, appliances, pipes or wires, shall be deemed guilty of a misdemeanor and, on conviction thereof, shall be punished for each offense by a fine of not less than fifty (50) dollars, nor more than three hundred (300) dollars or by imprisonment in the county jail for a period of not less than thirty (30) days nor more than ninety (90) days, or by both such fine and imprisonment. (L. '03, p. 115, sec. 1; R. S. '08, sec. 1880.)

Connecticut General Statutes 1918

Offenses Against Private Property

Sec. 6294.—Every person who shall, without permission, knowingly withdraw or cause to be withdrawn, and appropriate to himself for his own use or for the use of any other person, any current of electricity from the wires of any person or corporation authorized to manufacture, sell or use electricity for the purpose of light, heat or power; and any person having permission to use the said electric current for certain specified purposes who shall knowingly, willfully and intentionally withdraw or cause to be withdrawn such electric current for any other purpose; and every person to whom such electric current is furnished from or by means of a meter who shall willfully and with intent to cheat and defraud any of said persons or corporations, alter or interfere with such meter, or by any contrivance whatsoever withdraw or take off the electric current in any manner except through such meter, shall be fined not more than $50 or imprisoned not more than ninety days, or both.

Sec. 6296.—Every person who, with intent to defraud any person or corporation authorized to manufacture, sell or use gas for lighting, heating or power, shall connect any instrument or contrivance with any pipe for supplying gas, so as to effect the consumption thereof, without its passing through the meter provided for receiving and registering the quantity of gas passing through such pipe, or shall use or assist in connecting such meter; or who shall, without permission of the person or corporation supplying such gas knowingly use or waste any gas which has not passed through the meter provided for registering the consumption thereof, or has passed through such meter in such a manner as not to register the amount of gas so used or wasted; or who shall, by any means or device, knowingly take gas from the pipes of such person or corporation, with intent to evade payment therefor, or who shall, with like intent, make connection with such pipes for the purpose of taking such gas for his own use or for the use of another; or who shall take from any prepayment gas meter belonging to such persons or corporation any money or other valuable, or break or force open any such meter for the purpose of taking any money or valuable therefrom; or any agent of any manufacturer of such gas, who shall defraud another in quantity or quality, in the sale of such gas, in any manner, shall be fined not more than $50 or imprisoned in the county jail not more than ninety days, or both.

Delaware Revised Statutes 1915

Offenses Against Private Property

Sec. 4763.—It shall be unlawful for any person, without the consent of the owner thereof and with the intent not to pay for the same, to divert or cause to be diverted any electric current, while such current is being conveyed and transmitted through wires or conduits from the plant of the manufacturer of said electric current to the electric meter on the premises of any consumer thereof, or to cause any such electric current to be transferred from said wires or conduits to the premises of any consumer thereof without passing it through an electric meter on said premises provided by such manufacturer for the purpose of measuring the electric current furnished said premises, or, knowing such electric current to be so diverted to use it; every person violating any of the provisions of this section shall be guilty of a misdemeanor, and upon conviction thereof shall be punished by a fine not exceeding $50 or by imprisonment not exceeding three months, or by both in the discretion of the court.

Sec. 4764.—It shall be unlawful for any person, without the consent of the owner thereof and with the intent not to pay for the same, to divert or cause to be diverted any illuminating gas, while such gas is being conveyed in pipes from the plant of the manufacturer of said gas to the gas meter on the premises of any consumer thereof, or to cause any such gas to be transferred from the said pipes to the premises of any consumer thereof without passing it through a gas meter on said premises provided by such manufacturer for the purposes of measuring the gas furnished said premises, or knowing such gas to be so diverted to use it; every person violating any of the provisions of this section shall be guilty of a misdemeanor, and upon conviction thereof shall be punished by a fine not exceeding $50, or by imprisonment not exceeding three months, or by both in the discretion of the court.

District of Columbia Code of Law 1924

Offenses Against Property

Sec. 826a.—Whoever shall knowingly connect or disconnect any electrical conductor belonging to any company using or engaged in the manufacture and supply of electric current for purposes of light, heat and power, or either of them, or makes any connection with any such electrical conductor for the purpose of using or wasting the electric current, or who in any wise tampers with any meter used to register current consumed, or who interferes with the operating of any dynamo or other electrical appliance of such company, or tampers with or interferes with the poles, wires, conduits, or other apparatus used by such companies, unless such person or persons shall be duly authorized by or be in the employ of such company, shall be punished by a fine not exceeding $1,000, or imprisonment not exceeding one year, or both.

Florida Compiled General Laws 1927

Offenses Concerning Property

Sec. 7427.—Every person who shall willfully or fraudulently injure, or shall knowingly suffer to be injured any meter, wire, pipe or fittings connected with or belonging to an electric, gas or water plant owned or controlled by a person, firm or corporation, private or municipal, engaged in the business of furnishing electricity, gas or water to users thereof, or who shall willfully or fraudulently tamper or meddle with any meter or other appliance or plant in such manner as to cause loss or damage to the owner or operator of such plant, or shall willfully or fraudulently prevent any meter used for registering the same from registering the quantity so passing through the same, or shall alter the index or break the seal of any such meter or in any way hinder or interfere with its proper action of just registration, or shall fraudulently use or willfully waste or suffer the waste of electricity or gas or water passing through any such meter, wire, pipe or fitting, or other appliance or appurtenance connected with or belonging to any such plant after such meter, wire pipe fitting, appliance or appurtenance has been tampered with, injured or altered, shall be punished by fine not exceeding $500, or imprisoned not exceeding one year.

Sec. 7428.—Every person who, with intent to injure or defraud any person, firm or corporation, private or municipal, shall make or cause to be made any connection with any wire, main, service pipe or other pipe, appliance or appurtenance used for or in connection with an electric, gas or water plant, owned or controlled by any person, firm or corporation, private or municipal, engaged in the business of furnishing electricity, gas or water to users thereof, in such manner as to supply electricity, gas or water from such plant to any lamp, burner, orifice, faucet or other outlet whatsoever without such electricity, gas or water passing through a meter provided by the owner or manager of such plant and used for measuring and registering the quantity so passing through, or shall make or cause to be made, without the consent of the owner or operator of any such plant, any connection with any such plant, or any wire, main, pipe, service pipe, or other instrument or appliance connected with such plant, in such manner as to take, use or waste, without the consent of such owner or operator, any electricity, gas or water, or shall with intent to defraud the owner or operator of any such plant use any such electricity, gas or water so taken without the consent of such owner or operator shall be punished by a fine not exceeding $500 or by imprisonment not exceeding one year.

Georgia (Park's) Annotated Code of 1914 (Penal)

Interfering with Property of Electrical Companies

Sec. 783.—Whoever unlawfully and intentionally injures or destroys, or permits to be injured or destroyed, any meter, pipe, conduit, wire line, post, lamp, or other apparatus belonging to a company engaged in the manufacture or sale of electricity for lighting or power purposes, or unlawfully and intentionally prevents an electric meter from duly registering the quantity of electricity supplied, or in any way interferes with its proper action or just registration, or, without the consent of such company, unlawfully and intentionally diverts any electric current from any wire of such company, or otherwise unlawfully and intentionally uses or causes to be used, without the consent of such company, any electricity manufactured or distributed by such company, shall be punished as for a misdemeanor.

Sec. 1065.—Except where otherwise provided, every crime declared to be a misdemeanor is punishable by a fine not to exceed $1,000, imprisonment not to exceed six months, to work in the chain gang on the public roads, or on such other public works as the county or State authorities may employ the chain gang, not to exceed twelve months, any one or more of these punishments in the discretion of the judge; Provided, that nothing herein contained shall authorize the giving the control of convicts to private persons, or their employment by the county or State authorities in such mechanical pursuits as will bring the products of their labor into competition with the products of free labor. If the convict be a female, the judge may, in his discretion, sentence her to labor and confinement in the woman's prison on the State Farm, in lieu of a chain gang, sentence not to exceed twelve months: Provided, that the trial judge shall have the discretion also of sending any person convicted of a misdemeanor to the State Farm.

Sec. 230 (d). (Park's 1922 Supplement to Penal Code.)—Whoever unlawfully and intentionally injures or destroys, or permits to be injured or destroyed, any meter, pipe, conduit or other apparatus belonging to a company engaged in the manufacture or sale of gas for heating or lighting purposes, or unlawfully and intentionally prevents any gas meter from duly registering the quantity of gas supplied, or in any way interferes with its proper action or just registration or, without the consent of such company, unlawfully and intentionally diverts the flow of gas from any pipe of such company, or otherwise unlawfully or intentionally uses or causes to be used, without the consent of such company, any gas manufactured or distributed by such company, shall for every such offense be punished as provided in section 1065 of this code.

Idaho Compiled Statutes 1919

Larceny

Sec. 8447.—Whoever shall, without permission or authority of any person, firm or corporation engaged in the generation or distribution of electricity, make connections, or cause connections to be made, by wire or wires or by any other device, with the wires, cables or conductors, or any of them, of any such person, firm or corporation, for the purpose of obtaining or diverting electric current from such wires, cables or conductors, or whoever shall, without permission or authority from any person, firm or corporation using any meter or meters erected or set up for the purpose of registering or recording the amount of electric current supplied to any customer of such person, firm or corporation within this State, connect or cause to be connected by wire or any other device, any such meter or meters, or change or shunt the wiring leading to or from any such meter or meters, or by any device or appliance or means whatsoever tamper with any such meter or meters in such manner that such meter or meters do not measure or record the full amount of electric current supplied to such customer, shall be guilty of a misdemeanor, and upon conviction thereof shall be punished by a fine not exceeding $300, or by imprisonment in the county jail for a term not exceeding six months, or by both such fine and imprisonment; provided, that nothing herein contained shall be deemed to affect the right of any person, firm or corporation to recover by action in any court of competent jurisdiction damages for any injury done by such unlawful acts. ('05, p. 72, sec. 1.)

Sec. 8448.—Any person or persons aiding, abetting or counseling the acts, or any of them, mentioned in the preceding section, shall, upon conviction thereof, be equally guilty with the principals and subject to the same penalties. ('05, p. 72, sec. 2.)

Sec. 8449.—In all prosecutions under the two preceding sections, proof that any of the acts herein forbidden were done on or about the premises owned or occupied by the defendant charged with the commission of such offense, or that he received the benefit of any such electric current on account of the commission of such acts, shall be prima facie evidence of the guilt of such defendant. ('05, p. 72, sec. 3.)

Ch.208, Idaho Session Laws 1921

Sec. 1.—Any person who, with intent to injure or defraud any company, corporation, copartnership or individual, authorized to manufacture, generate, sell or use illuminating or inflammable gas for lighting, heating or power purposes, shall injure, alter, obstruct or prevent the action of any meter, provided for the purpose of measuring the quantity of gas consumed by, or at, any burner, orifice or place, or supplied to any lamp, stove, range, furnace, machine, motor, appliance or contrivance, or who shall cause, or procure, or aid, the injuring or altering of any such meter or the obstruction or prevention of its action, or who shall make or cause to be made, with any pipe, tube or any appliance, any connection, so as to conduct or supply illuminating or inflammable gas to any burner, or orifice, or lamp, or stove, or range, or furnace, or motor, or other machine or appliance from which such gas may be consumed or utilized without passing through, or being registered by such meter, without the permission, consent or acquiescence of the company, corporation, copartnership, or individual, furnishing or transmitting such gas, or who shall knowingly use or utilize any such gas which has not passed through the meter provided for the registration of the consumption thereof, or who shall by any means, device, appliance or contrivance, knowingly use or utilize such gas for his own use, or for the use of another, with intent to evade payment thereof, shall be guilty of a misdemeanor, and upon conviction thereof shall be punished by a fine not exceeding three hundred dollars ($300), or by imprisonment in the county jail for a term not exceeding six months, or by both such fine and imprisonment.

Sec. 2.—Any such company, corporation, copartnership or individual, authorized to manufacture, generate, sell or use illuminating or inflammable gas, who shall have probable cause to believe that any person, firm, company, copartnership or corporation is violating the provisions of this act, shall, upon making the affidavit required in, and complying with all the provisions of Chapter 332, of Title 61, of the Compiled Statutes, be entitled to have a search warrant issued to it and served in the manner provided in said Chapter 332, of Title 61.

Sec. 3.—Nothing herein contained shall be deemed to affect the right of any company, corporation, copartnership, firm or individual, to recover by civil action, in any court of competent jurisdiction, the reasonable value of such gas used, or damages for any injury done by such unlawful acts.

Illinois (Cahill) Revised Statutes 1927

Chapter 38—Criminal Code

Par. 279.—Any person who, with intent to injure or defraud any company, body corporate, copartnership or individual, shall injure, alter, obstruct or prevent the action of any meter provided for the purpose of measuring and registering the quantity of gas, water or electric current consumed by or at any burner, orifice or place, or supplied to any lamp, motor, machine or appliance, or shall cause or produce or aid the injuring or altering of any such meter, or the obstruction or prevention of its action, or shall make or cause to be made with any gas pipe, water pipe or electrical conductor any connection so as to conduct or supply illumination or inflammable gas, water, or electric current to any burner or orifice, or lamp, or motor, or other machine or appliance from which such gas, water or electricity may be consumed or utilized without passing through or being registered by a meter or without the consent or acquiescence of the company, municipal corporation, body corporate, copartnership or individual furnishing or transmitting such gas, water or electric current through such gas pipe, water pipe or electrical conductor shall be punished by imprisonment not exceeding three (3) months, or a fine not exceeding two hundred and fifty dollars ($250), or both. (J. & A., par. 3698.)

In Woods vs. The People, 222 Ill. 293, 298, James Woods and Thomas Light were indicted for the crime of larceny, namely, the larceny of illuminating and natural gas from the Peoples Gas, Light & Coke Company. On the trial, Light was acquitted and Woods was convicted, the property taken having been found by the jury to exceed $15 in value, and he was sentenced to the penitentiary for an indeterminate period. Woods prosecuted a writ of error from the Supreme Court to reverse said judgment.

It appears from the evidence that the plaintiff in error was a dancing master, and from March, 1903, to December, 1904, conducted a dancing academy in a building located at 3947 Michigan Avenue, in the city of Chicago, which building was to be lighted and heated by gas furnished through meters located in said building under and by virtue of a contract between the plaintiff in error and said light and coke company; that at regular intervals during said period the plaintiff in error or his employees removed the meters and by rubber hose connections caused the gas to pass from the gas service pipes of said light and coke company in said building direct to the gas burners in said building, where it was ignited and burned by the plaintiff in error for illuminating and heating purposes without being registered, his scheme being to remove the meters and substitute the rubber hose connections each month immediately after the meter reader had visited said premises and read the meters, and to allow said rubber hose connections to remain in place for about twenty days, or until about ten days before the reader of meters would return to said building, when he would replace the meters and allow them to remain in position until the meter reader had read them, when he would again remove said meters and substitute the rubber hose connections therefor; that sometime prior to the 14th day of December, 1904, he substituted for the rubber hose connections a system of pipes which were concealed in the walls of the building and which connected the gas burners within the building with the regular service pipes of said light and coke company which entered said building, and which concealed pipes were fitted with a stopcock, which, when turned, prevented the gas flowing through the meters and caused the same to flow direct to the gas burner, where it was ignited and used for illuminating and heating purposes in said building. The larceny of plaintiff in error was discovered by the inspectors of the light and coke company on the evening of Dec. 14, 1904, at which time gas was passing through the concealed pipes in the wall to the burners in the building and being consumed in large quantities for illuminating and heating purposes without being registered. The plaintiff in error at that time admitted gas had been passing through said concealed pipes for three or four days prior to Dec. 14, and the evidence shows that the plaintiff in error had used gas for lighting and heating purposes in said building, admitted through the said rubber hose and without the same passing through the meters and being registered, for stated periods of about twenty days in each month from April, 1903, to December, 1904. There is, therefore, no question but that the plaintiff in error was properly convicted, if the taking of gas in the manner above described constitutes the crime of larceny and no reversible error was committed on the trial.

In affirming the judgment of the lower court, the Supreme Court said:

> The first contention made by plaintiff in error is, that the offense made out against him by the evidence falls within the special statutory crime created by section 117 of the Criminal Code (1 Starr & Cur. Stat.—2nd ed.—par. 234, chap. 58, p. 1288), and not under section 167 of the Criminal Code, which defines the crime of larceny, and that he should have been prosecuted for a violation of said section 117, and not for the crime of larceny. We do not agree with such contention. The law is well settled that gas used for illuminating and heating purposes may be the subject of larceny. (Commonwealth vs. Shaw, 4 Allen, 308; State vs. Wellman, 34 Minn. 221; Regina vs. White, 6 Cox C. C. 213.)
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> Section 117 of the statute above referred to does not undertake to punish a person who unlawfully abstracts gas from the pipes of a gas company, but that section of the statute was passed with a view to protect gas, water or electric meters from being tampered with or false connections being made with gas or water pipes or electrical conductors, so that gas, water or electricity might be consumed or utilized without passing through or being registered by a meter. The crime of larceny and the crime created by that section of the statute are therefore entirely separate and distinct offences, and the doctrine announced in Stoker vs. People, 114, Ill. 320, and kindred cases, relied upon by plaintiff in error, has no application to the case at bar. The plaintiff in error might have been guilty of a violation of said section 117 without obtaining any gas from said light and coke company. The two offences are not the same,

and the evidence which would support a conviction for a violation of same section 117 of the statute would not necessarily even tend to show the plaintiff in error guilty of larceny. The trial court did not, therefore, err in holding that the plaintiff in error was not entitled to his discharge on the ground that he was being prosecuted for the wrong offence.

It is next contended that, conceding the plaintiff in error was guilty of larceny, the evidence does not show him to be guilty of grand larceny, as it is said there is no evidence in the record that the value of the gas converted by him to his own use at any one time exceeded in value the sum of $15. The correctness of this contention depends upon whether the evidence shows the plaintiff in error to have been guilty of a continuing offence. If the gas abstracted on each day is a single and complete offence then the contention of the plaintiff in error would be correct, as the evidence failed to show that more than $15 worth of gas was consumed at 3947 Michigan Avenue during any one day while the plaintiff in error was in possession of said premises. On the contrary, however, if it be the law that all the gas which was consumed by the plaintiff in error during any one period while the service pipes of said light and coke company were connected with the burners in said building by said rubber hose or the concealed pipes should be treated as one continuous taking, then clearly the evidence shows the plaintiff in error to have been guilty of grand larceny. In Bishop on Criminal Law (vol. 2—7th ed.—p. 799) it is said: "Illuminating gas may be the subject of larceny; and the asportation is sufficient where the prisoner, receiving gas of a gas company, diverts some of it to his burners without its passing the meter to be measured, the means employed being to use a pipe running directly from the entrance to the exit pipe. While the pipe remains thus connected there is held to be one continuous taking."

It is finally contended that the court erred in directing the jury that in fixing the value of the gas stolen, if any, they should be guided by the selling price of the gas in question to consumers in the district in which the gas was abstracted, and not by the cost value of the material from which the gas was made. We are of the opinion the court did not err in so instructing the jury. The ordinary test of the value of property is the price it will command in the market if offered for sale, which in this case was the selling price of gas to consumers in the vicinity where the plaintiff in error wrongfully converted the gas of the light and coke company to his own use.

Indiana (Burns') Annotated Statutes 1926

Offenses Against Property

Sec. 2509.—Whoever, unlawfully and intentionally, injures or destroys, or permits to be injured or destroyed, any meter, pipe, conduit, wire, line, post, lamp or other apparatus belonging to a company engaged in the manufacture or sale of electricity for light, heat, power or other purposes; or whoever, unlawfully and intentionally, prevents an electric meter from duly registering the quantity of electricity supplied, or in any way interferes with its proper action or just registration; or whoever, without the consent of such company, unlawfully and intentionally diverts any electric current from any wire of such company, or otherwise unlawfully and intentionally uses or causes to be used, without the consent of such company, any electricity manufactured or distributed by such company, shall be deemed guilty of a misdemeanor, and, on conviction, shall, for every such offence, be punished by a fine not exceeding $100, or by imprisonment in the county jail not exceeding one year, or by both such fine and imprisonment.

Offenses Against Honest Dealing

Sec. 2971.—Whoever knowingly constructs, or uses or furnishes to gas consumers to be used, any false meter provided for measuring and registering the quantity of gas consumed by any person under a contract with any gas company, shall, on conviction, be fined not less than $10, nor more than $100.

Miscellaneous Offenses

Sec. 3011.—It is hereby declared to be unlawful for any person, in any manner whatever, to change, extend or alter, or cause to be changed, extended or altered, any service or other pipe or attachment of any kind connecting or through which natural or artificial gas is furnished from the gas mains or pipes of any person, company or corporation without first procuring from said person, company or corporation written permission to make such change, extension or alteration.

Sec. 3012.—It is hereby declared to be unlawful for any person to make, or cause to be made, any connection or reconnection, with the gas mains or service pipes of any person, company, or corporation, furnishing to consumers natural or artificial gas, or to turn on or off, or in any manner interfere with, any valve or stopcock, or other appliances belonging to such person, company or corporation, and connected with its service or other pipes, or to enlarge the orifice of mixers, or to use natural gas for heating purposes except through mixers, without first procuring from such person, company or corporation a written permit to turn on or off such stopcock or valve, or to make such connections or reconnection, or to enlarge the orifice of mixers, or to use gas for heating without mixers, or to interfere with the valves, stopcocks, or other appliances of such person, company or corporation, as the case may be.

Sec. 3015.—Any person violating any provision of this act shall, upon conviction, be fined in any sum not less than $5 nor more than $100 for such offence.

In State vs. Moore, 27 Ind. App. 83, 86-87, the defendant was prosecuted under Sections 2705 and 2706 of the Indiana laws, supra, on the charge of interfering with natural gas connections without first having procured a written permit to do so. He was acquitted, and the State appealed. In sustaining the appeal, the court said:

> The court instructed the jury that the defendant should not be convicted unless the jury believed that, in doing the acts charged, he acted with an evil intent, or intended to perform a wrongful act. And also that if the defendant executed to a company a gas and oil lease on his farm, and the company thereafter constructed a well thereon which produced gas in large quantities, and piped the gas therefrom to consumers without right to do so and in violation of the contract, and used gas for no other purpose, and was so using it at the time of the offence, the defendant had the legal right to turn off the gas from the line and prevent the wrongful use thereof by the company.
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> The maxim, "Actus non facit reum, nisi mens sit rea," cannot have a like application in all cases. It must be given a meaning with reference to the particular definitions of the crimes. The mens rea in manslaughter means a guilty mind, but it would be contradictory to say these words mean a guilty mind in a case of manslaughter by negligence—to say that the mere absence of mind is a guilty mind. It is evident the maxim cannot have a universal application, and that an act may be a crime without the element of intent.
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> It is a matter of common knowledge that natural gas is a dangerous agency, and of that fact courts take judicial notice. As such agency it is clear that its use may be made the subject of police regulation. The legislature, in the act in question, concluded, as it had the power to do, that the public safety and welfare required that the use of natural gas is a subject properly within legislative control. The act charged is not made a crime because of its moral turpitude or the criminal intent with which it was committed, but it is a prohibited act from motives of public policy. The statute makes the act charged unlawful. The doing of the act is a misdemeanor. The question is not whether he intended to perform a wrongful act. If he did the act without having the written permit, he violated the statute regardless of whether or not it was done with evil intent. If the agreement or lease introduced in evidence contained anything that might be construed as a

permit to appellee to interfere with the main under certain conditions, a different question would be presented. But the lease contains no such stipulation, nor anything that might be construed as such. If appellee had a contract that was being violated, a court would have granted relief. Appellee was charged with the voluntary commission of an act prohibited by a statute passed to subserve a public policy, and the voluntary doing of the act, regardless of his intent, constitutes the offence; State vs. Engle, 156 Ind. 339, and cases cited; Commonwealth vs. Raymond, 97 Mass. 567; State vs. Hartiel, 24 Wis. 60; Eagle vs. Nowline, 94 Fed. 646, See Barton vs. State, 99 Ind. 89; Tilford vs. State, 109 Ind. 359; Edwards vs. State, 121 Ind. 450.

The appeal is sustained.

In Gary Heat, Light & Water Co. vs. George Christ et al., P. U. R. 1921 C. 355, 358-359, the Indiana Public Service Commission said:

It would be an unjust discrimination to permit individual consumers, who have made separate contracts for service, to rearrange the service pipes so that two or more could receive gas through one meter.

The shifting of the meters in the manner disclosed by the evidence is a misdemeanor, which, under the statutes of Indiana, is punishable by a fine of not less than $5 nor more than $100. It is unlawful for any person, in any manner whatsoever to change, extend or alter, or cause to be changed, extended or altered any service or other pipe or attachment of any kind connecting or through which natural gas or artificial gas is furnished from the gas mains or pipes of any person, company or corporation, without first procuring from said person, firm, company or corporation written permission to make such change, extension or alteration. B. R. S. 1914, Sec. 2705.

The running of a service pipe from the premises of Christ to the premises of Apostoles Brothers, without the consent or authority of petitioner, in the manner disclosed by the evidence, is also a misdemeanor with the same penalty attaching. It is unlawful for any person to make, or cause to be made, any connection or reconnection, with the gas mains or service pipes of any person, company or corporation, furnishing to consumers natural or artificial gas, or to turn on or off, or in any manner interfere with any valve or stopcock, or other appliances belonging to such person, company or corporation, and connected with its service or other pipes, or to enlarge the orifice of mixers, or to use natural gas for heating purposes except through mixers, without first procuring from such person, company or corporation a written permit to turn on or off such stopcock or valve, or to make such connection or reconnection, or to enlarge the orifice of mixers, or to use gas for heating without mixers, or to interfere with the valves, stopcocks or other appliances of such person, company or corporation, as the case may be. B. R. S. 1914, Sec. 2706.

The prosecution of any person for a violation of either of the two above mentioned statutes is, of course, entirely beyond the jurisdiction of the commission.

Iowa Code 1927

Larceny

Sec. 13014.—If any person wilfully, and with intent to defraud, in any manner takes from the wires, pipes, meters, or any other apparatus of any electric motor, electric light, water, steam heating, or gas plant or works, any electric current, water, steam, steam heat, or gas, he shall be guilty of larceny and shall be punished accordingly.

Sec. 13006.—When the value of the property stolen exceeds $20, he shall be punished by imprisonment in the penitentiary not more than five years, or in the county jail not more than one year, or by fine of not more than $1,000, or by both such fine and imprisonment; when the value does not exceed $20, by fine not exceeding $100, or imprisonment in the county jail not exceeding thirty days.

Injuries to Internal Improvements and Common Carriers

Sec. 13120.—If any person maliciously injure, remove or destroy any electric railway or apparatus belonging thereto, or any bridge, rail or plank road; or place or cause to be placed, any obstruction on any electric railway, or on any such bridge, rail or plank road; or willfully obstruct or injure any public road or highway; or maliciously cut, burn, or in any way break down, injure or destroy any post or pole used in connection with any system of electric lighting, electric railway, or telephone or telegraph system or break down and destroy or injure and deface any electric light, telegraph or telephone instrument; or in any way cut, break or injure the wires of any apparatus belonging thereto; or shall willfully tap, cut, injure, break, disconnect, connect, make any connection with, or destroy any of the wires, mains, pipes, conduits, meters, or other apparatus belonging to, or attached to, the power plant or distributing system of any electric light plant, electric motor, gas plant or water plant; or shall aid or abet any other person in so doing, he shall be imprisoned in the penitentiary not more than five years, or be fined not exceeding $500, or imprisoned in the county jail not more than one year, or by both such fine and imprisonment, at the discretion of the court.

Kansas Revised Statutes Annotated 1923

Telegraph, Telephone and Transmission Lines

Sec. 17-1908.—Any person who shall unlawfully and willfully cut, break, tap or make connection with any telegraph, telephone line or electric transmission line, wire or cable, shall be deemed guilty of a misdemeanor, and be punished by a fine not exceeding $500, or by imprisonment in the county jail not exceeding one year, or by both such fine and imprisonment. (L. 1921, Ch. 151, Sec. 2; May 25.)

Oil and Gas

Sec. 55-107.—That it shall be unlawful for any person to make or cause to be made any connection or reconnection with the gas mains or surface pipes of any person, company or corporation furnishing natural gas, or to turn on or off or in any manner interfere with any valve, stopcock or other appliance belonging to such person, company or corporation and connected with its surface or other pipes, or to alter or injure the orifice of mixers, or to use natural gas for heating purposes except through mixers, without first procuring from such person, company or corporation a written permit to turn on or off such stopcock or valve, or to make such connections or reconnections, or to alter or injure the orifice of mixers, or to interfere with the valves, stopcocks or other appliances of such person, company or corporation, as the case may be. (L. 1901, Ch. 224, Sec. 5; March 22.)

Sec. 55-109.—Any person violating any of the provisions of Sec. 5, 6 and 7 of this act shall be deemed guilty of a misdemeanor, and upon conviction shall be fined not less than $25 nor more than $100, and shall be liable to the said person, company or corporation whose property was so changed, injured, altered or destroyed, in a civil action for the amount of damages sustained, together with all the costs in the case. (L. 1901, Ch. 224, Sec. 8; March 22.)

Kentucky (Carroll's) Statutes 1922

Offenses Against Property

Sec. 1262a-1.—That any person who, without the consent of any person, firm, co-partnership or corporation engaged in the manufacture or distribution of electricity, shall unlawfully convert to his own use, from any wire of such person, firm, co-partnership or corporation any portion of such electric current or electricity, or who shall prevent such current, or any part thereof, from passing through any meter provided for measuring it by such person, firm. co-partnership or corporation, or who shall, in any manner prevent such meter from correctly registering the current passing through it, or shall aid, in any manner, in the unlawful conversion to his use or the use of another, of any portion of such electric current, shall be fined not less than $50 nor more than $500, or imprisoned not less than three months nor exceeding twelve months, or both so fined and imprisoned, in the discretion of the jury trying the case.

Sec. 1262a-2.—Any person who shall unlawfully and maliciously destroy, injure or otherwise interfere with any meter, pipe, conduit, wire, line, pole, lamp or other apparatus belonging to any person, firm, co-partnership, or corporation engaged in manufacturing and selling electricity, shall be punished by a fine of not less than $5 nor more than $500, or imprisoned not less than ten days nor more than one year, or both so fined and imprisoned, in the discretion of the jury.

Sec. 1262a-3.—Any person who shall have in his possession any machine, appliances or contrivance of any character, used or intended to be used to prevent a meter from correctly registering the electric current passing through such meter or for diverting the electric current that should pass through such meter, shall be punished by a fine of not less than $50 nor more than $500, or imprisoned not less than three months nor more than twelve months, or both so fined and imprisoned, in the discretion of the jury.

Sec. 1262a-4.—Anyone who shall knowingly accept and receive the use and benefit of a current of electricity diverted as provided for in Sec. 3 hereof, shall be guilty of a misdemeanor; and upon conviction shall be fined not less than $50 nor more than $500, or imprisoned in the county jail for not less than three months nor more than one year, or both so fined and imprisoned, in the discretion of the jury.

Sec. 1262a-5.—Any indictment shall be valid which charges any or all of the acts denounced in Sec. 1, 2, 3 and 4 hereof in one count, and all of said acts may be charged and embraced in a single count in an indictment. (This section is an act of March 22, 1902; the numbers of the sub-sections are the numbers of the act.)

Acts of the Legislature of the State of Louisiana for the Year of 1926

Damaging, Injuring, Defacing or Defrauding, Etc., of Gas and Electric Meters

Act. No. 116.—Making it unlawful to obtain for use, or to attempt to obtain for use, or to aid or to assist anyone in obtaining for use, or in attempting to obtain for use, electricity manufactured and held for sale or distribution, by persons, firms or corporations engaged in the manufacture, sale or distribution of electricity, without the consent of, and with intent to defraud such persons, firms or corporations, through the means and devices of diverting from the wires or cables of such persons, firms or corporations electricity manufactured, held for sale or distribution by such persons, firms, or corporations; or preventing the electric meter or meters furnished by such persons, firms or corporations from registering the quantity of electric current passing through such meter or meters, or from registering the correct amount of electricity used; of interfering with the proper action of just registration of such electric meter or meters; of preventing electric current from passing through such meter or meters; defining what shall be prima facie evidence of the provisions thereof; making the violations of the provisions of this act a misdemeanor and providing penalties therefor.

Sec. 1.—Be it enacted by the Legislature of Louisiana, That if any person or persons obtains for use and whoever aids or assists such person or persons in obtaining for use electricity manufactured, or held for sale or distribution by persons, firms or corporations engaged in the manufacture, sale or distribution of electricity with the intent to defraud them and without the consent of such persons, firms or corporations, by diverting the said electricity, by any means or device or devices, from the wires or cables of such persons, firms or corporations, the said person or persons so obtaining such electricity for use and anyone aiding or assisting in so obtaining for use such electricity, shall be deemed guilty of a misdemeanor, and upon conviction shall be punished by imprisonment in the Parish Prison for not less than thirty days nor more than six months.

Sec. 2.—That if any person or persons attempts to obtain for use, and whoever aids or assists such person or persons in attempting to obtain for use electricity manufactured, held for sale or distribution by persons, firms or corporations engaged in the manufacture, sale or distribution of electricity, without the consent of such persons, firms or corporations, and with intent to defraud such persons, firms and corporations by any means, or by any device or devices by which electricity is diverted from the wires or cables of such persons, firms or corporations, the said person or persons so attempting to obtain for use such electricity, and all those aiding or assisting therein, shall be deemed guilty of a misdemeanor, and upon conviction shall be punished by imprisonment in the Parish Prison for not less than ten days nor more than thirty days.

Sec. 3.—That if any person or persons obtains for use and whoever aids or assists such person or persons in obtaining for use electricity manufactured, or held for sale or distribution by persons, firms or corporations engaged in the manufacture, sale or distribution of electricity, without the consent of such persons, firms or corporations, and with the intent to defraud such persons, firms or corporations, through or by means of any device or devices that prevent electric current belonging to such persons, firms or corporations from passing through any meter or meters belonging to such persons, firms or corporations, and furnished to register the quantity of current of electricity passing through such meter or meters, or the amount used, such person or persons so obtaining for use such electricity, and anyone aiding and assisting therein, shall be guilty of a misdemeanor and upon conviction shall be punished by imprisonment of not less than ten days nor more than thirty days in the Parish Prison.

Sec. 4.—That if any person or persons obtains for use and whosoever aids or assists such person or persons in obtaining for use electricity manufactured by or held for sale or distribution by persons, firms or corporations engaged in the manufacture, sale or distribution of electricity without the consent of such persons, firms or corporations and with intent to defraud them, by or through any means or device that interferes with the proper action or just registration of any meter or meters belonging to such persons, firms or corporations and furnished to register the current of electricity passing through such meter or meters or the amount used, such person or persons shall be deemed guilty of a misdemeanor and upon conviction shall be punished by imprisonment of not less than ten days nor more than thirty days in the Parish Prison.

Sec. 5.—That if any person or persons attempts to obtain for use, and whoever aids or assists such person or persons in attempting to obtain for use electricity manufactured or held for sale or distribution by persons, firms or corporations engaged in the manufacture, sale or distribution of electricity without the consent of such persons, firms or corporations and with the intent to defraud such persons, firms or corporations, through or by means of any device or devices that prevent electric current belonging to such persons, firms or corporations from passing through any meter or meters belonging to such persons, firms or corporations, and furnished to register the quantity of current of electricity passing through such meter or meters, or the amount used, such person or persons so attempting to obtain for use such electricity, and anyone aiding and assisting therein, shall be deemed guilty of a misdemeanor, and upon conviction shall be punished by imprisonment of not less than ten days nor more than thirty days in the Parish Prison.

Sec. 6.—That if any person or persons attempting to obtain for use, and whoever aids or assists any person or persons in attempting to obtain for use electricity manufactured or held for sale or distribution by persons, firms or corporations engaged in the manufacture, sale or distribution of electricity without the consent of such persons, firms or corporations and with intent to defraud them, by or through any means or device that interferes with the proper action or just registration of any meter or meters belonging to such persons, firms or corporations and furnished to register the current of electricity passing through such meter or meters or the amount used, such person or persons and anyone aiding or assisting them, shall be deemed guilty of a misdemeanor and upon conviction shall be punished by imprisonment of not less than ten days nor more than thirty days in the Parish Prison.

Sec. 7.—That the presence at any time on or about such meter or meters, on or about such wire or cables, of any device or wire resulting in the diversion of electric current, or resulting in the prevention of the proper action of just registration of the meter or meters, as above set forth, or preventing the meter or meters from registering, shall constitute prima facie evidence of knowledge on behalf of the person or persons having custody or control of the place or room where such device or wire is located, of the existence thereof and the effect thereof, and shall constitute prima facie evidence of the intention of such person or persons to defraud and acting with consent and shall bring such person or persons prima facie within the scope, meaning and penalties of this Act.

Sec. 8.—That, if any clause, sentence, paragraph, or part of this act shall for any reason be adjudged by any court of competent jurisdiction to be invalid, such judgment shall not affect, impair or invalidate the remainder of this act, but shall be confined in its operation to the clause, sentence, paragraph, or any part thereof, directly involved in the controversy in which such judgment has been rendered.

Act No. 117.—Making it unlawful to obtain for use, or to attempt to obtain for use, or to aid or to assist anyone in obtaining for use gas manufactured, held for sale or distribution by persons, firms or corporations engaged in the manufacture, sale, or distribution of gas without the consent of, and with intent to defraud such persons, firms or corporations, through the means and devices of diverting from the pipes or mains of such persons, firms or corporations gas manufactured, held for sale or distribution by such persons, firms or corporations; of preventing the gas meter or meters furnished by such persons, firms or corporations from registering the quantity of gas passing through such meter or meters, or from registering the correct amount of gas used; of interfering with the proper action of just registration of such gas meter or meters; or preventing gas from passing through such meter or meters; defining what shall be prima facie evidence of the provisions thereof; making the violations of the provisions of this act a misdemeanor and providing penalties therefor.

Sec. 1.—Be it enacted by the Legislature of Louisiana, That if any person or persons obtains for use and whoever aids or assists such person or persons in obtaining for use gas manufactured, or held for sale or distribution by persons, firms or corporations engaged in the manufacture, sale or distribution of gas, with the intent to defraud them and without the consent of such persons, firms or corporations, by diverting the said gas, by any means or device or devices, from the pipes or mains of such persons, firms or corporations, the said person or persons so obtaining such gas for use and anyone aiding or assisting in so obtaining for use such gas, shall be deemed guilty of a misdemeanor and upon conviction shall be punished by imprisonment in the Parish Prison for not less than thirty days nor more than six months.

Sec. 2.—That if any person or persons attempts to obtain for use and whoever aids or assists such person or persons in attempting to obtain for use gas manufactured, held for sale or distribution by persons, firms or corporations engaged in the manufacture, sale or distribution of gas, without the consent of such persons, firms or corporations and with intent to defraud such persons, firms and corporations by any means, or by any device or devices, by which gas is diverted or could be diverted from the pipes or mains of such persons, firms or corporations the said person or persons so attempting to obtain for use such gas and all those aiding or assisting therein, shall be deemed guilty of a misdemeanor, and upon conviction shall be punished by imprisonment in the Parish Prison for not less than ten days nor more than thirty days.

Sec. 3.—That if any person or persons obtains for use and whoever aids or assists such person or persons in obtaining for use gas manufactured, or held for sale or distribution by persons, firms, or corporations, engaged in the manufacture, sale or distribution of gas, without the consent of such persons, firms or corporations and with the intent to defraud such persons, firms or corporations through or by means of any device or devices that prevents gas belonging to such persons, firms or corporations from passing through any meter or meters belonging to such persons, firms or corporations, and furnished to register the quantity of gas passing through such meter or meters, or the amount used, such person or persons so obtaining for use gas and anyone aiding and assisting therein shall be deemed guilty of a misdemeanor and upon conviction shall be punished by imprisonment of not less than ten days nor more than thirty days in the Parish Prison.

Sec. 4.—That if any person or persons obtains for use and whoever aids or assists such person or persons in obtaining for use gas manufactured by or held for sale or distribution by persons, firms or corporations engaged in the manufacture, sale or distribution of gas without the consent of such persons, firms or corporations and with intent to defraud them, by or through any means or device that interferes with the proper action or just registration of any meter or meters belonging to such persons, firms or corporations and furnished to register, the gas passing through such meter or meters or the amount used, such person or persons shall be deemed guilty of a misdemeanor and upon conviction shall be punished by imprisonment of not less than ten days nor more than thirty days in the Parish Prison.

Sec. 5.—That if any person or persons attempts to obtain for use and whoever aids or assists such person or persons in attempting to obtain for use gas manufactured or held for sale or distribution by persons, firms or corporations engaged in the manufacture, sale or distribution of gas without the consent of such persons, firms or corporations and with the intent to defraud such persons, firms or corporations, through or by means of any device or devices that prevents gas belonging to such persons, firms or corporations from passing through any meter or meters belonging to such persons, firms or corporations and furnished to register the quantity of gas passing through such meter or meters, or the amount used, such person or persons so attempting to obtain for use such gas and anyone aiding and assisting therein shall be deemed guilty of a misdemeanor and upon conviction shall be punished by imprisonment of not less than ten days nor more than thirty days in the Parish Prison.

Sec. 6.—That if any person or persons attempts to obtain for use and whoever aids or assists such person or persons in attempting to obtain for use gas manufactured by or held for sale or distribution by persons, firms or corporations engaged in the manufacture, sale or distribution of gas without the consent of such persons, firms or corporations and with intent to defraud them, by or through any means or device that interferes with the proper action or just registration of any meter or meters belonging to such persons, firms or corporations and furnished to register the gas passing through such meter or meters or the amount used, such person or persons and anyone aiding or assisting them shall be deemed guilty of a misdemeanor and upon conviction shall be punished by imprisonment of not less than ten days nor more than thirty days in the Parish Prison.

Sec. 7.—That the presence at any time on or about such meter or meters, on or about such pipes or mains or any device or wire resulting in the diversion of gas, or resulting in the prevention of the proper action or just registration of the meter or meters as above set forth or preventing the meter or meters from registering shall constitute prima facie evidence of knowledge on behalf of the person or persons having custody or control of the place or room where such device or wire is located, of the existence thereof and the effect thereof and shall constitute prima facie evidence of the intention of such person or persons to defraud and acting without consent, and shall bring such person or persons prima facie within the scope, meaning and penalties of this Act.

Sec. 8.—That, if any clause, sentence, paragraph, or part of this act shall for any reason be adjudged by any court of competent jurisdiction to be invalid, such judgment shall not affect, impair, or invalidate the remainder of this act, but shall be confined in its operation to the clause, sentence, paragraph, or any part thereof, directly involved in the controversy in which such judgment has been rendered.

Act No. 118.—Making it unlawful to willfully or intentionally injure or deface any electric meter; or any electric meter inclosing device; or any seals placed upon any electric meter or electric meter inclosing device; defining the terms "electric meter," and "electric meter inclosing device"; making any violation of the provisions of this act a misdemeanor and providing penalties therefor.

Sec. 1.—Be it enacted by the Legislature of Louisiana, That whoever shall willfully or intentionally injure or deface any electric meter, or any electric meter inclosing device, or any seals placed upon any electric meter or electric meter inclosing device, shall be deemed guilty of a misdmeanor and upon conviction shall be punished by a fine of not less than $10 nor more than $100, or by imprisonment for not less than ten days nor more than ninety days, or both.

Sec. 2.—The term "electric meter" as used in this act shall mean any instrument, contrivance, apparatus or machine belonging to any person, firm or corporation, engaged in the manufacturing, sale or distribution of electricity and furnished to register the quantity of electricity used by the user or consumer thereof. The term "electric meter inclosing device" as used in this act shall mean any instrument, contrivance or apparatus within which such electric meter may be placed or housed.

Act 119.—Making it unlawful to willfully or intentionally injure, or deface any gas meter, or any gas meter inclosing device; or any seals placed upon any gas meter or gas meter inclosing device. Defining the terms "gas meter," and "gas meter inclosing device"; making any violation of the provision of this act a misdemeanor and providing penalties therefor.

Sec. 1.—Be it enacted by the Legislature of Louisiana, That whoever shall willfully or intentionally injure or deface any gas meter, or any gas meter inclosing device, or any seals placed upon any gas meter or gas meter inclosing device, shall be deemed guilty of a misdemeanor and upon conviction shall be punished by a fine of not less than $10 nor more than $100, or by imprisonment for not less than ten days nor more than ninety days, or both.

Sec. 2.—The term "gas meter" as used in this act shall mean any instrument, contrivance, apparatus or machine belonging to any person, firm or corporation, engaged in the manufacturing, sale or distribution of gas and furnished to register the quantity of gas used by the user or consumer thereof. The term "gas meter inclosing device" as used in this act shall mean any instrument, contrivance or apparatus within which such gas meter may be placed or housed.

Maine Revised Statutes 1916

Chapter 129—Malicious Mischiefs and Trespasses

Sec. 11.—Whoever unlawfully and intentionally injures or destroys or suffers to be injured or destroyed any meter, pipe, conduit, wire, line, pole, lamp or other apparatus belonging to an individual, co-partnership or corporation engaged in the manufacture or sale of gas or electricity for lighting purposes or power purposes, or belonging to any water company, or unlawfully and intentionally prevents an electric, water or gas meter from duly registering the quantity of electricity, water or gas supplied, or in any way interferes with its proper action or just registration, or without the consent of such individual, co-partnership or corporation unlawfully and intentionally diverts any electric current from any wire of such individual, co-partnership or corporation, or otherwise unlawfully and intentionally uses or causes to be used without the consent of such individual, co-partnership or corporation any electricity manufactured or distributed by such individual, co-partnership or corporation, or unlawfully and intentionally and without the consent of such company taps, or interferes with the pipes or fixtures of any gas company, shall for every such offence be punished by a fine of not more than one hundred dollars, or by imprisonment for not more than one year, or by both such fine and imprisonment.

Maryland (Bagby) Annotated Code 1924

Article 27—Fraud—Upon Gas Companies

Sec. 179.—Any person who, with intent to injure or defraud any gas company, body corporate of this State, shall make, or cause to be made, any pipe, tube or other instrument or contrivance, or connect the same, or cause it to be connected, with any main service pipe or other pipe for conducting or supplying gas, in such manner as to connect with and be calculated to supply gas to any burner or orifice, by or at which gas is consumed, around or without passing through the meter provided for the measuring and registering of the quantity of gas there consumed, shall be deemed guilty of a misdemeanor, and, upon conviction thereof, shall be punished by imprisonment not exceeding six months, or by fine not exceeding $250, or both, in the discretion of the court. The existence of any pipe or tube connection or other instrument or contrivance, as aforesaid, permitting the use of gas furnished by any gas company, body corporate in this State, without it being measured or registered on a meter provided therefor by such gas company, shall be prima facie evidence of intent to violate and of the violation of this section by the person or persons who would receive the direct benefits from the use of the gas without it being measured or registered on a meter as aforesaid. (Amended, Laws 1927, c. 677.)

Sec. 180.—Any person who, with intent to injure or defraud any gas company, body corporate of this State, shall wilfully injure, alter or obstruct, or prevent the action of any meter provided for the purpose of measuring and registering the quantity of gas consumed by or at any burner, orifice or place, or cause or procure any such meter to be injured or altered, or the action thereof to be obstructed or prevented, shall be deemed guilty of a misdemeanor, and, upon conviction thereof, shall be punished by imprisonment not exceeding six months, or by fine not exceeding $250, or both, in the discretion of the court. The existence of any injury or alteration of such meter which obstructs or prevents the action thereof as aforesaid, shall be prima facie evidence of intent to violate and of the violation of this section by the person or persons who would receive the direct benefits from the use of gas passing through such injured or altered meter. (Amended, Laws 1927, c. 677.)

Fraud Upon Electric Companies, and Damaging, Interfering, or Tampering with the Property of Such Companies

Sec. 180-a.—It shall be unlawful for any person or persons to wilfully connect or disconnect any electrical conductors belonging to any company using or engaged in the manufacture and supply of electric currents for purposes of light, heat and power or either of them, or to make any connection with any such electrical conductors for the purpose of using or wasting the electric current, or to in anywise tamper with any meter used to register current consumed, or to interfere with the operation of any dynamo or other electrical appliance of such company, or to tamper with or interfere with the poles, wires or conduits used by such companies, unless such person or persons shall be duly authorized by or be in the employ of such company; provided, that nothing in this section shall in any way interfere with any lawful supervision and control of electric light and power companies, their electric conductors, appliances, machinery and poles by the municipality within which such companies are doing business, or by the officers of such municipality, nor shall anything in this section interfere with any right now existing in the councils of any municipality to pass ordinances relating to and regulating such electric light and power companies. Any person or persons found guilty of a violation of any of the provisions of this section shall be deemed guilty of a misdemeanor, and shall, upon conviction thereof, be imprisoned not exceeding six months or fined not exceeding $500, or both or either, in the discretion of the court. The existence of any connection, wire, conductor, meter alteration, or any device whatsoever which effects the diversion of electric current without the same being measured or registered by or on a meter installed by any company engaged in the manufacture and supply of electric current for the purposes of light, heat and power, or either of them, or the use of electric current furnished by such company, without it being measured or registered on a meter provided therefor by such company, shall be prima facie evidence of intent to violate and of the violation of this section by the person or persons using or receiving the direct benefits from the use of electric current passing through such connection, wire, conductor, device or altered meter, or being used without being measured or registered on a meter as aforesaid, and in case a check or test meter installed or employed by such company shows that a customer is using a larger amount of electricity than is registered on the meter installed by the company on the customer's premises for the purpose of registering the electricity used by customer, such condition shall constitute prima facie evidence that the unregistered current has been wrongfully diverted by such customer, and shall further constitute prima facie evidence of the intent to violate and of the violation of this section. (Added Laws 1927, c. 677.)

Massachusetts General Laws of 1921

Chapter 164—*Manufacture and Sale of Gas and Electricity*

Sec. 126.—Whoever willfully or fraudulently injures, disconnects, removes or otherwise interferes with, or suffers to be injured, disconnected, removed or otherwise interfered with, any meter, pipes or fitting belonging to a gas company, or prevents a meter from duly registering the quantity of gas supplied through the same, or in any way hinders or interferes with its proper action or just registration, or fraudulently burns or wastes the gas of such company, or whoever attaches a pipe or any appliance to a main or pipe belonging to a gas company or, without the written consent of such company, uses or causes to be used any gas supplied by it, unless the same passes through a meter set by the company, shall be punished by a fine of not more than one hundred dollars or by imprisonment for not more than one year, or both.

Sec. 127.—Whoever unlawfully and intentionally injures or destroys, or suffers to be injured or destroyed, any meter, pipe, conduit, wire, line, pole, lamp or other apparatus belonging to a corporation engaged in the manufacture or sale of electricity or unlawfully and intentionally prevents an electric meter from duly registering the quantity of electricity supplied, or in any way interferes with its proper action or just registration, or, without the consent of such corporation, unlawfully and intentionally diverts any electric current from any wire of such corporation, or otherwise unlawfully and intentionally uses or causes to be used, without the consent of such corporation, any electricity manufactured or distributed by it shall be punished by a fine of not more than $100 or by imprisonment for not more than one year, or both.

In Commonwealth vs. Caroline Shaw, 86 Mass. (4 Allen) 308-309-310, the defendant was indicted for the larceny of several hundred "cubic feet of illuminating gas, each cubic foot being of the value of three mills, of the property, goods and chattels of the Boston Gas Light Co." The gas company, upon the non-payment by the defendant of the gas rates, removed the meter and shut off the gas by closing a stopcock in the service pipe, upon the premises occupied by her and gave her notice thereof; after which she, without the consent or knowledge of the company, and to avoid paying for the gas, made a connection by means of a lead pipe between the service pipe and the pipe inside the house occupied by the defendant, and turned the cock in the service pipe, and received and consumed gas belonging to the company. In affirming a verdict of guilty by a jury, the court said:

> There is nothing in the nature of gas used for illuminating purposes which renders it incapable of being feloniously taken and carried away. It is a valuable article of merchandise bought and sold like other personal property, susceptible of being severed from a mass or larger quantity and of being transported from place to place. In the present case it appears that it was the property of the Boston Gas Light Company; that it was in their possession by being confined in conduits and tubes, which belonged to them, and that the defendant severed a portion of that which was in a pipe of the company by taking it into her house and there consuming it. All this, being proved to have been done by her secretly, and with an intent to deprive the company of their property, and to appropriate it to her own use, clearly constituted the crime of larceny.
>
> It was suggested by the counsel for the defendant that, if she was guilty of any offence, it was not larceny, but embezzlement, inasmuch as it appeared that the gas was intrusted to her possession by the Company, and that at the time of the alleged felonious taking she was the bailee thereof. But the facts proved entirely negative the existence of any such relation between her and the company. The gas was not in her possession. On the contrary, the pipe had been severed from the meter by closing a stopcock in the service pipe, which belonged to the company, for the very purpose of preventing her obtaining possession of it. The fact that the end of the pipe was on the premises occupied by her is wholly immaterial. It was not placed there to be in her custody or control, and she had no possession of it or its contents. The facts proved at the trial are similar to those which were shown to exist in the case of Regina vs. White, 6 Cox C. C. 213, in which a conviction of the defendant for the larceny of gas was affirmed by the court of criminal appeal. That case, however, was not so strong against the defendant as the present one, because it there appeared that the owners of the gas had not caused it to be shut off from the premises of the defendant, to prevent him from making use of it.

Michigan Compiled Laws 1915

Offenses Against Property

Sec. 15361.—Every person who wilfully or fraudulently injures, or suffers to be injured, any meter, wire, line, pipe or appliance belonging to any water, steam, electric or gas company, prevents any water, steam, electric or gas meter belonging to such company from duly registering the quantity of water, steam, electric current or gas measured through the same, or in any way hinders or interferes with its proper action or just registration, or attaches any line, wire or pipe to any line, wire, pipe or main belonging to such water, steam, electric or gas company, or otherwise uses or burns or causes to be burned or used any water, steam, electric current or gas supplied by such company, without the written consent of such company or its duly authorized agent, or officer, unless the same passes through a meter or is measured by a meter set by said company, or fraudulently uses its water, steam, electric current or gas, or wastes the same, shall, for every such offence, if the value of such water, steam, electric current, gas or damage so caused shall not exceed in value the sum of $25, upon conviction thereof, be punished by a fine not exceeding $100 or by imprisonment of not more than 90 days, or by both such fine and imprisonment in the discretion of the court, and if the value of such water, steam, electric current, gas or damage so caused, shall exceed in value the sum of $25, shall upon conviction thereof, be punished by a fine of not exceeding $1,000, or by imprisonment in the State prison for a term of not less than three months nor more than three years, or by both such fine and imprisonment in the discretion of the court: provided, that such criminal prosecution shall not in any way impair the right of such company to a full compensation in damages by civil suit.

Sec. 15362.—The provisions of this act shall extend to and apply to all offences against all water, steam, electric or gas companies and boards or municipalities owning or operating plants for producing, manufacturing, furnishing, transmitting or conducting water, steam, electricity or gas, either natural or artificial.

Sec. 15363—In all prosecutions under this act it shall be prima facie evidence on the part of the people of the violation of the provisions of this act, to show that the respondent other than a lessor had control of or occupied the premises where the offense was committed, or received the benefit of such water, steam, electric current or gas so used or consumed.

Minnesota General Statutes 1923

Injuries to Property

Sec. 10434—Every person who shall wilfully make any connection with any meter, pipe, conduit, wire, line or other apparatus belonging to any person, firm, company or municipality using, or engaged in the manufacture, supply, sales or distribution of electricity, electric current, gas, water or heat, for the purpose of taking, using or wasting such electricity, electric current, gas, water or heat, or shall wilfully prevent any meter from duly measuring or registering the quantity of such commodity supplied, or shall in any way interfere with its proper action or just registration, or shall without the consent of such person, municipality, firm or corporation, wilfully divert any such commodity of such person, municipality, firm or corporation, or in any way wilfully use or cause to be used without the consent of such person, municipality, firm or corporation, any such commodity manufactured or distributed by such person, municipality, firm or corporation, or shall aid, agree with, employ, or conspire with any other person to do any of the said acts, or who shall deposit in any meter or other apparatus used by an electric light or telephone company or other person, municipality, firm or corporation, for the pre-payment for current or service any token, article or device, except lawful coin of the United States, for the purpose of fraudulently obtaining such current or service, shall be guilty of a misdemeanor. (R. L. Sec. 5143, amended '07 c. 166, Sec. 1; L. 1927, c. 298.)

Sec. 9922.—Whoever is convicted of a misdemeanor for which no punishment is prescribed by any statute in force at the time of conviction and sentence shall be punished by imprisonment in the county jail for not more than three months or by a fine of not more than $100.

Hemingway's Annotated Mississippi Code 1927

Sec. 1046.—Whoever, intentionally, by any means or device, prevents electric current, water or gas from passing through any meter or meters belonging to any person, firm or corporation engaged in the manufacture, sale or distribution of electricity, water or gas for lighting, power or other purposes, furnished such persons to register current or electricity, water or gas, passing through meters, or intentionally prevents the meter from duly registering the quantity of electricity, water or gas supplied, or in any manner interferes with its proper action or just registration, or, without the consent of such person, firm or corporation, intentionally diverts any electrical current from any wire or cable, or water or gas from any pipe or main of such person, firm or corporation, or otherwise intentionally uses, or causes to be used, without the consent of such person, firm or corporation, any electricity or gas manufactured, or water produced or distributed by such person, firm or corporation or any person, firm or corporation who retains possession of, or refuses to deliver any meter or meters, lamp or lamps, or other appliances which may be, or may have been, loaned them by any person, firm or corporation for the purpose of furnishing electricity, water or gas, through the same, with the intent to defraud such person, firm or corporation, shall be guilty of a misdemeanor and upon conviction, shall be punished by a fine of not less than $10 and not more than $100, or by imprisonment in the county jail not more than three months, or by both fine and imprisonment in the discretion of the court.

Missouri Revised Statutes 1919, Vol. 1

Offenses Against Property

Sec. 3354—That any person who shall make a connection of any pipe, tube or device to any gas service pipe or main used to carry gas to a gas meter by any gas company furnishing gas for public or private use; or shall efface, puncture, move, remove, reverse or alter any gas meter or the connection thereof, owned or used by such gas company; or shall prevent any such gas meter from properly measuring or registering gas; or shall knowingly take, receive, use or convert to his own use or the use of another any gas which has not been measured; or shall cause, procure, permit, aid or abet any person to do any of the aforesaid acts, shall, upon conviction, be punished by imprisonment in the penitentiary for a term not exceeding two years or by fine not exceeding $500, or by both such fine and imprisonment. The existence of any of the aforesaid pipe connections or meter alterations, or the use of unmeasured gas, shall be prima facie evidence of intent to violate and of the violation of this section by the person or persons using or receiving the direct benefits from the use of the gas passing through such connections or meter, or being used unmeasured as aforesaid. (R. S. 1909, Sec. 4576, 4577, amended laws 1919, p. 260.)

Sec. 3355.—Any person who, without the consent of any person, firm or corporation engaged in the manufacture, distribution and sale of electricity, for public or private use, shall unlawfully and intentionally convert to his own use for the use of another party, from any wire or conductor of such person, firm or corporation, any portion of such electric current or electricity, or who shall unlawfully and intentionally prevent such current, or any portion thereof, from passing through any meter provided for measuring the same by such person, firm or corporation, or who shall in any manner, unlawfully and intentionally, prevent such meter from registering correctly the current passing through it, or aid in any manner the unlawful conversion to his use, or the use of another, of any portion of such electric current, shall be guilty of a misdemeanor, and shall, upon conviction, be punished by a fine of not less than $50 nor more than $500, or by imprisonment in the county jail for not less than three months nor more than twelve months, or by both such fine and imprisonment. (R. S. 1909, Sec. 4578.)

Sec. 3357—Anyone who shall knowingly accept or receive the use and benefit of electric current which should pass through a meter, but has been diverted therefrom, or which has been prevented from being correctly registered by a meter provided therefor, or which has been diverted from the wires or conductors of a person, firm or corporation producing electricity for public or private use, shall be guilty of a misdemeanor. The presence at any time, on or about such meter or meters, wires or conductors of any device whatsoever, which affects the diversion of electric current without the same being measured or registered by the person, firm or corporation producing the same, shall constitute prima facie evidence of knowledge on the part of the person who, as owner or lessee or otherwise at the time, has the use, custody or control of the room or building where such device exists, of the existence thereof and the effect thereof, and shall further constitute prima facie evidence of the intention on the part of such person to defraud and shall bring such person prima facie within the scope, meaning and penalties as prescribed for a misdemeanor, and in case a check meter, installed by any person, firm or corporation vending electricity, registers more current than is registered by the meter installed in a customer's premises, such condition shall constitute prima facie evidence that such unregistered current has been wrongfully diverted by such customer, and shall further constitute prima facie evidence of the intention on the part of such customer to defraud, and shall bring such person prima facie within the scope, meaning and penalties as prescribed for a misdemeanor. (R. S. 1909, Sec. 4580, amended laws 1919, p. 259.)

Montana Revised Codes, Penal, 1921

Larceny of Gas or Electricity

Sec. 11385.—Every person who, with intent to injure or defraud, procures, makes or causes to be made, any pipe, tube, wire or other conductor of gas or electricity, and connects the same, or causes it to be connected, with any main, service pipe or other pipe for connecting or supplying illuminating gas or any wires or other conductor of electricity to any lamp, motor, burner or orifice, by or at which illuminating gas or electricity is consumed, around or without passing through the meter provided for the measuring and registering the quantity consumed, or in any other manner so as to evade payment therefor, and every person who, with like intent, injures or alters any gas or electric meter, or obstructs its action, is guilty of a misdemeanor. In prosecution for offences under this section, proof that any of the acts herein forbidden have been done in, upon or about the premises owned or used by the defendant charged with the commission of such offence in such a manner as to decrease or lessen the amount he should pay under his understanding or contract with any person or corporation engaged in the business of furnishing and selling gas or electricity, shall be prima facie evidence of the guilt of said defendant.

Sec. 10725—Except in cases where a different punishment is prescribed by this code every offence declared to be a misdemeanor is punishable by imprisonment in a county jail not exceeding six months, or by a fine not exceeding $500, or both.

In State ex rel. Deeney vs. Butte Electric & Power Co., 43 Mont. 118, it was held to quote headnote:

Where the answer of defendant company in a proceeding in mandamus to compel it to furnish electricity to relator, failed to allege that it also had a gas franchise, a rule that it would not furnish electricity to one who had stolen gas from its mains until all reasonable bills therefor had been paid was not one which it had a right under its electricity franchise to adopt in protection of its gas business and was therefore no defense to its refusal to supply relator with electric light.

Nebraska Compiled Statutes 1922

(As amended by Chapter 86, Laws of 1923)

Sec. 7116.—Any person who connects any wire, cord, socket, motor, pipe, conduit or other instrument, device or contrivance with any wire transmitting or supplying or intending to transmit or supply electricity, electric current, or connects any pipe or conduit supplying gas or water, without the knowledge and consent of the person, partnership, corporation or company furnishing the electricity or electric current transmitted or supplied by said wire, or gas or water supplied by said pipe or conduit, in such manner that any portion of such electricity, electric current, gas or water may be transmitted or supplied to any globe, lamp, heating apparatus, motor or other instrument, by or at which electricity, electric current, gas or water may be consumed, shall be deemed guilty of a misdemeanor, and, upon conviction, shall be punished as provided in the fourth following section.

Sec. 7117.—Any person who connects or changes any wire, cord, socket, motor, pipe, conduit or other instrument, device or contrivance with any wire, pipe or conduit transmitting or supplying or intended to transmit or supply electricity, electric current, gas or water, without the knowledge and consent of the person, partnership, corporation or company furnishing the electricity, electric current, gas or water transmitted or supplied by said wire, pipe or conduit, in such manner as to transmit or supply any such electricity, electric current, gas or water to any globe, lamp, heating apparatus, motor or other instrument by or at which electricity, electric current, gas or water may be consumed without passing through the meter provided for measuring or registering the amount or quantity of electricity, gas or water passing through it, shall be deemed guilty of a misdemeanor, and upon conviction shall be punished as provided in the third following section.

Sec. 7118—Any person who wilfully injures, alters, or by any instrument, device or contrivance in any manner interferes with, or obstructs, the action or operation of any meter made or provided for measuring or registering the amount or quantity of electricity, gas or water passing through it, without the knowledge and consent of the person, partnership, corporation or company furnishing or supplying the electricity, electric current, gas or water passing or intended to pass through such meter, shall be deemed guilty of a misdemeanor, and upon conviction shall be punished as provided in the next but one following section.

Sec. 7119.—Any person who knowingly uses or who knowingly permits the use of any electricity, electric current, gas or water in any globe, electric motor, heating apparatus or other instrument or device by which electricity, gas or water may be consumed, owned, leased or used by such person, or by any partnership, company or corporation of which such person is a member, officer, representative or agent, when any portion or quantity of such electricity, electric current, gas or water passes through or along any line, cord, socket, motor, pipe, conduit or other instrument, device or contrivance which has been connected with any wire, pipe or conduit transmitting or supplying electricity, gas or water without the knowledge and consent of the person, partnership, corporation or company furnishing the electricity, electric current, gas or water transmitted or supplied by said wire, pipe or conduit, or when any portion or quantity of such electricity, electric current, gas or water passes around, or by, or through any meter provided for measuring or registering the amount or quantity thereof, without being so measured or registered by reason of such meter being changed, interfered with or obstructed without the knowledge and consent of the person, partnership, corporation or company furnishing the electricity, electric current, gas or water, passing or intended to pass through the meter, or by reason of some wire, cord, socket, motor, pipe, conduit or other instrument, device or contrivance having been connected with a transmitting or supplying wire, pipe or conduit, without the knowledge and consent of the person, partnership, corporation or company furnishing the electricity, electric current, gas or water transmitted or supplied by said wire, pipe or conduit, shall be deemed guilty of a misdemeanor, and upon convicton shall be punished as provided in the next following section.

Sec. 7120.—Any person convicted of a violation of any of the provisions of the four next preceding sections shall be punished for such offence by a fine of not less than $50 nor more than $300, or by imprisonment in the county jail for a period of not less than thirty days nor more than ninety days, or by both such fine and imprisonment.

Sec. 7121.—Proof of the existence of any wire, pipe or conduit connection, or of any injury, alteration or obstruction of a meter, as in the foregoing sections, provided, shall be taken as prima facie evidence of the guilt of the person in possession of the premises where such connection, injury, alteration or obstruction is proven to exist.

Nevada Revised Laws 1912

Crimes and Punishments

Sec. 6733—Every person who wilfully, and with intent to injure or defraud:

1. Opens, breaks into, taps or connects with any pipe, flume, ditch, conduit, reservoir, wire, meter or other apparatus belonging to or used by any water, gas, irrigation, electric or power company or corporation, or belonging to or used by any other person, persons or association, or by the State, or by any county, city, district or municipality, and takes and removes therefrom, or allows to be taken, removed or flow therefrom, any water, gas, electricity or power belonging to another; or,

2. Connects a pipe, tube, flume, conduit, wire or other instrument or appliance with any pipe, conduit, tube, flume, wire, line, pole, lamp, meter or other apparatus belonging to or used by any water, irrigation, gas, electric or power company or corporation, or belonging to or used by any other person, persons or association, in such manner as to take therefrom water, gas, electricity or power for any purpose or use, without passing through the meter, or instrument, or other means provided for registering the quantity consumed or used; or,

3. Destroys, detaches, disconnects, alters, injures or prevents the action of a head-gate, meter or other instrument or means used to measure or register the quantity of water, gas, electricity or power consumed or supplied; or,

4. Injures or destroys, or interferes with the efficiency or use, or suffers to be injured or destroyed, any pipe, conduit, flume. wire, pole, line, lamp, fixture, hydrant or other attachment or apparatus belonging to or used by any water, irrigation, gas, electric or power company or corporation, or belonging to and used by any other person, persons or association;

Is guilty of a misdemeanor, and, upon conviction thereof, shall be punished by a fine not exceeding $500, or by imprisonment in the county jail not to exceed six months, or by both such fine and imprisonment, in the discretion of the court; and shall, moreover, be liable to the person, persons, association or corporations, or the owner or user whose property is injured, in a sum equal to treble the amount of actual damages sustained thereby.

New Hampshire Public Laws, 1926

Chapter 355, *Sec.* 7

Whoever shall wantonly and maliciously injure or destroy, or cause to be injured or destroyed, any meter, pipe, conduit, wire, line, post, lamp or other apparatus belonging to a person or corporation engaged in the manufacture or sale of electricity, or shall wantonly and maliciously prevent an electric meter from duly registering the quantity of electricity supplied, or cause it to be done, or shall wantonly and maliciously interfere with its proper action or just registration, or without the consent of such person or corporation shall wantonly and maliciously divert electric current from any of their wires, or shall cause it to be done, or shall otherwise wantonly and maliciously use or cause to be used the electric current from such wire, shall, except as otherwise provided, be fined not more than $300 and shall pay treble damages to such person or corporation.

New Jersey Compiled Statutes 1709-1910

Crimes

Sec. 164.—Any person who shall, without permission, connect by wire or in any other manner with the wire or wires of an electric light or other electric company, or who shall, without permission, connect or disconnect the meters, pipes or conduits of any gas or water company, or in any other manner without such permission tamper or interfere with such meters, pipes or conduits, or who shall, without such permission, connect with the meter, pipes or conduits of such company by pipes, conduits or other instrument, for the purpose of obtaining power or electric current or gas or water with intent to defraud such company or companies, shall be guilty of a misdemeanor. (P. L. 1898, p. 839, as amended P. L. 1903, p. 388.)

Sec. 218.—Any person found guilty of any crime which by this or any other statute is declared to be a misdemeanor, shall be punished by a fine not exceeding $1,000, or by imprisonment, with or without hard labor as the court may direct, for any term not exceeding three years, or both. (P. L. 1898, p. 854.)

Sec. 164-a.—Whoever shall without permission or authority connect or cause to be connected by a wire or wires, or by any other device with the wires, cables or conductors of any electric company for the purpose of obtaining electric current for light, heat or power; or, whoever shall, without permission or authority, connect or cause to be connected by wires or other devices any meter or meters erected or set up for the purpose of registering or recording the amount of electric current supplied to any customer by any electric company within this State, or change or shunt the wiring leading to or from any such meter, or by any device, appliance or means whatsoever tamper with any such meter in such a manner that such meter or meters will not measure or record the full amount of electric current supplied to such customer shall be guilty of a misdemeanor, and on conviction thereof shall be punished by a fine not exceeding $500 or imprisonment at hard labor for any term not exceeding six months, or both; provided, that nothing herein contained shall be deemed to effect the right of any person or corporation to recover by an action at law damages for any injury done by such unlawful connection for the loss of electric power. (P. L. 1899, p. 210.)

In State v. Block, 70 N. J. L. 398, Block was convicted of a misdemeanor upon an indictment based upon the statute to punish persons who unlawfully obtain electric current. In sustaining the judgment the court held, to quote the headnote:

Upon the trial of an indictment under the act of March 22, 1899 (Pamph. L., p. 210), which charged the defendant with having unlawfully tampered with the meter of an electric light company which supplied him with electric light, thereby preventing the meter from recording or measuring the full amount of the current supplied to him, fixing the date of the offence Sept. 3, 1902, it was satisfactorily proven that on the day named the meter was found to have been tampered with by removing the seal and inserting a pin between the disk and magnets, so that although the current was passing to the lights which were burning, the disk did not rotate and cause the current to be recorded or measured, as it was its office to do; so that the only question left for the jury was as to whether the defendant had been connected with the tampering with the meter. The defendant offered to prove by the books of the company the amounts charged to him during the years 1901, 1902 and 1903 with the purpose of showing the absence of any discrepancy in the amount charged for the month during which the tampering occurred, and also for the purpose of effecting the credibility of a witness for the State. The offer was overruled by the trial judge. Held, on error, that the evidence offered, if relevant at all, bore so remotely upon the issues involved, that its admission or rejection was within the discretion of the trial judge, so that its rejection was no ground for reversal.

New Mexico Statutes Annotated 1915

Injuring Property

Sec. 1579.—Any person who shall willfully or maliciously affix, attach to, or connect with any electric power transmission line in the State of New Mexico any article or thing whereby leakage, or loss of electric current from said line shall or may be effected, and any person who shall willfully or maliciously by any means cause leakage or loss of electric current from any such power transmission line, shall be deemed guilty of a misdemeanor and, upon conviction thereof, shall be punished by a fine of not more than $100, or by imprisonment in the county jail not more than thirty days, or by both such fine and imprisonment.

New York Penal Law

Larceny

Sec. 1293-c.—Any person who shall operate or cause to be operated, or who shall attempt to operate or attempt to cause to be operated any automatic vending machine, slot machine, coin box telephone or other receptacle designed to receive lawful coin of the United States of America in connection with the sale, use or enjoyment of property or service, by means of a slug or of any false, counterfeited, mutilated or sweated coin, or by any means, method, trick or device whatsoever not lawfully authorized by the owner, lessee or licensee of such machine, coin box, telephone or receptacle; or who shall take, obtain or receive from or in connection with any automatic vending machine, slot machine, coin box telephone or other receptacle designed to receive lawful coin of the United States of America in connection with the sale, use or enjoyment of property or service, any goods, wares, merchandise, gas, electric current, article of value, or the use or enjoyment of any telephone or telegraph facilities or service, or of any musical instrument, phonograph or other property, without depositing in and surrendering to such machine, coin box telephone or receptacle, lawful coin to the amount required therefor by the owner, lessee or licensee of such machine, coin box telephone or receptacle, shall be guilty of a misdemeanor and punishable by imprisonment for not more than six months, or by a fine of not more than $250, or by both fine and imprisonment. (Added by L. 1916, ch. 367.)

Sec. 1431.—A person who willfully, with intent to injure or defraud:

1. Connects a tube, pipe, wire or other instrument or contrivance with a pipe or wire used for the conducting or supplying illuminating gas, fuel, natural gas or electricity in such a manner as to supply such gas or electricity to any burner, orifice, lamp or motor where the same is or can be burned or used without passing through the meter or instrument provided for registering the quantity consumed, or uses such gas or electricity obtained by reason of the making of such connection; or,

2. Obstructs, alters, injures or prevents the action of a meter or other instrument used to measure or register the quantity of illuminating fuel, natural gas or electricity consumed in a house or apartment, or at an orifice or burner, lamp or motor, or by a consumer or other person or a person other than a State inspector or deputy inspector of gas meters or an employee of the company owning any gas or electric meter, who willfully shall detach or disconnect such meter, or make or report any test of, or examine for the purpose of testing any such meter so detached, or disconnected; or,

3. In any manner whatever changes, extends or alters any service or other pipe, wire or attachment of any kind, connecting or through which natural or artificial gas or electricity is furnished from the gas mains or pipes or wires of any person, company or corporation without first procuring from said person, company or corporation written permission to make such change, extension or alterations, or uses gas or electricity obtained by reason of such changes, extensions or alterations without first procuring the written permission aforesaid; or,

4. Makes any connection or re-connection with the gas mains, service pipes or wires of any person, company or corporation furnishing to consumers natural or artificial gas or electricity; or turns on or off or in any manner interferes with any valve or stopcock or other appliances belonging to such person, company or corporation, and connected with its service or other pipes or wires, or enlarges the orifice of mixers, or uses natural gas for heating purposes except through mixers, or uses electricity or artificial gas for any purpose before it has passed through an instrument for measuring the quantity consumed, without first procuring from such person, company or corporation a written permit to turn on or off such stopcock or valve, or to make such connections or re-connections or to enlarge the orifice of mixers or to use for heating purposes without mixers, or to interfere with the valves, stopcocks, wires or other appliances of such person, company or corporation as the case may be; or,

5. Retains possession of or refuses to deliver any mixer or mixers, meter or meters, lamp or lamps or other appliances which may be or may have been loaned or rented to them by any person, company or corporation for the purpose of furnishing gas, electricity or power through the same, or who sells, loans or in any manner disposes of the same to any person or persons other than the said person, company or corporation entitled to the possession of the same; or,

6. Sets on fire any gas escaping from wells, broken or leaking mains, pipes, valves or other appliances used by any person, company or corporation in conveying gas to consumers, or interferes in any manner with the wells, pipes, mains, gate-boxes, valves, stopcocks, wires, cables, conduits, or any other appliances, machinery or property of any person, company or corporation engaged in furnishing gas to consumers unless employed by or acting under the authority and direction of such person, company or corporation; or,

7. Opens or causes to be opened or re-connects or causes to be re-connected any valve lawfully closed or disconnected by a district steam corporation; or,

8. Turns on steam or causes it to be turned on, or to reenter any premises when the same has been lawfully stopped from entering such premises, is guilty of a misdemeanor.

Sec. 1431-a.—The existence of any of the conditions with reference to meters, or attachments described in Sec. 1431 of this article is presumptive evidence that the person to whom gas, electricity, water or steam is at the time being furnished by or through such meters or attachments has, with intent to defraud created or caused to be created with reference to such meters or attachments, the condition so existing. (Added L. 1926, ch. 849.)

Sec. 1937.—A person convicted of a crime declared to be a misdemeanor, for which no other punishment is specially prescribed by this chapter, or by any other statutory provision in force at the time of the conviction and sentence, is punishable by imprisonment in a penitentiary or county jail for not more than one year, or by a fine of not more than $500, or by both.

In the People vs. Wilber, 4 Parker (N. Y.) Criminal Reports 19, it was held to quote the head notes:

In the indictment under the first section of chapter 109 of the Laws of 1854, entitled, "An Act for the protection of gas light companies," it is not sufficient to charge the act complained of in the words of the statute.

The relations of the party, whom it is alleged the defendant intended to defraud, to the means by which the fraud is sought to be perpetrated, must be alleged, so that the court can judicially see that the act complained of is calculated, as well as intended, to defraud; and where an indictment alleged, in the words of the statute, that the defendant connected certain pipes, etc., with intent to defraud a gas company, and contained no allegation, that the company supplied the gas consumed at the burners; held that the indictment was defective.

Whether the bare mention of the name of a gas company in an indictment, necessarily implies an allegation of its corporate existence; *cuere*.

The general rules of pleading, and the exceptions thereto, as applicable to an indictment under this statute, and what such an indictment should contain, discussed and stated.

North Carolina Code 1927

Interfering with Gas and Electric Appliances

Sec. 4323.—If any person shall willfully, with intent to injure or defraud, commit any of the acts set forth in the following subsections, he shall be guilty of a misdemeanor:

1. Connect a tube, pipe, wire or other instrument or contrivance with a pipe or wire used for conducting or supplying illuminating gas, fuel, natural gas or electricity in such a manner as to supply such gas or electricity to any burner, orifice, lamp or motor where the same is or can be burned or used without passing through the meter or other instrument provided for registering the quantity consumed; or,

2. Obstruct, alter, injure or prevent the action of a meter or other instrument used to measure or register the quantity of illuminating fuel, natural gas or electricity consumed in a house or apartment, or at an orifice or burner, lamp or motor, or by a consumer or other person other than an employee of the company owning any gas or electric meter, who willfully shall detach or disconnect such meter, or make or report any test of, or examine for the purpose of testing any meter so detached or disconnected; or,

3. In any manner whatever change, extend or alter any service or other pipe, wire or attachment of any kind, connecting with or through which natural or artificial gas or electricity is furnished from the gas mains or pipes of any person, without first procuring from said person written permission to make such change, extension or alterations; or,

4. Make any connection or reconnection with the gas mains, service pipes or wires of any person, furnishing to consumers natural or artificial gas or electricity, or turn on or off or in any manner interfere with any valve or stopcock or other appliance belonging to such person, and connected with his service or other pipes or wires, or enlarge the orifice of mixers, or use natural gas for heating purposes except through mixers, or electricity for any purpose without first procuring from such person a written permit to turn on or off such stopcock or valve, or to make such connection or reconnections, or to enlarge the orifice of mixers, or to use for heating purposes without mixers, or to interfere with the valves, stopcocks, wires or other appliances of such, as the case may be; or,

5. Retain possession of or refuse to deliver any mixer, meter, lamp or other appliance which may be leased or rented by any person, for the purpose of furnishing gas, electricity or power through the same, or sell, lend or in any other manner dispose of the same to any person other than such person entitled to the possession of the same.

Sec. 4173.—All misdemeanors, where a specific punishment is not prescribed shall be punished as misdemeanors at common law; but if the offense be infamous, or done in secrecy and malice, or with deceit and intent to defraud, the offender shall be punished by imprisonment in the county jail or State prison for not less than four months nor more than ten years, or shall be fined.

North Dakota Compiled Laws 1913

Larceny

Sec. 9927.—Every person who, with intent to defraud, makes, or causes to be made, any pipe or other instrument or contrivance, and connects the same, or causes it to be connected, with any pipe laid for illuminating gas, so as to conduct gas to a point where the same may be consumed without its passing through the meter provided for registering the quantity consumed, or in any other manner so as to evade paying therefor, and every person who with like intent injures or alters any gas meter or obstructs its action, is guilty of a misdemeanor. (R. C. 1905, Sec. 9200; Pen. C. 1877, Sec. 594; R. C. 1899, Sec. 7459.)

Fraudulently Using Electric Current

Sec. 9942.—Every person who, with intent to defraud, makes or causes to be made, any wires or other instruments or contrivances or connection, and connects the same, or causes it to be connected, with any wire laid or strung for conducting electric current, so as to conduct or carry electric current to a point where the same may be consumed without its passing through the meter provided for registering the quantity consumed or in any manner to evade paying therefor, and every person who with like intent injures or alters any electric meter or any electrical appliance, instrument, wire or connection, or obstructs their action, is guilty of a misdemeanor. (1907, ch. 248.)

Sec. 9205.—Except in cases where a different punishment is prescribed by this code or by some existing provisions of law, every offence declared to be a misdemeanor is punishable by imprisonment in a county jail not exceeding one year, or by a fine not exceeding $500, or by both such fine and imprisonment. (R. C. 1905, Sec. 8542; Pen. C. 1877, Sec. 14; R. C. 1895, Sec. 6812.)

Throckmorton's Ohio General Code Annotated 1926

Gas Companies

Sec. 9337.—Every person who willfully or fraudulently injures, or suffers to be injured, a meter belonging to a gas company, or prevents a meter from duly registering the quantity of gas supplied through it, or hinders or interferes with its proper action or just registration, or attaches a pipe to a main or pipe belonging to such company, or otherwise burns or uses or causes to be used gas supplied by such company, without the written consent of an officer thereof, unless it passes through a meter set by the company; or fraudulently burns the gas of the company, or wastes it, for every such act shall forfeit and pay to the company not more than $100, to be recovered in an action brought by it against such offender, and in addition thereto pay the company the amount of damage by it sustained by reason of such injury, prevention, waste, consumption or hindrance. (R. S. Sec. 3560.)

Offenses Pertaining to Property

Sec. 12507.—Whoever willfully or maliciously injures or destroys or intentionally permits to be injured or destroyed, disconnects, displaces, cuts, breaks, taps, grounds, or makes a connection with, or willfully or maliciously interferes with any pole, pier, cable, tower, wire, legally erected, put or strung, electrical apparatus, appliances or machinery used in the construction or operation of an electrical railway, electric light plant, plant used in generating or transmitting electricity, or any meter, pipe, conduit, wire, line, post, lamp, burner, heater, machine, motor or other appliance or apparatus, used in the construction or operation of any such electrical railway or electrical plant, or willfully or maliciously prevents any electric meter used in the construction or operation of such electrical railway or electrical plant, from duly registering the quantity of electricity supplied, or interferes with the proper action or just registration by such meter, or alters the index in such meter, or, without the consent of the owner of such electrical railway or electrical plant, willfully or maliciously diverts electric current from any such wire or otherwise willfully or maliciously uses or causes to be used without the consent of the owner of such electrical railway or electrical plant, electricity manufactured or distributed by any such electrical railway or electrical plant, shall be fined not less than $50 nor more than $1,000, or imprisoned not less than thirty days nor more than one year, or both. (R. S. Sec. 3467a.)

Sec. 12508.—Whoever, having in his possession or under his control a meter used in the construction or operation of an electrical railway, electric light plant, or plant used in generating or transmitting electricity, willfully permits any person unlawfully and without consent of the owner of such meter to disconnect, change, alter or interfere with the wires running into such meter so as to divert current and prevent such meter from duly registering the quantity of electricity supplied or willfully or maliciously aids, agrees with, employs or conspires with any person to do any of the aforementioned acts, shall be fined not less that $50 nor more than $1,000, or imprisoned not less than thirty days nor more than one year, or both. (R. S. Sec. 3467a.)

Sec. 12512.—Whoever, not the agent or employee for that purpose of the owner, manufacturer or operator thereof, maliciously opens, closes, adjusts or interferes with a valve, regulator, gauge, gate, disk, curb cock, stopcock, meter or other regulating, operating or measuring device or appliance in or attached to the wells, tanks, conduits, pipe-lines, mains, service-pipes, house-pipes, display-pipes or other pipes of a gas company, manufacturer or furnisher of gas with intent to cause the escape of gas or to injure or destroy such property, or maliciously enlarges or alters a mixer furnished or approved by a gas company, manufacturer or furnisher of gas to or for a consumer of gas, or maliciously removes from its connection a mixer so furnished or approved, or, without express permission first obtained, consumes for fuel the gas of a gas company, manufacturer or furnisher of gas without the use of a mixer so furnished or approved by such gas company, manufacturer or furnisher of gas, or taps, severs or opens a main or pipe used or intended for the transmission of gas or connects with such main or pipe any other main or pipe, shall be fined not less than $25 nor more than $300, or imprisoned not more than thirty days, or both. (88 v. 241, Sec. 1.)

Oklahoma Compiled Statutes Annotated 1921

Larceny

Sec. 2114.—Any person who, with intent to defraud, makes or causes to be made, any pipe or other instrument or contrivance, and connects the same, or causes it to be connected, with any pipe laid for conducting illuminating gas, so as to conduct gas to a point where the same may be consumed without its passing through the meter providing for registering the quantity consumed, or in any other manner so as to avoid paying therefor, and every person who, with like intent, injures or alters any gas meter, or obstructs its action, is guilty of a misdemeanor.

Sec. 1508.—Except in cases where a different punishment is prescribed by this chapter or by some existing provisions of law, every offence declared to be a misdemeanor is punishable by imprisonment in the county jail not exceeding one year or by a fine not exceeding $500, or by both such fine and imprisonment.

Oregon Laws 1920

Crimes Against Property

Sec. 1992.—Any person who willfully or maliciously with intent to injure or defraud:

1. Connects a tube, pipe, wire or other instrument or contrivance with a pipe or wire used for the conducting or supplying of illuminating gas or fuel or electricity in such a manner as to supply such gas or electricity to any burner, orifice, lamp or motor where the same is or can be burned or used, without passing through the meter or instrument provided for registering the quantity consumed; or,

2. Obstructs, alters, injures or prevents the action of a meter or other instrument used to measure or register the the quantity of illuminating gas or fuel or electricity consumed or used in a building, house, department or office, or at any orifice or burner, or lamp or motor, or by a lawful consumer; or any person other than a city official, inspector or deputy inspector, or an employee of the company owning any gas or electric meter, who willfully shall detach or disconnect such meter, or make or report any test, or examine for the purpose of testing any such meter so detached or disconnected; or,

3. In any manner whatever changes, extends or alters any service or other pipe, wire or attachment of any kind connecting or through which artificial gas or electricity is furnished from the gas mains or pipes or wires of any person, company or corporation, without procuring from said person, company or corporation written permission to make such change, extension or alteration; or,

4. Makes any connection or re-connection with the gas mains, service pipes or wires of any person, company or corporation furnishing to consumers gas or electricity, or turns on or off or in any manner interferes with any valve or stopcock or other appliances belonging to such person, company or corporation, and connected with its service or other pipes or wires, or uses electricity for any purpose without first procuring from such person, company or corporation a written permit to turn on or off such stopcock or valve, or to make such connections or re-connections, or to interfere with the valves, stopcocks, wires or other appliances of such person, company or corporation, as the case may be; or,

5. Retains possession of or refuses to deliver any meter or meters, lamp or lamps, or other appliances which may be or may have been loaned or rented to them by any person, company or corporation for the purpose of furnishing gas, electricity or power through the same, or who sells, loans or in any manner disposes of the same to any person or persons other than the said person, company or corporation entitled to the possession of the same; or,

6. Sets on fire any gas escaping from leaking mains, pipes, valves or other appliances used by any person, company or corporation in conveying gas to consumers, or interferes in any manner with the pipes, mains, gate boxes, valves, stopcocks, wires, cables, conduits or any other appliances, machinery or property of any person, company or corporation engaged in furnishing gas or electricity to consumers, unless employed by or acting under the authority or direction of such persons, company or corporation; or,

7. Without lawful authority displaces, removes, injures, interferes with, alters or destroys any lawfully connected line or lines of wire or cable, or any material, property or apparatus belonging thereto used for conducting or transmitting electricity, for any purpose whatsoever, or cuts, breaks, taps or makes connections with any such line or lines or wire or cable, or material, property or apparatus; or,

8. Breaks, injures, interferes with, alters or destroys any arc or incandescent lamps or their appurtenances, or any gas lamp lawfully used for lighting any street, road, public place or private place; or,

9. Aids, assists, agrees with, employs or conspires with any person or persons to do or causes to be done or permitted any of the acts hereinabove mentioned which by this act is made punishable, shall be punished by imprisonment in the county jail not less than thirty days nor more than one year, or by imprisonment in the penitentiary not less than six months nor more than two years, or by fine not less than $50 nor more than $500, or by both such imprisonment and fine.

Digest of Pennsylvania Statute Law 1920

Electric Light, Heat and Power Companies

Sec. 5867.—That it is hereby made unlawful for any person or persons to connect or disconnect any electrical conductors belonging to any company, using or engaged in the manufacture and supply of electric current for purposes of light, heat and power, or either of them, or to make any connection with any such electrical conductors for the purpose of using or wasting the electric current, or to in any wise tamper with any meter used to register current consumed, or to interfere with the operating of any dynamo or other electrical appliance of such company, or to tamper with or interfere with the poles, wires or conduits used by such companies, unless such person or persons shall be duly authorized by or be in the employ of such company. Provided, that nothing in this act shall in any way interfere with any lawful supervision and control of electric light and power companies, their electric conductors, appliances, machinery and poles by the municipality within which such companies are doing business, or by the officers of such municipality, nor shall anything in this act interfere with any right now existing in the councils of any municipality, to pass ordinances relating to and regulating such electric light and power companies. (1895, June 25; P. L. 302, Sec. 1.)

Sec. 5868.—That any person or persons found guilty of a violation of any of the provisions of Sec. 1 of this act shall be deemed guilty of a misdemeanor, and shall, upon conviction thereof, be imprisoned not exceeding one year, or fined not exceeding $1,000, or both, or either, at the discretion of the court. (1895, June 25; P. L. 302, Sec. 2.)

Sec. 5869.—Any person who injures or destroys, or permits to be injured or destroyed, any meter, pipe, conduit, wire, line, pole, lamp, motor, generator or other apparatus belonging to any company using, or engaged in the manufacture or sale of electricity for the purpose of light, heat and power, or either of them; or any person, who is a consumer or customer, who shall knowingly have in his possession or under his control an electric meter which has been tampered with, or prevented from duly registering the quantity of electricity supplied or consumed; or any person who shall in any way interfere, or permit any interference, with the proper action and just registration of any meter, or who shall, without the consent of such company or corporation, divert any electric current from any wire of such company; or otherwise to use or cause to be used, without the consent of such company, any electricity manufactured or supplied by such company, shall for every such offence be deemed guilty of a misdemeanor, and shall be, upon conviction thereof, imprisoned not exceeding six months, or fined not exceeding $100, or both or either, at the discretion of the court: Provided, that nothing in this act shall in any way interfere with any lawful supervision or control of electric light and power companies, their electric conductors, appliances, machinery and poles, by the municipality within which the said companies are doing business, or by the officers of such municipality nor shall anything in this act interfere with any right now existing in the councils of any municipality to pass ordinances relating to regulating such electric light and power companies. (1911, June 8; P. L. 716, Sec. 1.)

Gas and Water Companies

Sec. 5921.—Whoever, except the authorized agent or employee for the purpose of the owner, manufacturer or operator thereof, maliciously opens, closes or in any manner or to any extent adjusts or interferes with any valve, regulator, gage, gate, disk, curb cock, stopcock, meter or other regulating, operating or measuring device or appliance in or attached to the wells, tanks, conduits, pipe lines, mains, service pipes, house pipes, display pipes or other distributing pipes of any gas company, manufacturer or furnisher of gas, with the intent to cause the escape of any gas or to injure or destroy any of such property, or maliciously enlarges or alters any mixer, furnished or approved by any gas company, manufacturer or furnisher of gas, to or for a consumer of its, his or their gas, or maliciously removes from its connection any mixer so furnished or approved of, or puts on any mixer without express permission first obtained, or consumes for fuel or light the gas of any gas company, manufacturer or furnisher of gas, or taps, severs or opens any main or pipe used or intended for the transmission of gas, or connects with such main or pipe any other main or pipe, shall be deemed guilty of a misdemeanor, and upon conviction thereof be sentenced to pay a fine not exceeding $300 or undergo an imprisonment not exceeding three months, or both, or either, at the discretion of the court. (1895, June 26; P. L. 319, Sec. 1.)

Rhode Island General Laws of 1923

Offenses Against Private Property

Sec. 6109.—Every person who, with intent to injure or defraud any gas light company or any corporation supplying water in this State at a stipulated rate of payment, shall make or cause to be made any pipe, tube or other instrument or contrivance, and connect the same or cause the same to be connected with any main, service pipe or other pipe, appliance or appurtenance used for or in connection with the works or apparatus employed for conducting or supplying illuminating gas or water, in such manner as to be calculated to supply such gas or water to any burner, orifice, faucet or other outlet whatsoever, without such gas or water passing through a meter provided or used for measuring or registering the quantity thereof so passing through, or without the consent of said company or corporation to such connections aforesaid, or who shall otherwise use any such gas or water with the intent to defraud said company or corporation of payment therefor, shall be deemed guilty of a misdemeanor and shall be imprisoned not exceeding thirty days or be fined not exceeding $100.

Sec. 6110.—Every person or corporation who shall wilfully collect of any person or persons a larger sum for gas or water than appears to be due on inspection of the meter put in to regulate and register the same, or shall wilfully furnish a meter that shall not correctly register the quantity of gas or water so consumed, shall be fined not exceeding $500.

Sec. 6124.—Every person who, with intent to injure or defraud any person, persons, association or corporation generating, conducting, using or supplying the electric current, either for the purpose of his, its or their own business, or for the purpose of selling such electric current at a stipulated rate of payment, shall make or cause to be made, any wire or other instrument or contrivance and connect the same or cause the same to be connected with any electric wire, appliance, apparatus or appurtenance used for or in connection with the wires supplying such electric current, in such manner as to be calculated either to waste and dissipate such electric current or to supply such electric current to any lamp, burner, heater, machine, motor or other apparatus or appliance whatsoever, without such electric current passing through a meter provided by said person, persons, association or corporation, and used for registering the quantity thereof so passing through, or without the consent of said person, persons, association or corporation to such connections aforesaid, or who shall otherwise use any such electric current with the intent to defraud said person, persons, association or corporation of payment therefor, shall be deemed guilty of a misdemeanor, and shall be imprisoned not exceeding thirty days or be fined not exceeding $100.

South Carolina Code of Laws 1922, Criminal Laws

Offenses Against Property

Sec. 49 (21).—Any person who has no contract, agreement, license or permission with or from any person or corporation authorized to manufacture, sell or use electricity for the purpose of light, heat or power, or with or from any authorized agent of such person or corporation for the use of electrical current belonging to, or produced or furnished by, any such person or corporation, who shall wilfully withdraw, or cause to be withdrawn, in any manner, and appropriate such current from the wires of any such person or corporation, for his own use, or for the use of any other person or corporation, shall be guilty of a misdemeanor, and upon conviction thereof shall be punished by a fine not exceeding $100, or by imprisonment not exceeding thirty days, or by both such fine and imprisonment. And any person who shall aid, abet or assist such other person in such withdrawing and appropriating of such current from such wires to or for the use of such other person, or to or for the use of any other person or corporation, shall be guilty of a misdemeanor and shall, upon conviction, be punished in like manner.

Sec. 50 (22).—Any person who has no contract, agreement, license or permission with or from any person or corporation authorized to manufacture, sell or use gas for the purpose of light, heat or power, or with or from any authorized agent of such person or corporation, for the use of gas belonging to, or produced or furnished by, any such person or corporation, who shall wilfully withdraw, or cause to be withdrawn, in any manner and appropriate such gas from the pipes or conduits of any such person or corporation, for his own use, or for the use of any other person or corporation, shall be guilty of a misdemeanor, and upon conviction thereof shall be punished by a fine not exceeding $100, or by imprisonment not exceeding thirty days, or by both such fine and imprisonment. Any person who shall aid, abet or assist such other person in such withdrawing and appropriating of such gas from such pipes or conduits to or for the use of such other person, or to or for the use of any other person or corporation, shall be guilty of a misdemeanor and shall, upon conviction, be punished in like manner.

Sec. 51 (23).—Any person who has a contract, agreement, license or permission, oral or written with or from any person or corporation authorized to manufacture, sell or use gas for the purpose of light, heat or power, or with or from any authorized agent of same, for the use of the gas belonging to, or produced or furnished by, any such person or corporation, for certain specified purposes, who shall wilfully and intentionally withdraw, or cause to be withdrawn, in any manner and appropriate to his own use, or to the use of any other person or corporation, for purposes other than specified, shall be guilty of a misdemeanor and, upon conviction thereof, shall be punished as provided in Sec. 22 of this chapter. And any such person to whom such gas is furnished from or by means of a meter, who shall wilfully and with intention to cheat and defraud any of said persons or corporations, alter or interfere with such meter, or by any contrivance whatsoever withdraw or take off gas in any manner except through such meter, shall be guilty of a misdemeanor, and punished as provided in Sec. 22 of this Chapter.

Sec. 52 (24).—Any person who has a contract, agreement, license or permission, oral or written, with or from any person or corporation authorized to manufacture, sell or use electricity for the purpose of light, heat or power, or with or from any authorized agent of the same, for the use of the electrical current belonging to, or produced or furnished by, any such person or corporation, for certain specified purposes, who shall wilfully and intentionally withdraw, or cause to be withdrawn, in any manner, and appropriate to his own use, or to the use of any other person or corporation, for purposes other than those specified, shall be guilty of a misdemeanor and, upon conviction thereof, shall be punished as provided in Sec. 21 of this Chapter. And any such person to whom such electrical current is furnished from or by means of a meter, who shall wilfully and with intention to cheat and defraud any of said persons or corporation, alter or interfere with such meter, or by any contrivance whatsoever withdraw or take off electrical current in any manner except through such meter, shall be guilty of a misdemeanor, and be punished as provided in Sec. 21 of this Chapter.

South Dakota Revised Code 1919

Miscellaneous Crimes

Sec. 4396.—Any person who shall, without lawful authority, connect or cause to be connected, with any main or service pipe or conductor of any gas, water or electric company, private or municipal, any pipe, wire or other device for the purpose of obtaining gas, water or electrical current therefrom; or who shall, with intent to defraud, connect or cause to be connected, with any meter installed by such company for the purpose of registering the amount of gas, water or electricity supplied to any customer, any pipe, wire or other device, or disconnect, change or in any manner so interfere with any such meter or any pipe, wire or appliance connected therewith, as that such meter will not measure or register the full amount of gas, water or electricity supplied to any customer, shall be guilty of a misdemeanor and, upon conviction thereof, shall be punished by a fine of not exceeding $100 or by imprisonment in the county jail for not exceeding sixty days, or by both such fine and imprisonment.

Sec. 4397.—Nothing contained in the preceding section shall be deemed to affect the right of any such company or corporation to recover, by an action at law, for the loss of gas, water or electricity, or any injury caused by such unlawful connection.

Sec. 4398.—Any person employed to read meters who knowingly reports to his employer that any consumer of gas, water or electricity has used a greater quantity of gas, water or electricity than the amount actually used by said consumer, shall be punished by imprisonment in the county jail not exceeding three months, or by a fine not exceeding $250, or both; and any person who shall knowingly collect from any consumer of gas, water or electricity an amount greater than that actually used by such customer, shall be punished by a fine not exceeding $500.

Tennessee Annotated Code 1918

Trespasses on Property, and Malicious Mischief

Sec. 6506 (8).—It is a misdemeanor in any person wilfully to injure, remove or destroy any turnpike or plank road; or wilfully to cut, burn or in any way break down, injure or destroy any telegraph post, wires or other apparatus thereto belonging; or wilfully to injure, remove or destroy any gas fixture or other property of any gas company.

Sec. 6507.—Any person convicted of any of the foregoing offences enumerated in this article shall be punished by fine not less than $10 (where not otherwise provided).

Sec. 6507a1.—It shall be unlawful for any person, firm or corporation to tap off of, or use without authority, or to wilfully cut, break down or otherwise interrupt or interfere with the current, lines, poles or appliances of an electric light and power company, or any company engaged in furnishing light, heat or power by electricity. (1897. Ch. 102, Sec. 1.)

Sec. 6507a2.—Any such cutting, breaking down, interruption or interference shall be a misdemeanor, punishable by a fine of not less than $5 nor more than $50, or imprisonment in the county workhouse, if there be such, or in the county jail, if there be no workhouse in such county, for a period of not less than ten days nor more than twelve months, for each and every offence, or both, at the discretion of the court. (1897, Ch. 102, Sec. 2.)

Texas (Vernon's) Annotated Penal Code, 1926

Diverting from Meters

Art. 1056.—Whoever, intentionally, by any means or device, prevents electric current, water or gas from passing through any meter belonging to a person, corporation or company engaged in the manufacture or sale of electricity, water or gas for lighting, power or other purposes, furnished such person to register the current of electricity, water or gas, passing through meters, or intentionally prevents a meter from duly registering the quantity of electricity, water or gas supplied, or in any way, interferes with its proper action or just registration, or without the consent of such person, corporation or company, intentionally diverts any electric current from any wire, or water or gas from any pipe or pipes of such person, corporation or company, or otherwise intentionally uses, or causes to be used, without the consent of such person, corporation or company any electricity or gas manufactured, or water produced or distributed, by such person, corporation or company, or any person who retains possession of, or refuses to deliver, any meter, lamp, or other appliances which may be, or may have been loaned them by any person, corporation or company for the purpose of furnishing electricity, water or gas, through the same, with the intent to defraud such person, corporation or company, shall for every such offense be fined not less than $25 nor more than $100. The presence at any time, on or about any such meter, wire or pipe of any device or pipes or wires resulting in the diversion of electric current, water or gas, as above defined or resulting in the prevention of the proper action or just registration of the meter or meters, as above set forth, shall constitute prima facie evidence of knowledge on the part of the person having custody and control of the room or place where such device or pipe or wire is of the existence thereof, and the effect thereof and shall further constitute prima facie evidence of intention on the part of such person to defraud and shall bring such person prima facie within the scope, meaning and penalties of this article.

Utah Compiled Laws of 1917

Larceny

Sec. 8300.—Every person who, with intent to injure or defraud, makes or causes to be made any pipe, tube or other instrument, and connects the same, or causes it to be connected, with any main, service pipe or other pipe used for conducting or supplying any artificial or natural gas, in such manner as to supply such gas to any burner or orifice, by or at which such gas is consumed, around or without passing through the meter provided for the measuring and registering the quantity consumed, or in any other manner so as to evade payment therefor, and every person who, with like intent, injures or alters any gas meter, or obstructs its action is guilty of a misdemeanor.

Sec. 8301.—Every person who, with intent to injure or defraud, makes or causes to be made any connection by wire or other instrument with any cable or wire used for conducting or supplying electricity for power, lighting, heating or other purposes to any burner or orifice by or at which such electricity is used or consumed for lighting, heating, power or any other purpose, around or without passing through the meter provided for measuring and registering the quantity used or consumed, or in any other manner, so as to evade payment therefor, and every person who, with like intent, injures or alters any electric meter, or obstructs its action, is guilty of a misdemeanor.

Sec. 7905.—Except in cases where a different punishment is prescribed by law, every offence declared to be a misdemeanor is punishable by imprisonment in a county jail not exceeding six months, or by a fine in any sum less than $300, or by both. In all cases, where a corporation is convicted of an offence for the commission of which a natural person would be punishable as for a misdemeanor, and there is no other punishment prescribed by law, such corporation is punishable by a fine not exceeding $1,000.

In Morrison Pie Co. vs. Utah Power & Light Co., P. U. R. 1921 C. 191, it was held by the Utah Public Utilities Commission to quote the headnote:

A consumer whose meter had been so tampered with as to result in the registration of less current than actually consumed, was ordered to install such protection as should be necessary to prevent interference, upon penalty of discontinuance of service.

Vermont General Laws of 1917

Trespasses and Malicious Injuries

Sec. 6972.—A person who taps gas pipes with intent to take gas therefrom, or who connects pipes with such gas pipes so that gas may be used without passing through the meters for measurement, or who knowingly burns gas without measurement by gas meters, without the consent of the owner, shall be imprisoned not more than one year, or fined not more than $100, or both; and the owner of the gas may recover of the person so unlawfully tapping or connecting such pipes or using gas the actual damages, with costs, in an action of tort.

Sec. 6973.—A person who wilfully commits or causes to be committed an act with intent to injure a machine, apparatus or structure appertaining to the works of a person, firm, association or corporation engaged in manufacturing, selling or distributing electrical energy in this State, or whereby such works may be stopped, obstructed or injured, or who taps an electrical line of a person, firm, association or corporation so that electricity can be taken therefrom, or knowingly uses electricity taken from such line without the consent of such person, firm, association or corporation, shall be imprisoned not more than two years, or fined not more than $300, or both; and such person shall also be liable to such person, firm, association or corporation or to anyone injured for actual damages, with full costs, in an action of tort. Justices shall have concurrent jurisdiction with county, municipal and city courts of offences arising under this section. (Amended L. 1927, Act No. 129.)

Sec. 6974.—A person, other than an authorized agent or employee acting for the owner, manufacturer or operator thereof, who maliciously opens, closes, breaks into or in any manner adjusts or interferes with a meter, or other regulating or measuring device or appliance attached to or connected with wires, pipe lines, mains, service pipes or house pipes owned or used by a manufacturer or furnisher of electricity, gas or water, shall be imprisoned not more than three months or fined not more than $100, or both.

Virginia Code of 1924

Offenses Against Property

Sec. 4478.—Any person who shall unlawfully injure or destroy, or having the right to prevent it, shall permit to be injured or destroyed any meter, pipe, conduit, wire, line, post, lamp or other apparatus belonging to a city or town or to a company engaged in the manufacture or sale of electricity or gas for lighting or power purposes, or who shall unlawfully prevent an electric or gas meter from duly registering the quantity of electricity or gas supplied, or in any way unlawfully interfere with its proper action or just registration, or who shall without the consent of such company or city or town unlawfully divert any electric current from any wire of such company or city or town, or who shall otherwise unlawfully use or cause to be used without the consent of such company or city or town any electricity or gas manufactured or distributed by such company or city or town, shall be deemed guilty of a misdemeanor. (1897-8, p. 254.)

Sec. 4782.—A misdemeanor, for which no punishment or no maximum punishment is prescribed by statute, shall be punished by fine not exceeding $500 or confinement in jail not exceeding twelve months, or both, in the discretion of the jury or of the justice, or of the court trying the case without a jury. (Code 1887, Sec. 3902; 1902-3-4, p. 784.)

Washington (Remington's) Compiled Statutes 1922

Crime Against Property

Sec. 2657.—Every person who, with intent to injure or defraud, shall—

(1) Break or deface the seal of any gas, electric, steam or water meter; or,

(2) Obstruct, alter, injure or prevent the action of any meter or other instrument used to register or measure the quantity of gas, electricity, steam or water supplied to a consumer thereof, or,

(3) Make any connection by means of a wire, pipe, conduit or otherwise with any wire, main or pipe used for the delivery of gas, electricity, steam or water to a consumer thereof, in such manner as to take gas, electricity, steam or water from said wire, main or pipe without its passage through the meter or other instrument provided for registering the amount or quantity consumed; or use any gas, electricity, steam or water so obtained; or,

(4) make any connection or reconnection with such wire, main or pipe, or turn on or off, or in any manner interfere with any valve, stop-cock or other appliance connected therewith; or,

(5) Prevent by the erection of any device or construction, or by any other means, free access to any meter or other instrument for registering or measuring the amount of gas,

electricity, steam or water consumed, or interfere with, obstruct or prevent, by any means, the reading or inspection of such meter or instrument, by the person, company or corporation owning the same; or,

(6) Take or use any water from any irrigation flume, ditch or lateral, without the consent of the owners thereof, or open, close or interfere with any gate connected therewith;

Shall be guilty of a misdemeanor. (L. '09, p. 1018, Sec. 405.)

Sec. 2266—Every person convicted of a misdemeanor for which no punishment is prescribed by any statute in force at the time of conviction and sentence, shall be punished by imprisonment in the county jail for not more than ninety days, or by a fine of not more than $250. (L. '09, p. 894, Sec. 14.)

West Virginia Acts of 1923

Chapter 65

Sec. 1.—Every person who, with intent to injure or defraud, procures, makes, or causes to be made, any pipe, tube, wire, or other conductor of gas, water, or electric energy, and connects the same, or causes it to be connected, with any main, service pipe or other pipe for conducting or supplying gas, or water, or any wires or other conductor of electric energy, in such manner as to supply gas, water, or electric energy to any lamp, motor, burner, orifice, or any other device, by or at which gas, water or electric energy is consumed, around or without passing through the meter provided for the measuring and registering of the quantity of gas, water or electric energy consumed, or in any other manner so as to evade payment therefor, and every person who, with like intent, injures or alters any gas, water or electric meter, or obstructs its action, shall be guilty of a misdemeanor, and upon conviction thereof shall be punished by imprisonment in the county jail not exceeding twelve months, or by a fine not exceeding $1,000, or both, at the discretion of the court.

Sec. 2.—Every person who, with intent to injure or defraud, connects, or causes to be connected, any pipe, tube, wire, electrical conductor or other instrument with any main service pipe, or other pipe or conduit or flume for conducting water, or with any main service pipe, or other pipe or conduit for conducting gas, or with any main, service wires or other electric conductor, used for the purpose of conducting electric energy for light, heat or motive services, for the purpose of taking therefrom, water, gas or electric energy, without the knowledge of the owner thereof and with intent to evade payment therefor, shall be guilty of a misdemeanor, and, upon conviction thereof, shall be punished by imprisonment in the county jail not exceeding twelve months, or by a fine not exceeding $1,000, or both, at the discretion of the court. (Barnes' Annotated Statutes, Supp. 1925, c. 145, Sec. 37.)

Wisconsin Statutes 1927

Offenses Against Property

Sec. 343.33 (2).—Or any person who wilfully, with intent to cheat or defraud the buyer or seller of electric current, gas, water, or steam, shall make or cause to be made or aid in the making of any electric conductor, gas pipe, water pipe, steam pipe, or other instrument or contrivance, or any connection as to conduct or supply or intended to conduct or supply electric current, gas, water, or steam to any lamp or motor or machine or burner or orifice or appliance from which such electricity, gas, water, or steam may be consumed or utilized, without passing through or being registered by a meter; or any person who shall wilfully use a false meter for the measurement of electric current, gas, water, or steam in the buying or selling of the same; or who shall wilfully obstruct or interfere with the working of any meter used for such purposes, so as to cause or be intended to cause a false registration of the amount of electric current, water, gas, or steam consumed with the intent to cheat or defraud the seller or buyer of such electric current, gas, water, or steam, shall be punished by imprisonment in the county jail not more than one year or by a fine not exceeding $500; but in case the amount of damages occasioned by such cheat or fraud shall not exceed $20, he shall be punished by imprisonment in the county jail not more than three months or by fine not exceeding $100; and in computing the amount of damages occasioned, the value of such electric current, water, gas, or steam shall be the regular current price therefor, charged to the consumer by the seller thereof.

In Minkel vs. Wisconsin Gas & Electric Co., P. U. R. 1923 E, 732, the Wisconsin Railroad Commission held that it was not the proper tribunal to decide whether or not a gas consumer had interfered with the registration of a meter in violation of a penal statute, and, until declared otherwise by proper court proceedings, consumers must be presumed to be innocent of wrongdoing.

Wyoming Compiled Statutes Annotated 1920

Crimes Against Property

Sec. 7114.—Any person who connects any pipe or other conduit, device or contrivance with any gas main or lateral supply pipe, supplying or intended to supply gas to any house, store or other building, without the knowledge and consent of any person or corporation owning said gas main or lateral supply pipe, in such manner that any portion of such gas may be transmitted or supplied to any lamp burner, heating apparatus, engine or other instrument or thing by or at which gas is consumed or used, shall be deemed guilty of a misdemeanor and punished as provided in Sec. 7117 hereof. (L. 1911, c. 55, Sec. 1.)

Sec. 7115.—Any person who connects or changes any pipe or other conduit, device or contrivance with any gas main or lateral supply pipe, supplying or intended to supply gas to any house, store or other building, without the knowledge and consent of any person or corporation owning said gas main, or lateral supply pipe, in such manner that any portion of such gas may be transmitted or supplied to any lamp burner, heating apparatus, engine or other instrument or thing by or at which gas is consumed or used, around or without passing through the meter provided for measuring or registering the amount or quantity of gas passing through it, shall be deemed guilty of a misdemeanor and punished as provided in Sec. 7117 hereof. (L. 1911, c. 55, Sec. 2.)

Sec. 7116.—Any person who wilfully injures, alters, or by any instrument, device or contrivance in any manner interferes with or destroys the action or operation of any meter for measuring gas, or of the amount or quantity of gas passing through it without the knowledge or consent of the person or corporation owning the same, shall be deemed guilty of a misdemeanor and punished as provided in Sec. 7117 hereof. (L. 1911, c. 55, Sec. 3.)

Sec. 7117.—Any person convicted of a violation of any of the provisions of Sec. 7114 to 7116 shall be punished for each offence by a fine of not less than $50 nor more than $300, or by imprisonment in the county jail for a period of not less than thirty days or more than ninety days, or by both such fine and imprisonment. (L. 1911, c. 55, Sec. 4.)

Sec. 7118—Any person who connects or changes any wire, cord, socket, motor or other instrument, device or contrivance, with any wire transmitting or supplying, or intended to transmit or supply electricity to any house, store or other building, without the knowledge and consent of the person or corporation owning said wire, in such manner that any portion of such electricity may be transmitted or supplied to any globe, lamp, heating apparatus or other instrument by or at which electricity is consumed, shall be deemed guilty of a misdemeanor and punished as provided in Sec. 7121 hereof. (L. 1911, c. 59, Sec. 1.)

Sec. 7119.—Any person who connects or changes any wire, cord, socket, motor or other instrument, device or contrivance with any wire, transmitting or supplying or intended to transmit or supply electricity to any house, store or other building, without the knowledge and consent of the person or corporation owning said wire, in such manner as to transmit or supply any such electricity to any globe, lamp, heating apparatus or other instrument by or at which electricity is consumed, around or without passing through the meter provided for measuring or registering the amount or quantity of electricity passing through it, shall be deemed guilty of a misdemeanor and punished as provided in Sec. 7121 hereof. (L. 1911, c. 59, Sec. 2.)

Sec. 7120.—Any person who wilfully injures, alters or by any instrument, device or contrivance in any manner interferes with or obstructs the action or operation of any meter for measuring electricity, or the amount or quantity of electricity passing though it without the knowledge and consent of the person or corporation owning said meter, shall be deemed guilty of a misdemeanor and punished as provided in Sec. 7121 hereof. (L. 1911, c. 59, Sec. 3.)

Sec. 7121.—Any person convicted of a violation of any of the provisions of Sec. 7118 to 7120 shall be punished for each offence by a fine of not less than $50 nor more than $300, or by imprisonment in the county jail for a period of not less than thirty days, or more than ninety days, or by both such fine and imprisonment. (L. 1911, c. 59, Sec. 4.)

LOW TENSION METERING INSTALLATIONS

This serial report of the Meter Committee, Engineering National Section, N. E. L. A., presents the modern trend of low tension metering installation practice. Various schemes are discussed, and their advantages and disadvantages are pointed out.

General

The trend of modern installation practice is to provide metal inclosures for all service conductors and metering equipment between the electric company's mains and the load side of the meter. This is generally accomplished by inclosing the service wires in metal conduit installed so as to eliminate condulets and pull boxes, and inclosing the main switch, fuses, meter terminals, test facilities and connections in metal boxes or cabinets. The advantages of metal inclosures have become more generally recognized as they minimize accidental damage, make tampering more difficult, serve as a safety measure, and aid in the standardization of meter installations. These features have been determining factors in bringing about a more extended use of metal-inclosed equipment, particularly in the larger companies.

The use of service-entrance meter cabinets embodying the service switch, fuses, test facilities and meter mounting actually present an economic advantage in that no coordination of effort is required between the electrical contractor and the utility when making an electrical installation. The cabinet combines all the necessary component parts of the old style open wire installation.

In the initial development of service-entrance meter cabinets, one of the most difficult problems was to provide simple and economical devices for fitting meters of diversified types and shapes. Metal fittings and inclosures suitable for top-connected meters in general were not applicable to those having side connections, and metal cabinets made for the latter were not suitable for bottom-connected meters. These conditions contributed to the complications encountered in the design and production of cabinets of simple construction for fitting the various makes, types and kinds of meters. A large variety of ingenious adapting devices were consequently developed, many of which were protected by patents covering particular designs and methods of construction.

Developments in metering practice led to a general demand for a bottom-connected single-phase meter, and a result of its production was the elimination of the necessity for a large number of the adapting devices which have since become obsolete. This reduction in the number and kinds of fittings and devices to be manufactured aided in the progress of standardization.

Location of Service Fuses

Simplification in installation practice and improvements in methods of connecting small installations, especially those for residences, necessitated some modifications in service-entrance meter cabinet designs. In accordance with the practice of some utilities the service fuses must be under seal, inaccessible to the customer but accessible to authorized employees. Other utilities require cabinet construction which will permit the use of main fuses accessible to the customer. It is generally conceded that the most desirable construction does not permit the customer to have access to live parts on the service side of the meter.

Service fuses accessible to the customer may be arranged in several ways to comply with the requirements of utilities operating under different rulings of regulatory bodies or agencies. An acceptable design of installation embodying this feature consists of connecting the fuses ahead of the meter and arranging the service switch so as to entirely disconnect the fuses from the line and load, at which time the fuses become accessible to the customer. This method of connection protects the customer against contact with live parts and wires. The use of six-terminal, three-wire meters having the potential circuit connected to the line ahead of the fuses on three-wire circuits is a protection against tampering when this method of connection is employed.

Another installation practice is to connect the fuses, arranged so as to be open or in a box, ahead of the meter, making them accessible to the customer at all times. This arrangement, however, nullifies the chief advantage of the use of inclosed protected service to the meter and meter connection cabinet and makes tampering easier on account of the accessibility of live parts on the service side of the meter.

An alternative, where permitted by the National Electric Code and by local inspection authorities, is the use of accessible fuses on the load side of the meter only, using on the service side of the meter a sealed and inclosed switch which may be operated externally. With this method of connection there would be no advantage in the use of six-terminal three-wire meters, as the meter is connected ahead of the fuses. Protection to testers against possible short circuits may be provided by the use of fuses in the test leads.

In one arrangement of this nature the fuses are eliminated entirely from the service-entrance meter cabinet, and only the service switch is placed therein. The customer's fuses serve as a protection in case of overloads or short circuits.

Service-Entrance Cabinets

Thought and consideration has been given to the question of the elimination of duplicate equipment installed in conjunction with service-entrance cab-

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inets. This applies to cases where, in addition to the switch of the service-entrance cabinet, the customer provides a house switch and fuses, or in group installations, where an additional main switch is installed. Simplification in practice has been effected to some extent by regulatory rules which have permitted under certain conditions the elimination of the main service switch. The use of protective devices such as circuit breakers may result in changes in practice which may be somewhat different from the methods employed at present.

The simplification of service-entrance cabinet equipment has also resulted from the universal elimination of the neutral fuse and its accompanying switch blade. Where the neutral is grounded practically all cabinets now provide one fuse and one blade for 100 to 125-volt two-wire meters, and two fuses and two blades for three-wire circuits with a neutral strap or suitable means for disconnecting the neutral wire.

Standardization of Bases for Single-Phase Meters

The Meter Committee realized that much could be accomplished to reduce the diversity of requirements for meter cabinets by effecting such standardization in meter design, as base dimensions, terminal chamber construction and connections, as this would permit the use of the different kinds of meters interchangeably with a simply constructed service-entrance meter cabinet equipment.

With this in view, the committee, cooperating with the meter manufacturers, standardized the bases for single-phase meters of 5 to 25-ampere rating (about 85 per cent of the total number of meters manufactured) by providing a projection on the bottom of the meter base to fit an adapter opening having dimensions of 3 11/16 in. × 1 13/32 in. The different makes of meters are now available in this design which will permit the use of a single adapter opening for 5 to 25-ampere single-phase meters.

A similar development has been accomplished with 50 to 75-ampere meters, and meters of these ratings with a standardized base projection to fit an adapter opening having the dimensions of 4½ in. × 1 23/32 in. are now in production.

Polyphase Meters

The use of meter cabinets for installations of polyphase side-connected meters has been somewhat retarded on account of the necessity for the use of complicated adapting devices. With the collaboration of the meter manufacturers, the bottom-connected polyphase meter which represents a more difficult development has been produced for the simplification of this problem. Bottom-connected polyphase meters of ratings up to 75 amperes having terminal chamber dimensions of 6¾ in. × 2 3/16 in. (including the terminal chamber cover) will be available in the near future.

Need for Further Standardization

The improvements in meter construction, standardization of parts, and the progress in metering methods have made possible many modifications which have simplified the production of service-entrance equipment. It is, however, realized that there are many variations in the design and construction of component parts of the equipment which might be eliminated should further standardization be effected. These include such details as knockouts, endwalls, thickness of metal, finish, wiring space, size of switch parts, test facilities, provision for grounding, sequence of connections and other variants.

Small Capacity Circuit Breakers

The use of small capacity circuit breakers has been advocated in place of fuses. They possess the advantage of providing a simple method for the customer to restore service to any part of the installation without the necessity of replacing fuses, or calling upon the company's service maintenance department, or some other agency. The use of these breakers in lieu of fuses in the house circuits has not, however, been at all general. Such general usage would unquestionably be an incentive to the development of their use in service-entrance cabinets. The service-entrance meter cabinet requirements in connection with circuit breakers include simplicity of design, reliability of operation, the possibility of sealing, an arrangement which makes live parts of the service inaccessible to the customer, reasonably low first cost, and the necessity of very little maintenance. It is also necessary, for this kind of service, to provide automatic operation in case the breaker is closed against a short circuit.

Development work along these lines is in progress by manufacturers; and some member companies, who are conducting investigations, have sample installations under observation. It appears probable that there will be some interesting developments in service equipment along the lines indicated. The committee is making a further study of this subject and will present the results as soon as progress warrants.

Requirements of Service-Entrance Cabinets

In general, service-entrance cabinets should be designed so as to include the externally operated fused switch to meet the requirements of the National Board of Fire Underwriters, and should provide a means in the interests of economy for the conjoint assembly with the meter so that none of the connections are exposed and accessible when the meter is installed and the cabinet is sealed. Such an assembly can include, at no great expense, for the mutual advantage of all interested parties, simple, adequate test connections. The sequence of connection of the component parts, however, may vary with individual requirements, and in some cases municipal or other requirements may introduce variations in arrangement and design.

The policy affecting the installing of service-entrance cabinets varies. In some cases these cabinets are furnished and installed by the utility, in other cases the customer supplies and installs the cabinet and the utility only mounts and connects the meter, and in some instances the company supplies the cabinet to the contractor for installation.

Service-entrance cabinets differ in that, some provide for the mounting of the meter on the metal back plate of the cabinet, while in other cases the meter is installed on a wooden board which also supports the cabinet. In the former type the metal back plate usually provides for the mounting of various makes and types of meters. The meter committee has cooperated with the manufacturers, by providing for the retention of existing spacings of mounting holes wherever possible, for modifications in design and new types of meters.

The sizes of cabinets is governed by various conditions. In general, it is desirable to provide sufficient space so that the test connections may be made safely and conveniently. It is also desirable to provide ample space so that main service conductors of relatively large size may be carried through a bank of cabinets with provision for making taps for the individual services.

It is recognized that in view of the numerous variations in design introduced by manufacturers in order to adapt their respective products to different requirements, it is difficult at this time to standardize on cabinets of specific sizes and designs, for metering installations of all sizes and kinds required for the wide range of a-c. and d-c. services of different classes, as supplied to large and small customers under various contract conditions.

It appears, however, that some specifications as to the general requirements which the 30-ampere service equipment should fulfill would be of interest and value, especially to those who have not had an opportunity to closely follow the developments.

The meter committee is making a further study of the requirements of member companies and the methods employed, with a view of determining the factors that effect uniform practice, and of ascertaining what suggestions can be made to further standardize service-entrance equipment.

Suggested Specifications for Service-Entrance Meter Cabinets

The suggested specifications given below apply to service-entrance meter cabinets used at the service entrance on the customer's premises, when such service is supplied from the lines of public utility companies, and are not intended to apply to meter cabinets for other purposes or for special applications.

Classification

(1) Service-entrance meter cabinets may be considered in two general classes, viz.:

(a) Those in which service fuses are under seal and are accessible only to authorized employees.

(b) Those in which the service fuses are accessible to the customer.

(2) Either class may be of the "all metal" type in which the meter itself is bolted to the metal base plate; or cabinets which inclose only the fuse, switch and test device, and above which the meter is mounted by being attached to a wooden board which also supports the cabinet.

(3) Meters may be applied to the cabinets so that the terminal chamber of the meter extends into the cabinet, or so that the terminal chambers of the meters abut the cabinet.

General Requirements

(4) Cabinets of the 30-ampere rating intended for use with 5 to 25-ampere single-phase alternating-current meters (installed so that the terminal chambers of the meters abut the adapter of *the cabinet*) should be provided with the standardized opening of 3 11/16 in. × 1 13/32 in. with the two outer corners rounded to a radius of ⅛ in.

(5) Cabinets for single-phase alternating-current meters of 25, 50 and 75-ampere ratings arranged so that the meter terminal chamber enters the cabinet, should be provided with an opening of 4½ in. × 1 23/32 in.

(6) Cabinets provided for bottom-connected polyphase meters and designed for the terminal chamber of the meter to enter the cabinet should have an adapter opening of 6⅞ in. × 2 5/16 in.

(7) Cabinets provided for bottom-connected polyphase meters and designed for the bottom of the terminal chamber to abut the adapter should have an adapter opening of 6⅝ in. × 2 1/16 in.

(8) The adapter openings of new cabinets should be closed by a shutter or a blank adapter. When blank adapters or shutters are separate from the meter adapter, the meter adapter should be supplied with the cabinets.

(9) Service-entrance meter cabinets designed for use with the meters of public utilities should be confined to the meter control and protective equipment. The addition of branch circuit cutouts or other devices may not be desirable.

Sizes

(10) Service-entrance meter cabinets should be of such a size as to provide adequate space for testing.

(11) Service-entrance meter cabinets must provide space for carrying service conductors through the cabinet when such cabinets are intended mainly for banked installations.

Covers

(12) Covers should be hinged and so arranged that when open they will not obscure the meters or interfere with test wirings or connections.

Arrangement of Cabinets

(13) Where consideration has been given to the use of cabinets, either as a service-entrance meter cabinet or as a service-entrance cabinet in a banked installation with knockouts or troughs, they should be arranged so that a centrally located cabinet in a group installation may be removed without the necessity of dismantling adjacent cabinets.

(14) Service-entrance meter cabinets may be adaptable to banked or grouped installations. This may be done either by means of conduit connections or troughs.

(15) The test device, the service switch, and the fuses should be arranged so that test links, connecting screws, etc., used for testing or for purposes of installation are easily accessible either when the cabinet is used alone or as a unit in a banked installation.

Sealing

(16) The cabinets should be designed so that they may be opened by authorized employees without interrupting the circuit, but the method of sealing should be such that the cover cannot be opened without breaking the seal.

(17) Service switches should be arranged so that they may be sealed externally in the open position.

(18) Sealing methods should be such that either the conventional types of padlock seal, strip metal seal, or lead button and wire seal may be applied to properly lock the cabinet cover in the full closed position.

Testing Facilities

(19) Test devices must provide facilities for readily bridging the meter current coils.

(20) Adequate provision should be made for attaching the connections required for service meter testing to the test device.

(21) Test devices should be constructed so as to minimize the possibility of corrosion in service.

(22) A diagram of connections showing the internal and external connections of the test device should be provided in each cabinet.

(23) The test device for three-wire and polyphase meters should make provision for the series connection of the current elements for test purposes.

Current Carrying Capacity

(24) Current carrying parts should be designed so that their temperature rise will not exceed that permitted by the standard specifications of the Underwriters' Laboratories, when carrying continuously the maximum current permitted by the largest fuse which may be inserted in the cabinet. Heating tests, however, should be made with fuses or equivalent resistances in place.

Fuses and Circuit Breakers

(25) Where fuses are accessible to the customer, the design should be arranged so that the fuse receptacle is disconnected from the source of supply when the fuses are accessible for replacement.

(26) Cabinets for two-wire 115-volt meters should be equipped with one fuse, with proper provision for connecting the unfused grounded service wire to the corresponding load wire.

(27) Cabinets for three-wire meters, for single-phase or open-star connections should be equipped with two fuses, with provision for connecting the neutral load and service wires without fuses. Provision should be made for connecting the individual potential leads of meters with independent potential circuits ahead of the fuses without disturbing any of the current-carrying connections.

(28) Cabinets for two-phase three-wire grounded neutral systems should be equipped with two fuses with provision for connecting the neutral load and service wires without fuses.

(29) Cabinets for two-phase five-wire meters on grounded neutral systems should be equipped with four fuses, with provision for connecting the neutral load and service wires without fuses.

(30) Cabinets for three-phase three-wire delta-connected systems should be equipped with three fuses.

(31) Cabinets for three-phase four-wire meters on grounded neutral systems should be equipped with three fuses, with provision for connecting the neutral load and service wires without fuses.

(32) When circuit breakers are employed in place of fuses, their application should be in accordance with clauses 26 to 31 inclusive.

(33) Circuit breakers approved for use in service-entrance cabinets should be provided with facilities for sealing the current setting.

(34) Circuit breakers should be designed so as to be in accord with the complete specifications of the Underwriters' Laboratories.

Switches

(35) Service switches installed within meter cabinets should be externally operated.

(36) When the operating handle is located at the side of the cabinet, the design should be such that the switch is closed when the handle is in the upper extremity of its travel.

(37) Rotary switches should be so arranged that the switch is closed when the handle is in the upper extremity of its travel.

(38) Switch blades must be provided for all ungrounded lines. This will necessitate that the switch open all wires for which fuses are provided in accordance with paragraphs 26 to 31 inclusive.

(39) Switches should be arranged so that they may be sealed in either the open or closed positions.

(40) The details of mechanical and electrical design should be in accordance with the Standard Specifications of the Underwriters' Laboratories covering externally operated switches, knife switches and cutout bases.

Finish

(41) Service-entrance meter cabinets should be protected against corrosion by galvanizing, sherardizing, or by the use of moisture-proof paint both inside and outside.

(42) The cabinets and their accessories should be designed so that the operating parts will not become corroded through disuse in the normal service to which meter cabinets may be subjected.

SUMMARY OF PUBLIC UTILITY COMMISSION RULES AND REGULATIONS FOR ELECTRICITY METERS

Rules and regulations for electricity meters have been adopted in twenty-one States and the District of Columbia. In order to show clearly the similarities and differences in the service rules so far adopted by State commissions, abstracts of these rules have been segregated under appropriate headings in this report.

An attempt has been made to place the abstract of each rule under the heading best describing the subject matter of the rule. It is believed that all the rules of each commission have been abstracted and included in this report. To determine what each State's rules are, it is necessary only to read under each heading the abstract of the rules for the State in question. If no abstract is given, no rule has been adopted.

The purpose of the report is, obviously, to acquaint individuals interested in meters with the rules in effect throughout the country. It is hoped that Meter Committee members and others interested in these rules may take the necessary steps to eliminate some of the existing differences, and that ultimately the rules in all the States may become standardized.

Primary Standards

Colorado

Rule 5, Rule 34-A—Each utility shall provide such meter laboratory, standard meters and other equipment acceptable to the Commission and sufficient to make all the tests prescribed. Utilities with authorized standard laboratory may certify their own reference standards and those of other utilities.

Connecticut

Rule E-12, Rule 2—Each utility must provide and maintain such standards and portable testing instruments as may be deemed necessary and approved by the Commission.

Rule E-12-d—Any standardizing laboratory whose instruments and methods are approved by the Commission may certify portable and reference standards.

District of Columbia

Rule 3—Each electrical corporation shall provide and maintain suitable apparatus and facilities for testing the accuracy of meters.

Illinois

Rule 8-a—Each utility shall provide and maintain such meter laboratory and instruments as may be necessary to make the tests required by the Commission.

Indiana

Rule 11-b—Each utility shall maintain a standardizing laboratory. Each utility must provide and maintain such laboratory, standard meters and equipment as may be necessary to make all the tests required by the Commission.

Rule 11-a—If instruments and methods are approved by the Commission, the laboratory may certify the accuracy of its own meters and those of other utilities.

Maryland

Rule E-2—Each utility shall maintain and provide such meter testing facilities as are necessary to make all tests of its service meters.

Michigan

Rule 44—Each utility shall provide and properly maintain suitable primary standards to be used for checking reference standards.

Rule 41—If a utility is maintaining a laboratory, the Commission may authorize such utility to have power to test and certify meters of other utilities.

Missouri

Rule 35—Each utility may provide and maintain primary standards. If not, secondary or reference standards must be submitted to some testing laboratory of recognized standing at sufficiently frequent intervals.

Montana

Rule 27-a—Each utility with more than 250 meters in service shall maintain a standardizing laboratory equipped with standard meters, instruments and such facilities as are necessary to make tests required by the Commission.

New Hampshire

Rule 9—Each utility shall have available in proper working condition suitable standards for testing its meters and shall maintain these standards accurate within one-half of 1 per cent, or apply the proper corrections to each test.

New Jersey

Rule XIX-a—All utilities must provide and maintain such laboratory, meter testing shop, standards, instruments and such other facilities to make the test required by the Board.

Rule XIX-e—Any standardizing laboratory whose instruments and methods are approved by the Board may test and certify instruments and standards.

New York

Case No. 278-1921

Section 25—Each utility must provide and maintain suitable apparatus and facilities for testing and approving the accuracy of watt-hour meters.

Section 24—If a standardizing laboratory is maintained and approved by the Commission, it may certify meters and instruments for testing purposes.

North Dakota

Rule 11-b—Each utility, unless excused by the Commission, shall provide and maintain such laboratory standard meters and equipment as may be necessary to make the tests required.

Rule 11-a—If instruments and methods of a standardizing laboratory be approved by the Commission, such laboratory may certify meters and instruments for its own use and for other utilities.

Oklahoma

Rule 12-b—Each utility must provide and maintain such laboratory, standard meters and equipment as may be necessary to make the tests required by the Commission.

Publication No. 289-40, Serial Report, Meter Committee.

Rule 12-a—If instruments and methods are approved by the Commission, the laboratory may certify the accuracy of its own meters and those of other utilities.

Oregon

Rule 2-a—Each utility shall provide such laboratory, meter testing shop and other facilities as may be necessary to make the tests required by the Commission.

Pennsylvania

Rule XV—Each utility shall provide facilities approved by the Commission for testing its watt-hour meters, to include: test bench, one or more portable rotating standard watt-hour meters, a suitable check meter or meters mounted on test bench and such other equipment as required by the Commission.

South Carolina

Rule 13-a—Each utility shall, unless excused by the Commission, provide and maintain such laboratory, standard meters, instruments and facilities as may be necessary to make the test required by the Commission.

Washington

Rule E11-b—Each utility shall provide such meter laboratory, standard meters and other equipment and facilities for making the tests required by the Department.

Rule E11-a—Any standardizing laboratory whose instruments and methods are approved by the Department may certify meters and instruments for its own use and for other utilities. Utilities not maintaining standardizing laboratories may obtain authorization from the Department to have certification of meters made for them by any approved standardizing laboratory.

West Virginia

Rule 23-a—Each utility shall provide such laboratory, meter testing shop, instruments and equipment as may be necessary to determine the accuracy of its consumers' meters, unless relieved of such requirement by the Commission.

Rule 23-b—The minimum testing equipment shall be a portable rotating standard of sufficient capacity to test all service meters upon the utility's system.

Secondary Standards

Colorado

Rule 34-b—For testing accuracy of portable rotating standards and other portable standards each utility must provide suitable reference standards. Such reference standards may be of a service type of watt-hour meter if permanently mounted and used for no other purpose. Reference standards shall be checked once a year at an authorized laboratory.

Connecticut

Rule E-12-a—Reference standards shall be provided and maintained as deemed necessary and approved by the Commission.

Illinois

Rule 8-c—Each utility shall provide suitable instruments called reference standards for testing the accuracy of rotating standards and other working standards. For utilities with less than 500 meters in service a regular service type of meter may be used as a reference standard if placed permanently in a place free from vibration and other disturbing influences and used for no other purpose.

Reference standards shall be checked once a year in some approved laboratory.

Indiana

Rule 11-C—Each utility not excused by the Commission, shall provide and maintain reference standards to check the accuracy of portable standards. If the reference standard is of the service watt-hour meter type, it must be permanently mounted in the meter laboratory.

Reference standards of all kinds should be tested at least once a year in a standardizing laboratory.

Maryland

Rule E-2—Utilities shall provide and maintain suitable electrical meters and instruments to be used as reference standards for testing the accuracy of the portable working standards. They may be of service type watt-hour meter, if permanently mounted in the laboratory and used for nothing else.

Reference standards should be tested and adjusted each year by the Commission.

Michigan

Rule 43—Each utility shall provide and maintain suitable electrical instruments to be used as reference standards, permanently mounted in meter laboratory.

Rule 45-f—Reference standards used to check portable watt-hour meters shall be tested and certified at least once every 6 months in an approved meter testing laboratory. Each reference standard shall be accompanied by a certificate of accuracy.

Missouri

Rule 35—Each utility having more than 250 meters in service shall own and maintain approved secondary standards for calibrating working standards. Each standard shall be accompanied by its calibration card, and when calibration cards are superseded they shall be kept on file.

Montana

Rule 27-c—Each utility shall provide reference standards for testing working standards. Such reference standards may be of the service type, if permanently mounted and used for no other purpose than checking working standards.

Reference standards should be certified by some approved laboratory at least once a year.

New Jersey

Rule XIX-c—Every utility shall provide and maintain suitable instruments as reference standards for testing the accuracy of portable meters used for testing customers' service meters. Such standards may be service type watt-hour meters, if permanently mounted in the laboratory and used for no other purpose than checking working standards.

All reference standards may be tested, adjusted and sealed by the Board.

New York

Case No. 278—1921

Section 26—Each utility shall provide and maintain suitable indicating electrical instruments as reference standards, mounted in a permanent position.

Reference standards shall be certified once every two months by comparison with the standards of a standardizing laboratory, or the standards of the Commission, or by specific permission, with the standards of other laboratories.

North Dakota

Rule 11-c—Each utility shall provide and maintain reference standards for testing the accuracy of portable testing meters. Such reference standards may be service type meters.

Reference standards should be tested once a year.

Oklahoma

Rule 12-c—Each utility, not excused by the Commission, shall provide and maintain reference standards to check the accuracy of portable standards.

Utilities with less than 500 meters in service may use a service type watt-hour meter as reference standard.

Reference standards of all kinds should be tested at least once a year in a standardizing laboratory.

Oregon

Rule 20-a—Secondary standards of some approved type shall be owned and maintained by each utility having more than 250 electric meters in service.

Pennsylvania

Section XV-I—Reference standard or check meter shall be tested periodically and adjusted when necessary by a representative of the Commission at such place as it may direct. Such meter shall be sealed and date-tagged immediately after adjustment, and the utility shall be furnished with correction curve dated and signed.

2—Portable rotating standards shall be tested and adjusted periodically by a representative of the Commission at such place as it may direct. Correction curve properly dated and signed shall be furnished to the utility.

3—During interval between tests by the Commission the portable standards shall be compared with a check meter at least once each week for commutating type, and every two weeks for induction type. Complete records of checks shall be kept two years.

Washington

Rule E-11-c—Each utility shall provide and maintain suitable reference standards for testing the accuracy of portable watt-hour meters called rotating standards and other portable instruments used for testing service meters. Such standards may be service type watt-hour meters if permanently mounted in the meter laboratory of the utility and used for no other purpose than checking working rotating standards.

Reference standards shall be certified bv comparison with the standards of a standardizing laboratory approved by the Department.

West Virginia

Rule 23-c—A utility may or may not have secondary standards. When no regular secondary standards are maintained, the utility must have more than one portable rotating standard, and alternately they shall be sent to a suitable laboratory, at least once every three months, for checking and certification. One such standard should be kept as an office standard and not used for field work. The standards used for field work shall be checked against the office standard at least every two weeks.

Minimum requirement for checking portable rotating standards is to install in the shop of the utility a 5-ampere, single-phase watt-hour meter with potential coils like the potential coils of one of the rotating standards; such meter to be adjusted accurate within one-fourth of one per cent, with 3 amperes flowing in the current coil. This meter shall be certified at least once every year.

When the minimum requirement is in effect the portable rotating standards shall be checked against the standard meters once every two weeks.

Wisconsin

Rule 18—Secondary or reference standards should be owned by electric utilities having more than 250 meters in service. Reference standards should be tested at least once a year in a standardizing laboratory.

Working Standards

Colorado

Rule 34-b—Rotating standards shall be compared with reference standards every week for commutator type and every two weeks for induction type. One per cent plus or minus is limit for error unless accompanied by calibration card.

Portable indicating instruments shall be checked against reference standards every week. One per cent of full scale deflection is limit for error.

All portable standards shall be accompanied by calibration card; when superseded such cards shall be filed in office of utility.

Connecticut

Rule E-12-b—Portable rotating standards shall be compared with reference standards at least once each week for commutator types and once every two weeks for induction types. If such check shows error in excess of 2 per cent, the rotating standard shall be readjusted and certified in an approved laboratory. Each portable rotating standard shall at all times be accompanied by a certificate of correction.

Rule E-12-c—Portable indicating testing instruments shall be checked against reference standards at least once a week. If in error at zero, or more than 1 per cent at commonly used scale deflections, it shall be adjusted and certified in an approved laboratory before being used again.

District of Columbia

Rule 4—All working standards shall be tested for accuracy as often as is necessary, to insure their maintenance in proper condition. If not checked in the laboratory of the electrical corporation, working standards shall be tested in a properly equipped laboratory of recognized standing.

Each working standard shall at all times be accompanied by a certificate giving date on which it was last checked and the corrections to be applied. When superseded the certificate shall be kept on file in the office of the utility.

Illinois

Rule 8-d—When rotating standards are regularly used they shall be compared with the reference standards at least once each week, if of the commutator or mercury type, or at least once each two weeks, if of the induction type. For utilities having less than 500 meters in service a regular service type watt-hour meter may be used for checking working standards in the district where the tests are being made, provided comparisons are made at least once a month with the approved reference standards of the central testing station. If the rotating standard is in error by more than 1 per cent it shall be adjusted, if possible. In any case, the correction indicated by the calibration card (see Rule 8-g) shall be applied.

Rule 8-e—All working standards of the indicating type shall be compared with reference standards at least once a week. If found in error at zero, or more than 1 per cent in error at commonly used scale deflections, the instrument shall be adjusted, or the proper correction factor shall be applied.

Rule 8-f—Station meters shall be checked at least once a year.

Rule 8-g—Each working or reference standard shall be at all times accompanied by a calibration card. When superseded they shall be kept on file in the utility office.

Indiana

Rule 11-c—Rotating standards should be compared with reference standards once a week for commutator types, and every two weeks for induction types. The error should be less than 1 per cent plus or minus, unless calibration card accompanies rotating standard. Records of certification and calibrations shall be kept on file in the office of the utility.

Portable testing instruments, such as voltmeters, ammeters and wattmeters shall be checked with reference standards once a week when continually in use. Error shall be less than 1 per cent of full scale value at commonly used scale deflections, unless accompanied by calibration card.

Maryland

Rule E-2—Each utility shall provide and maintain suitable portable testing equipment for use as working standards.

Michigan

Rule 42—Each utility shall provide and properly maintain portable testing instruments and rotating standards as deemed necessary and satisfactory by the Commission for testing service meters, switchboard meters and other electrical instruments in use.

Rule 45-d—All portable indicating and recording meters, such as voltmeters, ammeters, wattmeters, frequency meters and power factor meters, shall be compared with reference standards at frequent intervals when regularly used. If such check shows any portable meter to have an error greater than 1 per cent at any load at which the meter is used, the meter shall be tested and adjusted with instruments of precision in an approved laboratory, unless the meter is accompanied by an accurate calibration chart, in which case an error of more than 1 per cent will be allowed.

Missouri

Rule 35—Each utility shall maintain suitable working standards of a rugged type for testing electric service meters. These working standards must be calibrated frequently to insure their accuracy. Each standard shall be accompanied by its calibration card, and when superseded they shall be kept on file at the office of the utility.

Montana

Rule 27-d—Rotating standards shall be compared with reference standards once a week for commutator types and every two weeks for induction types. Unless accompanied with calibration card, the meter shall be tested and certified if in error more than 1 per cent, plus or minus.

Rule 27-e—Portable testing instruments, such as voltmeters and ammeters, shall be checked against reference standards once a week; if the error is more than 1 per cent of full scale deflection at commonly used scale deflections, they shall be calibrated, unless accompanied by calibration card.

New Jersey

Rule XIX-b—Each utility shall provide portable meters of suitable range and type for testing service watt-hour meters, switchboard instruments and other electrical instruments in use.

Rule XIX-d and e—Rotating standards and all portable standards when in regular service shall be compared with reference standards at least once each week. They shall be accompanied by a certificate, or calibration card. When superseded these certificates shall be kept on file for one year in the office of the utility.

New York

Case No. 278—1921

Section 27—Portable rotating standards shall be compared with reference standards once each week for commutator types and once every two weeks for induction types. If such comparison shows error more than 1 per cent, plus or minus, at any load on which the standard will be used, it shall be adjusted and certified by comparison with reference standards in the company's own laboratory before again being used.

Each portable rotating standard shall have a certificate attached, signed by the proper authority, giving date when last certified, and company's or manufacturer's number. The accuracy shall be shown either as per cent accuracy of the portable standard or as the actual per cent correction to be applied at the various ampere loads at one or more voltages. When certificates are superseded they shall be filed for six months.

North Dakota

Rule 11-c—Rotating standards shall be compared with reference standards once a week for commutator types and once in two weeks for induction types. The error shall be less than 1 per cent, plus or minus. All rotating standards shall be accompanied by calibration cards. Records of calibration shall be kept on file in the office of the utility.

Portable indicating testing instruments when in regular use for testing purposes, shall be checked against reference standards once a week. Error shall be less than 1 per cent of full scale value at commonly used scale deflections, unless accompanied by calibration card.

Oklahoma

Rule 12-c—Rotating standards shall be compared with reference standards once a week for commutator types and every two weeks for induction types. The error shall be less than 1 per cent, plus or minus. The calibration card shall accompany rotating standards at all times. Records of certification and calibrations shall be kept on file in the office of the utility.

Portable testing instruments, such as voltmeters, ammeters and wattmeters, shall be checked with reference standards once a week when continually in use. Error shall be less than 1 per cent of full scale value at commonly used scale deflections, unless accompanied by calibration card.

Oregon

Rule 20-a—Every electric utility shall own suitable working standards for testing meters and shall maintain them correct within one-half of one per cent or apply proper corrections.

Pennsylvania

Rule XV-1—Reference standard or check meter shall be tested periodically and adjusted when necessary by a representative of the Commission at such place as it may direct. Meters shall be sealed and date-tagged immediately after adjustment. The utility shall be furnished with correction curve dated and signed.

2—Portable rotating standards shall be tested and adjusted periodically by a representative of the Commission at such place as it may direct. Correction curves properly dated and signed shall be furnished to each utility.

3—During interval between tests by the Commission, the portable standards shall be compared with a check meter at least once each week for commutator types, and every two weeks for induction types. Complete record of each check shall be kept two years.

South Carolina

Rule 13-b—All portable electrical testing instruments when in regular use for testing purposes shall be checked periodically against suitable reference standards to insure their accuracy.

Washington

Rule E-11—Rotating standards shall be compared with reference standards at least once a week for commutator types and once every two weeks for induction types. Error shall be less than 1 per cent, plus or minus, at any load at which standard will be used.

Portable standard indicating instruments shall be checked against reference standards at least once a week. Error should be less than 1 per cent of full scale deflection at commonly used scale deflections unless accompanied by a calibration card.

West Virginia

Rule 23-c—A utility may or may not have secondary standards. When no regular secondary standards are maintained the utility must have more than one portable rotating standard and alternately they shall be sent to a suitable laboratory at least once every three months for checking and certification. One such standard should be kept as an office standard and not used for field work. The standards used for field work shall be checked against the office standard at least every two weeks.

Minimum requirement for checking portable rotating standards is to install in the shop of the utility a 5-ampere, single-phase watt-hour meter with potential coils like the potential coils of one of the rotating standards; such meter shall be adjusted accurate within one-fourth of one per cent with 3 amperes flowing in the current coil. This meter shall be certified at least once every year.

When the minimum requirement is in effect the portable rotating standards shall be checked against the standard meters once every two weeks.

Wisconsin

Rule 18—Working standards should be owned by all utilities unless excused by the Commission.

Rule 19—Each utility furnishing metered electric service shall own suitable working standards and either maintain the standards correct within one-half of one per cent or apply the proper correction to all tests.

Direct-current rotating standards should be checked against the secondary standards daily; when the rotating standards are found in serious error, the day's work shall be repeated.

Initial Requirements for Meters

Colorado

Rule 35—Meter must have correct gear ratio, register constant, test constant and dial train. Meter must not creep.

Meter must not be in error more than 2 per cent plus or 3 per cent minus at 5 to 10 per cent rated meter capacity, or 2 per cent, plus or minus, at 60 to 100 per cent rated meter capacity.

Connecticut

Rule E-15—Meter must have correct register constant, test constant, gear ratio and dial train. Must not register on no load. Average error of meter shall not be in excess of 2 per cent.

At 50 per cent lagging power factor and 100 per cent rated current the meter error shall not be in excess of 2 per cent.

District of Columbia

Rule 2-G—Meter must not creep. The meter error shall be less than 1 per cent at 10 per cent of rated capacity of meter and less than 1 per cent at 60 to 100 per cent rated capacity of meter.

Illinois

Rule 10—Meter shall not make more than one complete revolution on no load. Meter must be mechanically perfect with correct constants.

Meters shall be adjusted so the error shall not exceed the amounts given: average error less than 2 per cent, for direct current and alternating current; error at full load less than 1 per cent, for direct current and alternating current; error at light load less than 4 per cent, for direct current and 3 per cent for alternating current.

Rule 13-c—Installation tests on watt-hour meters used on inductive loads shall consist either of tests approximating the customer's load at heavy and light load or of tests on non-inductive load at heavy and light load, provided a shop adjustment was previously made within 2 per cent at rated full load and 50 per cent lagging power factor.

Indiana

Rule 13-a and b—Meter shall not register at 110 per cent standard service voltage at no load. Meter shall be mechanically perfect and must have correct constants. Initial adjustment must be made so that the average error is not over plus or minus 2 per cent, while the error at heavy load is not over plus or minus 1 per cent and the error at light load is not over plus or minus 4 per cent.

Rule 13-c—At 50 per cent power factor and full rated current the meter error shall not be more than 2 per cent.

Maryland

Rule 4-a—Meter shall not creep under commercial range of voltage. Meter shall be mechanically right with correct ratio and constants. Meter error shall be less than 1 per cent. No meter shall be placed in service unless its accuracy has been established and marked with the seal of the Commission.

Michigan

Rule 27—Meter shall not register at no load when applied voltage is less than 110 per cent of standard voltage.

Rule 28—Meter shall be mechanically perfect and have proper constants. The average error shall be not over 2 per cent, plus or minus, while the light load error shall not be over 3 per cent, plus or minus. The heavy load error shall not be over 1 per cent, plus or minus.

Rule 26—At 50 per cent power factor and 100 per cent rated full load current meter error shall not be more than 2 per cent on meters which will or may be used on inductive load circuits.

Missouri

Rule 30—Meter shall have proper constants and dial trains and be mechanically perfect. Meter shall not creep at no load under maximum service voltage.

Rule 29—Each meter shall be adjusted as accurately as practicable on the following loads:

5 to 10 per cent rated capacity of meter.
50 per cent rated capacity of meter.
100 per cent rated capacity of meter.

Where the normal load under which meter operates is from 60 to 100 per cent of rated meter capacity, an equivalent test load may be substituted for the 50 and 100 per cent rated capacity loads.

Any meter operating on inductive load should be tested under the approximate P.F. condition at which it operates.

Where necessary to adjust a meter fast at light or heavy load for correct registration at normal load or to correct for inductive load, such fast adjustments should not exceed 2 per cent.

Montana

Rule 22—Meter shall not register at 110 per cent standard service voltage at no load. The allowable average error shall be less than 2 per cent, plus or minus. The error shall be less than 1 per cent, plus or minus, at heavy load, and less than 4 per cent, plus or minus, at light load.

Error shall be less than 2 per cent at power factor conditions approximating the power factor of the connected load.

New Hampshire

Rule 2—Meter shall not creep and shall have correct gear ratio, register constant, test constant and dial train.

Meter shall not be in error more than 4 per cent at light, normal and heavy loads.

New Jersey

Rule XXI—Meter shall not register on no load.

New York

P. S. Comm. Law, 1921, *Section* 67, *Subdivision* 3

No corporation, person, or municipality shall furnish, set or put in use any electric meter the type of which shall not have been approved by the Commission.

Case No. 278

Section 7—Each meter shall be tested and adjusted within the limits specified in Section 22, before installation or within 60 days after installation. Each direct-current watt-hour meter shall be tested and adjusted within 60 days after installation.

No reports of these tests need be filed, and they will not be considered as periodic, office or complaint tests.

Section 22—Meters shall be adjusted so as to register with an error of not more than 1 per cent at 10 and 100 per cent capacity (light and full load).

Section 23—A meter shall be considered as creeping when, on no load, the disk rotates 1 revolution in 5 minutes or less. This observation shall be made with all house wires removed from the meter. All meters in service shall be left without creep.

North Dakota

Rule 13—Meter shall not register at 110 per cent standard service voltage at no load. Meter shall be mechanically perfect and have correct constants. The average error shall be not more than 2 per cent, plus or minus. The error at heavy load shall be not over 1 per cent, plus or minus, and at light load it shall be not over 4 per cent, plus or minus.

A-C. service meters which are to be used on circuits supplying inductive load shall be tested, before installing, at 100 per cent of rated current and 50 per cent lagging power factor.

Oklahoma

Rule 13—Meter shall not creep. Meter shall have correct register constants, test constants, gear ratio, dial train and be mechanically perfect. The average error shall be not more than 2 per cent. The light load error shall be not more than plus 2 per cent or minus 4 per cent, while at heavy load the error shall be not more than plus or minus 2 per cent.

Rule 16-B—At 50 per cent power factor and full rated current the error shall be less than 2 per cent.

Oregon

Rule 24-a—Meter shall not register at no load nor have incorrect register constant, test constant, gear ratio or dial train.

Pennsylvania

Rule XI—Meter shall not register at no load when voltage is less than 110 per cent of standard service voltage. Meter must have proper constants, be mechanically perfect, and its error must be not more than 4 per cent.

Rule XIX—Error shall be less than 4 per cent, plus or minus, at 50 per cent lagging power factor.

South Carolina

Rule 15—Meter shall not creep at 110 per cent of standard service voltage at no load. Meter shall be mechanically perfect with correct constants and have errors less than 1 per cent, plus or minus, at full load, 2 per cent, plus or minus, at light load, with an average less than 2 per cent, plus or minus.

Washington

Rule E-12—Meter shall have proper register constant, test constant, gear ratio and dial train, and shall not register at no load.

Error shall not be over 4 per cent, plus or minus, at 10 per cent and 100 per cent capacity of meter. Meter shall be adjusted as nearly 100 per cent as possible.

Rule E-9—Error shall be less than 2 per cent at 50 per cent power factor and 100 per cent rated current.

West Virginia

Rule 24-a—Meter shall be mechanically right without creep. The error shall be less than 1 per cent at light and normal loads.

Wisconsin

Rule 14—Meter shall not creep.

Rule 15—Meter shall have correct register constant, test constant, gear ratio and dial train, and its error shall be less than 4 per cent between light and full connected loads.

Requirements for Meters with Auxiliary Apparatus

Colorado

Rule 35-d—Meters installed with instrument transformers or shunts shall be tested jointly with such transformers or shunts, otherwise the ratio of transformation of the transformers and the resistance of the shunts must have been previously determined within five years and be on file at the office of the utility.

Connecticut

Rule E-13-b—Meters installed with instrument transformers or shunts may be tested independently of such transformers or shunts provided the utility applies the correction indicated by a certificate from the manufacturer; otherwise the meters and transformers or shunts shall be verified as a measuring unit.

District of Columbia

Rule 2-E—Where meter is installed with instrument transformers and line voltage exceeds 600 volts or the current is greater than 150 amperes, the meter shall be tested self-contained provided transformers have been tested within 5 years preceeding test.

Illinois

Rule 10-d—Watt-hour meters installed with instrument transformers or shunts shall be tested as a unit, unless the ratio of transformation of the transformers and the resistance of the shunts have been previously determined within ten years and are on file at the office of the utility.

Indiana

Rule 14-c—Meters installed with instrument transformers or shunts must be tested jointly with transformers or shunts, otherwise the ratio of transformation of the transformers or the calibration of the shunts must be determined at least every ten years.

Michigan

Rule 35—If watt-hour meter is installed with shunts or instrument transformers it shall be tested jointly with these accessories, provided that if the phase angle and ratio of transformers or the calibration of the shunts is verified previous to the installing of meter, and the meter accordingly adjusted, such test shall not be required.

Instrument transformers used with meters may be used for operating relays only when the total burden does not exceed the rated capacity of the transformers, and provided also that the tests required by the first part of this rule be made with such relays connected to the transformers concerned.

New Hampshire

Rule 3—Meters installed with instrument transformers or shunts must be tested jointly, otherwise the ratio of transformation of transformers or the calibration of the shunts must be determined at least once every five years and records kept of such tests.

New York

Case 278—1921

Section 11—Meters with instrument transformers in circuits exceeding 350 volts shall be tested separately from transformers and the ratio be correctly applied. Meters with transformers or shunts in circuits less than 350 volts may be tested jointly with shunts or transformers.

Section 12—An approved protective short circuiting device shall be permanently installed on current transformer secondary circuits, unless the primary circuit can be open circuited for test.

Section 13—In periodic tests or office tests the transformer or shunt shall have a calibration certificate dated within ten years of the time of test.

Section 14—In complaint tests the Commission will accept the calibration certificates of the transformers or shunts provided they are dated within two years preceding the time the meter is tested.

Section 15—Shunts for direct-current meters exceeding 800 amperes may be permanently installed, provided the calibration certificate is on file dated within the periods specified in Sections 13 and 14.

North Dakota

Rule 14-c—Meters installed with instrument transformers or shunts must be tested jointly with transformers or shunts, otherwise the ratio of transformation of the transformers or the calibration of the shunts must be determined at least once every ten years.

Oklahoma

Rule 15-b—Meters installed with instrument transformers or shunts shall be tested jointly with such transformers or shunts, otherwise the ratio of transformation of the transformers and the resistance of the shunts must have been previously determined within ten years.

Pennsylvania

Rule XXI—When watt-hour meter is connected to line through shunts, multipliers or instrument transformers, the test may be made on the meter as a self-contained unit and the ratio of the accessories may be used to determine the error of the meter, provided the certificates of the accessories bear a date within five years of the test and are satisfactory to the Commission.

Washington

Rule E-16-b—Meters with instrument transformers in circuits exceeding 350 volts shall be tested independently and corrections shown on ratio certificates applied. When circuits are less than 350 volts the certificates need not be supplied if meters are tested jointly with the transformers or shunts.

In periodic tests the ratio certificates should be dated within less than ten years of the test date.

In complaint tests the calibration certificates shall be dated within two years of test date.

Wisconsin

Rule 16—Meters installed with shunts or instrument transformers must be tested jointly with the transformers or shunts otherwise the ratio of transformation of the transformers or the calibration of the shunts must be determined at least once every five years.

Meter Testing Methods and Testing Loads

California

Rule 15—All meters shall be tested before installation.

Colorado

Rule 34-a—Meters shall be tested according to rules and regulations. Light load shall be from 5 to 10 per cent rated capacity of meter, and heavy load shall be from 60 to 100 per cent rated capacity of meter.

Connecticut

Rule E-13—All meters shall be tested in place of permanent location on customers' premises with approved testing apparatus.

Rule E-14—Light load shall be not over 10 per cent of rated capacity of meter and heavy load shall be not less than 60 per cent of rated capacity of meter.

District of Columbia

Rule 2-B—Meters shall be tested in place under operating conditions.

Rule 2-C—Light load shall be 10 per cent of rated capacity of meter and full load between 60 to 100 per cent of rated capacity of meter.

Normal load for request referee and office tests:

Residences and apartments	25 per cent
Elevators	40 per cent
Factories (individual drives), churches and offices	45 per cent
Factories (line shafting), theatres, clubs and stores	60 per cent
Restaurants, pumps and compressors	70 per cent
Signs, show windows and blowers	100 per cent

Illinois

Rule 9-a—Light load shall be between 5 and 10 per cent of rated capacity of meter on induction meters and approximately 10 per cent on commutators and mercury types. Heavy load to be at least 75 per cent of rated capacity of meter. Two observations at least 30 seconds long shall be recorded at each load. The observations must agree within 1 per cent at light load and one-half per cent at heavy load. The error on the two loads shall be averaged and called the average error.

Indiana

Rule 14-a—Meters shall be tested in place of permanent location. Light load shall be not over 10 per cent of rated capacity of meter. Heavy load shall be at least 75 per cent of rated capacity of meter.

Maryland

Rule 6-c—Meters shall be tested in permanent position after installation.

Rule 4-b—Light load shall be between 5 and 10 per cent of rated capacity of meter for induction types and 15 per cent of rated capacity of meter for commutating types. Heavy load shall be 100 per cent rated capacity of meter.

Rule 5-c—Normal load:

Residences and apartments	25 per cent
Elevators	40 per cent
Factories (individual drives), churches and offices	45 per cent
Factories (line shafting), theatres, clubs and stores	60 per cent
Restaurants, pumps and compressors	70 per cent
Signs, show windows and blowers	100 per cent

Michigan

Rule 33—Meters shall be tested in place of permanent location.

Rule 25—Light load shall be between 5 and 10 per cent of rated full load capacity of watt-hour meters and 20 per cent of full load capacity of demand meters. Heavy load shall be approximately 75 per cent of the full load capacity of the meter. The full connected load may be used for full load if this is less than 75 per cent of the rated full load.

Missouri

Rule 31—Light load shall be approximately 5 per cent for induction type meters and 10 per cent for commutator types of meters. Full load shall be 100 per cent rated capacity of meters.

Rule 31—Normal load:

Residences and apartments	25 per cent
Elevators	40 per cent
Factories (individual drives), churches and offices	45 per cent
Factories (line shafting), theatres, clubs and stores	60 per cent
Restaurants, pumps and compressors	60 per cent
Signs, show windows and blowers	100 per cent

Montana

Rule 23—Meters shall be tested in permanent position in place of service.

Rule 22-b—Light load shall be less than 10 per cent of rated capacity of meter. Heavy load shall be at least 75 per cent of rated capacity of meter.

New Hampshire

Rule 1—Meters shall be tested at light, normal and heavy loads. Normal load shall be:

Residences and apartments	25 per cent
Elevators	40 per cent
Factories (individual drives), churches and offices	45 per cent
Factories (line shafting), theatres, clubs and stores	60 per cent
Restaurants, pumps and compressors	70 per cent
Signs, show windows and blowers	100 per cent

New Jersey

Rule XX—Light load shall be between 5 and 10 per cent rated capacity of meter for induction types and between 10 and 15 per cent for commutator types. Full load shall be more than 60 per cent rated capacity of meter. Normal load shall be the following percentages of the 'total connected load:

Residences and apartments	25 per cent
Elevators	40 per cent
Factories (individual drives), churches and offices	45 per cent
Factories (line shafting), theatres, clubs and stores	60 per cent
Restaurants, pumps and compressors	70 per cent
Signs, show windows and blowers	100 per cent

New York

Case No. 278—1921

Section 10—Watt-hour meters shall be tested in the place of permanent location on the consumers' premises and under local conditions of operation.

Section 16—Watt-hour meters on periodic tests shall be tested at light load, normal load and full load. Light load shall be at 10 per cent of rated capacity of meters. Normal load shall be between 50 and 60 per cent of rated capacity of meters. Full load shall be between 85 and 100 per cent of rated capacity of meters.

Section 17—The classification and percentage of installation to be used to obtain normal load on complaint or office tests are given below:

Residences and apartments	25 per cent
Elevators	40 per cent
Factories (individual drives), churches and offices	45 per cent
Factories (line shafting), theatres, clubs and stores	60 per cent
Restaurants, pumps and compressors	70 per cent
Signs, show windows and blowers	100 per cent

Section 18—When an installation consists of more than one of the above classes of loads, normal load shall be obtained by multiplying the watt load of each class by the percentage specified and adding the results.

Section 19—The normal load determination shall include every power, lighting and heating device found so connected that it may be operated by installing fuses, closing a switch or operating a controlling device, or by any combination of these three methods.

North Dakota

Rule 14-a—Watt-hour meters shall be tested in place of permanent position on consumers' premises at light load and heavy load.

Rule 12—Light load shall be 10 per cent of rated capacity of meter. Heavy load shall be at least 75 per cent of rated capacity of meter.

Oklahoma

Rule 15-a—Watt-hour meters shall be tested in place of permanent position under actual conditions at light, normal and heavy loads.

Rule 13-c—Light load shall be between 5 and 10 per cent of rated capacity of meter. Heavy load shall be between 60 and 100 per cent of rated capacity of meter. Normal load shall be:

Residences and apartments	25 per cent
Elevators	40 per cent
Factories (individual drives), churches and offices	45 per cent
Factories (line shafting), theatres, clubs and stores	60 per cent
Restaurants, pumps and compressors	70 per cent
Signs, show windows and blowers	100 per cent

Oregon

Rule 22-a—Meters shall be tested in permanent location on customers' premises. At least two test runs of 30 seconds each which agree within 1 per cent should be made on each load. Meters shall be adjusted to within 1 per cent at three-quarters and one-tenth of rated load.

Pennsylvania

Rule XX—Watt-hour meters shall be tested in place of permanent installation under local conditions with approved equipment.

Rule XII—Light load shall be within 10 per cent of rated capacity of meter for induction types and 10 to 15 per cent rated capacity of meter for commutator and mercury type meters. Heavy load shall be between 75 and 100 per cent rated capacity of meter.

South Carolina

Rule 16—Watt-hour meters shall be tested in place of permanent location under local conditions.

Rule 14—Light load shall be 10 per cent of rated capacity of meter. Heavy load shall be at least 75 per cent of rated capacity of meter.

Washington

Rule E-16—Watt-hour meters shall be tested at light and heavy loads. Light load shall be at least 10 per cent of rated capacity of meter and heavy load shall be from 75 to 100 per cent of rated capacity of meter.

West Virginia

Rule 24-d—Watt-hour meters shall be tested at light, heavy and normal loads. Light load shall be approximately 10 per cent of rated capacity of meter. Full load shall be from 85 to 100 per cent of the rated capacity of the meter. Normal load shall be from 50 to 60 per cent of the rated capacity of the meter.

Wisconsin

Rule 16—Each watt-hour meter shall be checked for accuracy at approximately three-quarters and one-tenth of full load.

Rule 17—Each watt-hour meter must be adjusted if it is found to be in error more than 1 per cent, the tests both before and after adjustments being made at approximately three-quarters and one-tenth of the rated capacity of the meter.

Meter Accuracy Limits

California

Rule 15—No meter shall be in error more than 2 per cent under normal operating conditions.

Colorado

Rule 34—Working standards shall be considered correct when their errors are within 1 per cent, otherwise corrections shall be applied.

Rule 35—Watt-hour meter errors shall be less than 2 per cent plus and 3 per cent minus at light load and 2 per cent plus or minus at heavy load. Watt-hour meters shall not creep.

Connecticut

Rule E-15—Average watt-hour meter errors shall not be in excess of 2 per cent.

District of Columbia

Rule 4—Working standards shall be maintained in proper condition for testing watt-hour meters.

Rule 2-G—Service meters shall not creep, and they shall be adjusted so that their errors are within 1 per cent at light and full loads.

Idaho

Meters shall not vary more than 3 per cent in accuracy.

Illinois

Rule 8-d—Corrections shall be applied to working standards when used for testing service watt-hour meters. The working standard must be correct within 1 per cent or must be adjusted if possible.

Rule 10—Service meters shall not make more than one revolution on no load and shall have an average error less than 2 per cent plus or minus. The error at heavy load shall be within 1 per cent plus or minus, and the error at light load shall be within 4 per cent, plus or minus, for direct-current meters and within 3 per cent, plus or minus, for alternating-current meters.

Indiana

Rule 11—Working standards shall be correct within 1 per cent or corrections shall be applied.

Rule 13—Service watt-hour meters shall not creep and shall have an error less than 4 per cent, plus or minus, on light load, and 1 per cent, plus or minus, on heavy load. The average error shall be not over plus or minus 2 per cent.

Maryland

Rule E-2—Working standards shall be maintained in proper condition for testing service watt-hour meters.

Rule 6-b—Service watt-hour meters shall be adjusted within 1 per cent at light and full loads when found in error more than 2 per cent.

Massachusetts

Section 120—A meter shall be deemed correct for the purpose of this section if it appears from examination or test that it does not vary more than 5 per cent from the standard approved by the department.

Michigan

Rule 45-e—Working standards shall be within 1 per cent correct or corrections shall be applied.

Rule 28—Service watt-hour meters shall not creep and shall have an average error within 2 per cent, plus or minus. The error at heavy load shall be within 1 per cent, plus or minus, and the error at light load shall be within 3 per cent, plus or minus.

Missouri

Rule 35—Corrections shall be applied to all working standards when used to check service watt-hour meters.

Rule 29—Watt-hour meters shall be adjusted as accurately as possible on light and full load.

If it becomes necessary to make adjustment for normal load or for inductive load, the meter may be adjusted fast at light or full load, but such adjustment must not exceed 2 per cent.

Rule 31—Meters tested after being in service may be considered as recording within allowable limits if correct within 4 per cent. After such test the accuracy must be adjusted according to Rule 29.

Montana

Rule 27—Working standards shall have an error of less than 1 per cent or corrections shall be applied.

Rule 24—Service meters shall have errors within 4 per cent and shall not creep.

New Hampshire

Rule 9—Working standards shall be maintained correct within one-half of 1 per cent, or corrections shall be applied.

Rule 2—Service watt-hour meters shall have an error less than 4 per cent at light, normal or heavy loads.

New Jersey

Rule XIX—Corrections shall be applied to all working standards when used to check service watt-hour meters.

Rule XX—Service watt-hour meters shall have an error less than 4 per cent, plus or minus, and shall not creep.

New York

Case No. 278—1921

Section 27—Corrections shall be applied to working standards when used to check service meters.

Section 22—Service watt-hour meters shall be adjusted to register with an error not more than 1 per cent at 10 per cent and at 100 per cent capacity, and shall be maintained in this condition as nearly as possible.

North Dakota

Rule 11-c—Working standards shall not have an error greater than 1 per cent.

Rule 13-e—A service watt-hour meter having an average error of not more than plus or minus 4 per cent may be considered correct as far as adjustments of charges are concerned.

Oklahoma

Rule 12—Working standards shall be within 1 per cent correct or corrections shall be applied.

Rule 13-b—Service watt-hour meters shall have an average error less than 2 per cent and shall not creep.

Oregon

Rule 21-a—Meters shall be adjusted to be correct within 1 per cent at approximately three-quarters and one-tenth of rated load.

Pennsylvania

Rule XV—Corrections shall be applied to working standards at all times.

Rule XI—Service meters shall not have an error greater than 4 per cent and shall not creep.

South Carolina

Rule 13—Working standards shall be maintained in proper conditions to make accurate tests of service meters.

Rule 15-d—Service meters shall not have an error greater than 3 per cent, plus or minus, and shall not creep.

Washington

Rule E-11—Working standards shall not be in error more than 1 per cent, otherwise corrections shall be applied.

Rule E-12—Service meters shall not be in error more than 4 per cent between 10 per cent and full load, and shall not creep.

West Virginia

Rule 23—Working standards shall be maintained in proper condition for accurately testing service watt-hour meters.

Rule 24-a—Service meters shall have an error less than 1 per cent at light and normal loads, and shall not creep.

Wisconsin

Rule 19—Working standards shall be maintained within one-half of 1 per cent correct, or corrections shall be applied to all tests.

Rule 15—Service meters shall not be in error more than 4 per cent between 10 per cent and full connected load, and shall not creep.

Meter Locations

California

Rule 13-b—All meters shall be installed in some convenient place accessible for inspection, reading and testing.

Colorado

Rule 33—Meters shall be located in the cellar or first floor as near as possible to service entrance in a clean, dry place, not subject to vibration or great variations in temperature. Meters must not be set in coal or wood bins or on the partitions of same, or where meter readers or meter testers would annoy consumer.

When several meters are on one meter board, the distance between centers should be at least 15 in., and meters shall be not less than 4 ft. or more than 7 ft. above the floor. Meters may be placed out of doors if properly protected from the elements.

Connecticut

Rule E-11—Meters should be located in the cellar or first floor as near as possible to the service entrance in a clean, dry, safe place, not subject to great variations in temperature and free from vibration. Meters shall be accessible for reading and testing; they shall not be placed in coal or wood bins or on the partitions forming the same or on any unstable partitions or supports, nor in attics, sitting rooms, bedrooms, bathrooms, restaurant kitchens, over doors, over windows or in any location where the visits of the meter reader or tester will cause annoyance to the consumer.

District of Columbia

Rule 1—Meters shall be located as near as possible where the service enters and shall be accessible with a minimum of annoyance to the tenants and with sufficient space for testing apparatus. They shall be installed on a stable support in a clean, dry place, not subject to great variations in temperature nor great vibration. When more than one meter is on the same meter board, the distance between centers shall be not less than 15 in. for commutator type meters, or 12 in. for mercury type meters, or 10 in. for induction type meters.

Illinois

Rule 7—Meters shall be located in basement or on first floor as near as possible to service entrance. They must not be installed where the accuracy would be affected by exposure to the elements or in coal or wood bins or any partitions forming the same, or in attics, bedrooms, toilet rooms, over doors, over windows, or any place where the meter reader or tester would cause annoyance to the consumer.

Indiana

Rule 10—Meters shall be located in the cellar or first floor as near as possible to service entrance in a clean, dry place, not subject to vibration or great variations in temperature. They must not be set in coal or wood bins or partitions of same, or where meter readers and testers would annoy the consumer.

When several meters are on one board, the distance between centers shall be not less than 15 in., and no meter shall be less than 4 ft. or more than 7 ft. above the floor.

Meters may be installed out of doors if properly protected from the elements.

Michigan

Rule 19—Meters shall be installed in cellar or first floor as near as possible to service entrance in a clean, dry place, not subject to vibration or great variations in temperature; if installed out of doors they must be protected from the elements.

Rule 20—Meters shall not be less than 4 ft. nor more than 7 ft. above the floor and shall be easily accessible.

Rule 21—When more than one meter is installed on one meter board, there shall be a clearance between meters of 4 in. for horizontal dimensions and 6 in. for vertical dimensions. For direct current meters, the distance shall be such as to prevent errors due to current in adjacent meters.

Rule 22—Meters should not be placed in basements where the only entrance is through a trap door, or on lattice or metal lath partitions. Meters should not be placed in coal or wood bins or on the partitions of such bins, or in sheds, attics, bedrooms, bathrooms, toilet rooms, restaurant kitchens, stairways or ventilating shafts, or in any place where the visits of the meter reader will cause inconvenience either to the consumer or the meter reader.

Rule 23—Meters should not be placed over windows, doors, stoves, sinks, tubs or in any place subject to flyings or excessive moisture or other fumes. Where it is necessary to install them in places subject to flyings, moisture or fumes, they should be protected by a suitable inclosure. Meters should not be placed in the neighborhood of gas, steam, water or other piping, or near belts and moving machinery. They should be placed at least 10 ft. and, if possible, 15 ft. from any electrical machinery, and at least 18 in. from any conductors carrying a current exceeding 100 amperes, excepting such conductors as carry current to the meters concerned.

Rule 24—In cases where it is necessary to recess a meter in the wall, a cabinet shall be provided, the walls and doors of which must be made of some fireproof material.

Montana

Rule 21—Meters shall be installed in cellar or first floor in a clean, dry place free from vibration and great changes in temperature. They must not be installed in coal or wood bins or on the flimsy partitions forming the same. If installed in stores, they shall be located where merchandise will not be piled in front of them. Meters shall be accessible at all reasonable hours without annoyance to consumer.

When several meters are installed, they shall be grouped and be not less than 15 in. between centers, and they shall be joined to well marked, continuous conduit.

New Jersey

Rule XVII—Meters shall be located in the cellar or first floor as near as possible to service entrance. No meter shall be less than 3 ft. nor more than 7 ft. above the floor, and must not be installed in or on coal or wood bins or flimsy partitions or supports, nor in attics, bedrooms, bathrooms, etc., where meter readers or testers will inconvenience or annoy the consumer.

All meters shall be installed strictly according to the National Electrical Code, current edition.

New York

Case No. 2115-1917

1. Meters shall be installed in a clean, dry, safe place not subject to vibration or great variations in temperature.

2. Where it is necessary to install meters in locations exposed to weather conditions, they shall be protected by suitable boxes or cabinets.

3. Meters should be easily accessible for reading, testing and making necessary adjustments and repairs.

North Dakota

Rule 10—Meters shall be installed in cellar or first floor as near as possible to service entrance in a clean, dry place, free from vibration and great variations in temperature, where the visits by meter reader or tester will not annoy the consumer.

Where several meters are grouped they shall be not less than 15 in. between centers and not less than 4 ft. nor more than 7 ft. above the floor.

Oklahoma

Rule 11—Meters shall be installed in cellars or first floors at the service entrance in a clean, dry, safe place, free from vibration and great temperature variations, on a support furnished by the consumer and where the readers or testers will not annoy consumer. Meters may be installed on porches or out of doors if properly protected from the weather.

Where there are several meters they shall be not less than 12 in. between centers, and not less than 4 ft. nor more than 7 ft. above the floor.

South Carolina

Rule 12—Meters shall not be installed where it is extremely hot, cold or damp or inaccessible, or on unstable supports or in coal or wood bins.

Where meters are grouped on one meter board, they should be not less than 15 in. between centers, and each wiring loop shall be marked plainly.

The customer shall provide suitable location for the meters where they will be accessible without annoyance at any reasonable hour.

Washington

Rule E-10—All new meters shall be installed as near as possible to the service entrance in clean, dry, safe places not subject to great temperature variations or vibrations, or where reading or testing of the meters shall annoy the consumer.

West Virginia

Rule 26—Meters shall be installed as near as possible to the service entrance in a clean, dry place, easily accessible and not on flimsy partitions. A board at least ¾ in. thick with one or more coats of paint and mounted not less than 5 ft. and not more than 7 ft. from the floor shall be provided to hold the meter. There shall be a 6-in. clearance all around the meter board and 30 in. in front of it. All the meters for one building shall be grouped at one place.

Installation Tests

California

Rule 15—All meters shall be tested before installation.

Colorado

Rule 36—All meters shall be tested before installation or within 60 days thereafter.

Connecticut

Rule 4—Meters shall be tested before installation or within 60 days thereafter.

Rule E-16—Meters shall be checked within 60 days after installation for correct connections, proper mechanical conditions and suitability of location.

District of Columbia

Rule 5—Tests shall be made on all direct-current meters after installation, before large registration appears on meter. An installation test, or an installation inspection, shall be made on all induction type meters.

Illinois

Rule 13-a—Each meter shall be checked for correct connections, proper mechanical condition and suitability of location in its permanent location within 60 days of installation.

Indiana

Rule 14-a—Each meter shall be checked for correct connections, proper mechanical condition and suitability of location in its permanent location within 60 days of installation.

Maryland

Rule 6—Induction type meters shall be tested before installation or within 30 days thereafter. All other type meters shall be tested within 60 days after installation.

Michigan

Rule 33—All watt-hour meters and demand meters shall be checked in position at time of installation or within 30 days thereafter.

Rule 34—All watt-hour meters and demand meters operating on a highly inductive circuit shall be tested in position at time of installation, or within 30 days thereafter, on the connected load, approximating light and heavy loads, and shall be readjusted if necessary.

Missouri

Rule 29—Each meter shall be tested before installation or within 30 days thereafter, but preferably after it has been set, when it can also be checked for location, mechanical condition and correct connection. Commutator meters should be allowed when feasible to remain in actual service at least 5 days before testing.

Montana

Rule 22-c—Meters shall be tested just before installation or within 60 days thereafter.

New Hampshire

Rule 3—Meters shall be tested within 60 days of installation.

New Jersey

Rule XXIII—Meters shall be tested within 30 days after installation or just before installation.

New York

Case No. 278—1921

Section 7—Meters shall be tested and adjusted before installation or within 60 days thereafter. Direct-current meters shall be tested and adjusted within 60 days after installation.

North Dakota

Rule 14-a—Meters shall be tested at time of installation or within 60 days thereafter.

Oklahoma

Rule 16-a—Induction type meters shall be tested before installation or within 60 days thereafter. Direct-current meters shall be tested in place of permanent location within 60 days after installation.

Oregon

Rule 21-a—Meters shall be tested at time of installation or within 30 days.

Pennsylvania

Rule XIV—Meters shall be tested within 90 days before installation and 60 days after installation.

South Carolina

Rule 15-b—Meters shall be tested before installation.

Washington

Rule E-9-c—Meters shall be tested within 60 days after installation or immediately before installation.

West Virginia

Rule 24-a—Meters shall be tested before installation.

Wisconsin

Rule 16—Meters shall be tested within 30 days after installation.

Periodic Tests

Colorado

Rule 37—Direct-current meters up to and including 15 amperes shall be tested every 24 months.

Direct-current meters exceeding 15 amperes up to and including 500 amperes shall be tested every 18 months.

Direct-current meters exceeding 500 amperes shall be tested every 12 months.

Alternating-current, single-phase meters up to and including 25 amperes shall be tested every 36 months.

Alternating-current, single-phase meters exceeding 25 amperes shall be tested every 24 months.

Polyphase meters in circuits up to 50 kilovolt-amperes shall be tested every 24 months.

Polyphase meters in circuits exceeding 50 kilovolt-amperes shall be tested every 12 months.

Connecticut

Rule E-17—Direct-current meters up to and including 50 amperes shall be tested every 18 months.

Direct-current meters exceeding 50 amperes shall be tested every 12 months.

Alternating-current, single-phase meters up to and including 25 amperes shall be tested every 36 months.

Alternating-current, single-phase meters exceeding 25 amperes shall be tested every 24 months.

Polyphase self-contained meters up to and including 50 kilovolt-amperes rating shall be tested every 18 months.

Polyphase self-contained meters exceeding 50 kilovolt-amperes rating shall be tested every 12 months.

Polyphase meters with transformers connected in circuits up to and including 50 kilovolt-amperes shall be tested every 24 months.

Polyphase meters with transformers connected in circuits exceeding 50 kilovolt-amperes shall be tested every 18 months.

District of Columbia

Rule 7—Direct-current meters up to and including 25 amperes shall be tested every 30 months.

Direct-current meters exceeding 50 amperes and up to and including 500 amperes shall be tested every 18 months.

Direct-current meters exceeding 500 amperes shall be tested every 6 months.

Alternating-current, single-phase meters up to and including 25 amperes shall be tested every 48 months.

Alternating-current, single-phase meters exceeding 25 amperes shall be tested every 24 months.

Polyphase meters up to and including 50 kilovolt-amperes shall be tested every 24 months.

Polyphase meters exceeding 50 kilovolt-amperes shall be tested every 12 months.

Illinois

Rule 14—Direct-current meters up to and including 50 amperes shall be tested every 18 months.

Direct-current meters exceeding 50 amperes shall be tested every 12 months.

Alternating-current, single-phase meters up to and including 25 amperes shall be tested every 48 months if they meet the requirements of the Code for Electricity Meters, Third Edition. Otherwise they must be tested every 30 months.

Alternating-current, single-phase meters, exceeding 25 amperes shall be tested every 24 months.

Polyphase, self-contained meters up to and including 50 kilovolt-amperes shall be tested every 24 months.

Polyphase self-contained meters exceeding 50 kilovolt-amperes shall be tested every 12 months.

Polyphase meters with transformers connected in circuits up to and including 50 kilovolt-amperes shall be tested every 24 months.

Polyphase meters with transformers connected in circuits exceeding 50 kilovolt-amperes shall be tested every 18 months.

At the time the watt-hour meter is tested any demand meter associated with it shall be inspected or tested. Each demand meter shall be tested at least as often as the meter with which it is associated and as nearly as practicable at the same time.

Indiana

Rule 15—Direct-current meters up to and including 50 amperes shall be tested every 18 months.

Direct-current meters exceeding 50 amperes shall be tested every 12 months.

Alternating-current, single-phase meters up to and including 25 amperes shall be tested every 36 months.

Alternating-current single-phase meters exceeding 25 amperes shall be tested every 24 months.

Polyphase self-contained meters up to and including 50 kw. shall be tested every 18 months.

Polyphase self-contained meters exceeding 50 kw. shall be tested every 12 months.

Polyphase meters with transformers connected in cricuits up to and includng 50 kw. shall be tested every 24 months.

Polyphase meters with transformers connected in circuits exceeding 50 kw. shall be tested every 18 months.

Maryland

Rule 6—All induction type meters shall be tested once every 36 months. All other types of meters shall be tested once every 18 months.

Michigan

Rule 36—Direct-current type meters not over 50 amperes shall be tested every 24 months.

Direct-current type meters exceeding 50 amperes and up to and including 500 amperes shall be tested every 12 months.

Direct-current type meters exceeding 500 amperes shall be tested every 6 months.

Alternating-current, single-phase meters up to and including 25 amperes shall be tested every 48 months.

Alternating-current, single-phase meters exceeding 25 amperes shall be tested every 24 months.

Polyphase meters up to and including 50 kilovolt-amperes shall be tested every 24 months.

Polyphase meters exceeding 50 kilovolt-amperes shall be tested every 12 months.

Missouri

Rule 32—Induction type meters not exceeding 50 amperes shall be tested every 24 months.

Induction type meters exceeding 50 amperes shall be tested every 12 months.

Direct-current meters not exceeding 50 amperes and 250 volts shall be tested every 12 months.

All other types of meters shall be tested every 6 months.

Montana

Rule 23—Direct-current meters up to and including 25 amperes shall be tested every 24 months.

Direct-current meters exceeding 25 amperes shall be tested every 18 months.

Alternating-current, single-phase meters up to and including 25 amperes shall be tested every 36 months.

Alternating-current, single-phase meters exceeding 25 amperes shall be tested every 24 months.

Polyphase self-contained meters up to and including 50 kw. shall be tested every 18 months.

Polyphase self-contained meters exceeding 50 kw. shall be tested every 12 months.

Polyphase meters connected with instrument transformers shall be tested every 24 months.

New Hampshire

Rule 4—Induction type single-phase meters up to and including 50 amperes shall be tested every 24 months.

Induction type single-phase meters exceeding 50 amperes shall be tested every 12 months.

Polyphase meters up to and including 25 amperes shall be tested every 24 months.

Polyphase meters exceeding 25 amperes shall be tested every 12 months.

Direct-current meters of all ratings shall be tested every 12 months.

New Jersey

Rule XVIII—Direct-current meters up to and including 25 amperes shall be tested every 13 months. (This figure is a typographical error in the original Public Utility Commission Publication. The correct figure in effect in New Jersey is 18 months.)

Direct-current meters exceeding 25 amperes up to and including 500 amperes shall be tested every 12 months.

Direct-current meters exceeding 500 amperes shall be tested every 6 months.

Alternating-current single-phase meters up to and including 50 amperes shall be tested every 48 months.

Alternating-current single-phase meters exceeding 50 amperes shall be tested every 24 months.

Polyphase meters up to and including 150 amperes shall be tested every 24 months.

Polyphase meters exceeding 150 amperes shall be tested every 12 months.

New York

Case No. 278—1921

Section 8—All direct-current meters installed on customer's premises shall be periodically tested as follows:

(a) Meters up to and including 25 amperes shall be tested every 30 months.

(b) Meters exceeding 25 amperes up to and including 200 amperes shall be tested every 18 months.

(c) Meters exceeding 200 amperes up to and including 400 amperes shall be tested every twelve months.
(d) Meters exceeding 400 amperes shall be tested every six months.

Section 9—All alternating-current meters installed on customer's premises shall be periodically tested as follows:

(a) Single-phase meters up to and including 25 amperes shall be tested every 60 months.
(b) Single-phase meters exceeding 25 amperes shall be tested every 24 months.
(c) Polyphase meters up to and including 150 amperes shall be tested every 24 months.
(d) Polyphase meters exceeding 150 amperes shall be tested every 12 months.
(e) Single-phase or polyphase meters up to and including 100 kw. on circuits having a voltage of 2000 volts and over shall be tested every 12 months.
(f) Single-phase or polyphase meters exceeding 100 kw. on circuits having a voltage of 2000 volts and over shall be tested every six months.

North Dakota

Rule 15—Direct-current meters up to and including 50 amperes shall be tested every 18 months.

Direct-current meters exceeding 50 amperes shall be tested every 12 months.

Alternating-current single-phase meters up to and including 25 amperes shall be tested every 36 months.

Alternating-current single-phase meters exceeding 25 amperes shall be tested every 24 months.

Polyphase self-contained meters up to and including 50 kw. shall be tested every 18 months.

Polyphase self-contained meters exceeding 50 kw. shall be tested every 12 months.

Polyphase meters with transformers up to and including 50 kw. shall be tested every 24 months.

Polyphase meters with transformers exceeding 50 kw. shall be tested every 18 months.

Oklahoma

Rule 17—Direct-current meters up to and including 50 amperes shall be tested every 24 months.

Direct-current meters exceeding 50 amperes up to and including 500 amperes shall be tested every 18 months.

Direct-current meters exceeding 500 amperes shall be tested every 6 months.

Induction type meters, single-phase, up to and including 25 amperes shall be tested every 48 months.

Induction type meters, single-phase, exceeding 25 amperes shall be tested every 24 months.

Polyphase meters up to and including 50 kilovolt-amperes shall be tested every 24 months.

Polyphase meters exceeding 50 kilovolt-amperes shall be tested every 12 months.

Polyphase meters with transformers up to and including 50 kilovolt-amperes shall be tested every 24 months.

Polyphase meters with transformers exceeding 50 kilovolt-amperes shall be tested every 18 months.

Oregon

Rule 22—Single-phase meters up to and including 50 amperes shall be tested every 36 months.

Single-phase meters over 50 amperes shall be tested every 12 months.

Polyphase meters not exceeding 550 volts and 50 amperes shall be tested every 12 months.

Direct-current meters not exceeding 550 volts and 50 amperes shall be tested every 12 months.

All other meters shall be tested every 6 months.

Pennsylvania

Rule XVI—Direct-current meters up to and including 50-amperes shall be tested every 18 months.

Direct-current meters exceeding 50 amperes shall be tested every 12 months.

Alternating-current single-phase meters up to and including 25 amperes shall be tested every 36 months.

Alternating-current single-phase meters exceeding 25 amperes shall be tested every 24 months.

Polyphase self-contained meters up to and including 50 kw. shall be tested every 18 months.

Polyphase self-contained meters exceeding 50 kw. shall be tested every 12 months.

Polyphase meters with transformers up to and including 50 kw. shall be tested every 24 months.

Polyphase meters with transformers exceeding 50 kw. shall be tested every 18 months.

South Carolina

Rule 16—Direct-current meters up to and including 50 amperes shall be tested every 18 months.

Direct-current meters exceeding 50 amperes shall be tested every 12 months.

Alternating-current single-phase meters up to and including 25 amperes shall be tested every 36 months.

Alternating-current single-phase meters exceeding 25 amperes shall be tested every 24 months.

Polyphase self-contained meters up to and including 50 kw. shall be tested every 18 months.

Polyphase self-contained meters exceeding 50 kw. shall be tested every 12 months.

Polyphase meters with transformers up to and including 50 kw. shall be tested every 24 months.

Polyphase meters with transformers exceeding 50 kw. shall be tested every 18 months.

Washington

Rule E-14—Direct-current meters up to and including 25 amperes shall be tested every 24 months.

Direct-current meters between 25 amperes and 200 amperes shall be tested every 18 months.

Direct-current meters exceeding 200 amperes up to and including 400 amperes shall be tested every 12 months.

Direct-current meters exceeding 400 amperes shall be tested every 6 months.

Alternating-current single-phase meters up to and including 25 amperes shall be tested every 60 months.

Alternating-current single-phase meters exceeding 25 amperes up to and including 75 amperes shall be tested every 36 months.

Alternating-current single-phase meters exceeding 75 amperes shall be tested every 24 months.

Polyphase meters up to and including 50 kw. shall be tested every 36 months.

Polyphase meters exceeding 50 kw. up to and including 150 kw. shall be tested every 24 months.

Polyphase meters exceeding 150 kw. shall be tested every 12 months.

Alternating-current meters in circuits exceeding 2000 volts shall be tested every 12 months.

West Virginia

Rule 27—Direct-current meters up to and including 25 amperes shall be tested every 18 months.

Direct-current meters exceeding 25 amperes up to and including 500 amperes shall be tested every 12 months.

Direct-current meters exceeding 500 amperes shall be tested every 6 months.

Alternating-current single-phase meters up to and including 25 amperes shall be tested every 36 months.

Alternating-current single-phase meters exceeding 25 amperes shall be tested every 24 months.

Polyphase meters exceeding 50 kw. shall be tested every 12 months.

Wisconsin

Rule 17—Alternating-current single-phase meters up to and including 50 amperes shall be tested every 48 months

Alternating-current single-phase meters exceeding 50 amperes shall be tested every 12 months.

Polyphase meters in circuits under 250 volts and 50 amperes rating shall be tested every 12 months.

Direct-current meters in circuits under 250 volts and 50 amperes rating shall be tested every 12 months.

All other types of meters shall be tested every 6 months.

Request and Referee Tests

California

Rule 15—Each utility will make a test on service meters upon consumers' requests.

Colorado

Rule 38—Each utility will test service meters upon request of consumer, if more than than 12 months have elapsed since the last regular test.

Rule 39—Public Service Commission will test consumer's meter upon written application to the Commission.

Connecticut

Rule 5—Utilities will test service meters upon written request of the consumer if more than one year has elapsed since last test.

The Public Service Commission will test service meters upon formal petition to the Commission.

District of Columbia

Rule 6—Each utility will test consumers' meters upon request if not more often than every 6 months.

Rule 10—Public Service Commission will test service meters upon formal application.

Idaho

Request tests shall be made when not requested oftener than twice a year.

Illinois

Rule 15—Each utility will test consumer's meter upon request if not within 6 months of last previous test.

Rule 16—Public Service Commission will test service meters upon written application.

Indiana

Rule 16—Each utility will test consumer's meter upon request if not more often than once every 12 months.

Rule 17—The Public Service Commission will test service meters upon formal application to the Commission.

Maryland

Rule 5—Each utility will make test of consumer's meter upon request, if meter has not been checked within one year.

The Public Service Commission will test service meters upon written formal application to the Commission.

Massachusetts

Section 120—Public Utility Commission will test service meters upon application.

Michigan

Rule 50—Utility will test consumer's meter upon request if not more often than once in six months.

Rule 51—Public Service Commission will test service meters upon formal application to the Commission.

Missouri

Rule 33—Utility shall make test of consumer's meter upon request if it has not been tested within 6 months. The consumer shall be notified of the time of test so that he may witness the test if he desires.

Rule 34—Upon written request to the School of Engineering of Missouri State University a referee test will be made on any service meter.

Montana

Rule 25—Utility will make test of consumer's meter upon request if not more often than once in 12 months.

The Public Service Commission will test any service meter upon written application to the Commission.

New Hampshire

Rule 5—Utility will make test of consumer's meter upon request if not more often than once in 6 months.

Rule 6—The Public Service Commission will make a test of any service meter upon formal application to the Commission.

New Jersey

Rule XXV—Utility will test consumer's meter upon request if not more often than 6 months.

Rule XXVI—The Public Service Commission will test any service meter upon formal application to the Commission.

New York

Case No. 278—1921

Section 1—A complaint test is a test of a meter made by an electrical corporation on the premises where the meter is installed, as a result of a complaint of the consumer.

North Dakota

Rule 16—Utility will test consumer's meter upon request if not more often than once in 12 months.

Rule 17—The Public Service Commission will test any service meter upon formal application to the Commission.

Oklahoma

Rule 18—Utility will test consumer's meter upon request if not more often than once each year.

Rule 19—The Public Service Commission will test any service meter upon formal application to the Commission.

Oregon

Rule 5-a—Utility shall test consumer's meter upon request if the meter has not been tested within a year, either by the utility or by the Commission.

Rule 5-b—Commission will make test for a fee.

Pennsylvania

Rule XVIII—Utility will test consumer's meter upon request of consumer.

South Carolina

Rule 17—Utility will test consumer's meter upon request if not more often than once in 6 months.

West Virginia

Rule 29—Utility will make test of consumer's meter upon request if not more often than once in 12 months.

Rule 28—The Public Service Commission will test any service meter upon formal application.

Wisconsin

Rule 20—Utility will test consumer's meter upon request if not more frequent than every 6 months.

Rule 21—The Public Service Commission will test any service meter upon written application to the Commission.

Original Test Records

Colorado

Rule 6-b—The original meter test record shall be kept with identification data reasons for the test, reading of the meter if removed and all necessary data to permit check on the methods and calculations of the test.

Connecticut

Rule 3-c—Original records of service meter tests shall be preserved and shall show the following:

1st—Identification of meter
2nd—Reading of meter
3rd—Computed accuracy "as found" and "as left"
4th—Sufficient data to permit the checking of methods and computations.

District of Columbia

Rule 8—A complete record shall be kept of all tests of meters made on consumers' premises.

Illinois

Rule 3-a—Records shall be kept of all tests for accuracy of meters and shall include the following:

1st—Identification data
2nd—Reason for test
3rd—Time and reading of meter
4th—Person making the test
5th—Statement about creepage
6th—accuracy "as found" and "as left" in tenths of 1 per cent and necessary data for checking methods of calculation.

Indiana

Rule 8-a—The original record shall be kept to identify each meter, reason for the test, the reading of the meter, the result of test and sufficient data to check method and calculation.

Maryland

Rule F-3—The original test record shall be kept showing the following:

1st—Identification of meter
2nd—Reason for test
3rd—Reading of meter
4th—Result of test
5th—Data for checking methods and calculation.

Massachusetts

Original test records shall be kept six (6) years.

Michigan

Rule 17—Original records of all meter tests shall be kept showing the following:

1st—Identification data
2nd—Reason for test
3rd—Reading of dial before and after test
4th—Accuracy before and after adjustment
5th—Data for checking test.

Missouri

Rule 2—Original test records shall be kept for at least two years and shall include the following:

1st—Identification data
2nd—Date and place of test
3rd—Person making the test
4th—Reason for the test
5th—Method of test
6th—Reading of meter before test
7th—Statement about creepage
8th—Result of test and data to allow check on calculation.

Montana

Rule 28-a—A complete record shall be kept showing the following:

1st—Identification data
2nd—Reason for test
3rd—Reading of meter
4th—Result of test
5th—Necessary data for checking methods employed.

New Hampshire

Rule 10—Original test records shall be kept showing identification, reasons for test, reading of meter, statement on creepage and all data to permit check on methods of calculation.

New Jersey

Rule XXIV—A complete record shall be kept of all tests.

New York

Case No. 278—1921

Section 6—A record of tests of each meter shall be continuous for a period of not less than 5 years, and in any event of sufficient length to cover three consecutive periodic tests.

North Dakota

Rule 8-a—A record shall be kept showing the following:

1st—Identification data
2nd—Reason for test
3rd—Reading of meter
4th—Result of test
5th—Data for checking methods and calculations.

Oklahoma

Rule 20-c—A complete record shall be kept of all tests made on electric meters for at least two periodic test periods.

Oregon

Rule 3—All original meter test records shall be kept accessible to the public and shall include:

1st—Date and hour of test
2nd—Name of tester
3rd—Number and capacity of meter
4th—Identification
5th—Reason for test
6th—Reading of meter
7th—Accuracy and necessary data for checking the calculations.

South Carolina

Rule 4-a—A complete record shall be kept of all tests and inspections made on consumers' premises.

Washington

Rule E-17—A complete record shall be kept of all tests of electric meters.

West Virginia

Rule 25—A complete record shall be kept of all tests with sufficient data for checking the tests and calculations. Such records shall be reported monthly to the Commission.

All electric meters shall be given a company number.

Wisconsin

Rule 18—Original test records shall be kept to identify each meter, reasons for test, reading of meter, statement on creepage and sufficient data to permit the checking of methods and calculations.

Meter Records

Colorado

Rule 6—Meter record shall show the following:

1st—Date of purchase of meter
2nd—Manufacturer's serial number
3rd—Record of use
4st—Tests made on meter
5th—Present location of meter.

Rule 38—A record shall be kept of all request tests.

Connecticut

Rule 3-d—Meter records shall be systematically arranged showing the following:

1st—Approximate date of purchase
2nd—Size or capacity of meter
3rd—Various places of installation
4th—Date of each repair, adjustment or test
5th—Reason for each test
6th—Result of each test.

All records other than those as above specified shall be preserved at least three years. Those specified above shall be kept until meter is destroyed or permanently removed from service.

District of Columbia

Rule 8—Meter records shall contain the following:
1st—Company number
2nd—Manufacturers' name and serial number
3rd—Type, volts, amperes and wire
4th—Average readings at light load, normal load and full load
5th—Date meter was installed and removed.

Rule 9—A monthly report of all tests shall be sent to the Commission on or before the 15th of the month.

Illinois

Rule 2—Meter and associated apparatus records shall include the following:
1st—Date of purchase
2nd—Company's number
3rd—Nameplate data
4th—Places of installation with the dates of installation and removal and the reason for the removal
5th—Dates and results of tests, repairs and final disposition.

Rule 3-b—Each utility with more than 250 meters shall make monthly and annual tabulations of the results of all tests on consumers' premises except initial tests and shop tests.

Rule 5-b—A complete record shall be kept of all complaints, including the name and address of consumer, the date, the nature of the complaint and the disposal of same.

Indiana

Rule 8-b—A numerical record shall be kept giving the following:
1st—Date of purchase
2nd—Identification
3rd—All tests on meters.

Rules 8-c—Annual tabulations of test results arranged according to types and intervals shall be made.

Rule 7—A record shall be kept of all complaints in regard to service, giving the name and address of the consumer, the date, the nature of complaint and the remedy.

Rule 9—Reports shall be submitted to the Commission as required.

Massachusetts

Meter records shall be kept six years.

Maryland

Rule F-4—A numerically arranged record shall be kept showing:
1st—Date of purchase of meter
2nd—Record of use and repairs
3rd—Results of tests
4th—Present location of meter.

Rule G—Reports shall be made to the Commission as and when called upon by the Commission.

Rule I—A record shall be kept of all complaints showing:
1st—Name and address of complainant
2nd—Date of complaint
3rd—Character of complaint
4th—Adjustment made.

Michigan

Rule 16—Records of meters owned or used shall be kept numerically arranged and properly classified, showing:
1st—Identification number
2nd—Date of purchase
3rd—Manufacturer
4th—Serial number
5th—Type and rating
6th—All installations and removals of the meter with names of consumers
7th—All tests and their results.

Rule 18—A periodic summary of all tests shall be made showing meters classified as to manufacturer, type, accuracy limits, intervals between tests and other information which may be conveniently summarized.

Rule 50—A record shall be kept in the utility office of all request tests.

Missouri

Rule 2—An alphabetical record shall be kept of all consumers with addresses and identification numbers of meters in use by consumers.

A numerical record shall be kept in accordance with the utility's numbers, indicating a proper description, date of purchase, record of use, repairs, adjustments and tests and present location of meter.

Montana

Rule 28-c—A numerically arranged record shall be kept showing:
1st—Date of purchase of meter
2nd—Identification number
3rd—Tests and results.

Rule 28-d—Annual tabulations or results of all tests shall be kept according to types of meters and intervals of tests.

Rule 29—Records shall be kept of all complaint tests and their disposal.

New Hampshire

Rule 10—A meter record shall be kept arranged numerically, showing:
1st—Purchase date
2nd—Identification
3rd—Places of installation and removal
4th—Dates and results of all tests.

New Jersey

Rule XXIV—A complete record shall be kept of all tests.

A periodic report shall be made to the Board giving a summary of the periodic, complaint and removal tests each month when more than 500 meters are involved, and quarterly when less than 500 meters are involved.

New York

Case No. 278—1921

Section 5—A meter record shall be kept showing:
1st—Owning company's number
2nd—Manufacturer's name and number
3rd—Type, rated volts, amperes and wire
4th—Date of each installation, removal and test.
5th—Average of the readings at full load, at light load and at normal load as found at each and every test, hereinafter prescribed.

North Dakota

Rule 8-b—A numerically arranged record shall be kept showing:

1st—Date of purchase of meter
2nd—Identification number
3rd—Tests and results.

Rule 8-c—Annual tabulation of test results shall be arranged according to types of meters and intervals of tests.

Rule 7—A record shall be kept of all complaint tests and disposal of same.

Oklahoma

Rule 20-a—A meter record shall be kept showing:
1st—Names and addresses of consumers with company serial numbers of the meters used by them
2nd—Date of purchase of meters, installation and removal.

Rule 20-b—A record shall be kept showing:
1st—Utility's number of meter
2nd—Manufacturer's name and serial number
3rd—Type and capacity

4th—Constants
5th—Date and kind of tests
6th—Per cent accuracy at heavy and light loads "as found" and "as left."

Rule 20-d—Such reports as are required shall be submitted to the Commission.

Oregon

Rule 3-c—A systematic record must be kept showing the following:
1st—Date of purchase
2nd Capacity and identification
3rd—Places of installation and removal
4th—Dates and general results of tests.

Pennsylvania

Rule XIII—Records shall be kept showing:
1st—Name of manufacturer
2nd—Type and rating
3rd—Date of purchase
4th—Date and location of all installations and removals
5th—Dates of all tests
6th—Reasons for tests
7th—Error "as found" and "as left."

Rule VI—A record shall be kept of all complaints from consumers regarding service and shall show the name and address of complainant, date and nature of complaint and the action taken with the date.

South Carolina

Rule 4-b—Records shall be kept showing:
1st—Date, time and place of test
2nd—Name of person making test
3rd—Result of test.

Rule 5—Each utility shall make reports to Commission as ruled.

Washington

Rule E-17—A record shall be kept showing:
1st—Utility's number of meter
2nd—Manufacturer's name and number
3rd—Type, volts, amperes and wire
4th—Date of each installation, removal and test
5th—Average of readings at full load and light load.

A test card shall be filed for each portable standard meter.

A copy of the approved form of calibration card for indicating and rotating reference standards shall be filed with the Commission.

West Virginia

Rule 25-d—A separate card for each meter shall be kept on file showing the date and data of each test with a marker showing the date for the next periodic test.

Wisconsin

Rule 18—All utilities with more than 250 meters in service shall have a numerically arranged record showing:
1st—When the meter was purchased
2nd—Identification of meter
3rd—Places of installation and removal
4th—Dates and results of all tests.

A monthly tabulation and an annual tabulation shall be made of the results of all tests according to types of meters and intervals of tests.

Adjustment of Bills

California

Rule 16—When meters are more than 2 per cent fast a refund shall be made to the consumer for the overcharge for the period meter was incorrect; this period shall not exceed six months.

If meter does not register more than 75 per cent of the actual consumption, the average amount not registered may be estimated and billed the consumer, subject to review of the Commission.

If the meter is more than 2 per cent slow, the utility may render a bill for the extra due, not to exceed a period of three months and subject to review by the Commission.

Colorado

Rule 40—When a meter is faster than 3 per cent, a refund shall be made to the consumer for the excess for a period equal to one-half of elapsed time since the last previous test, but not to exceed six months.

When a meter is slower than 3 per cent, the utility may charge consumer for the kilowatt-hours incorrectly metered for one-half of the time elapsed since the last test; such period not to exceed six months.

If the meter does not run, the utility may estimate the amount used by reference to previous periods and render bill to consumer.

Connecticut

Rule 6—When a meter is faster than the prescribed limits, the utility shall refund to the consumer the excess of the bills for the past six months, unless it can be found that the error existed for a greater or lesser period, in which case refund shall cover that period.

District of Columbia

Rule 10-a—The electric company shall make an adjustment for all meters registering fast in excess of 4 per cent; the adjustment to be based on the three previous months' bills.

Illinois

Rule 17—If a meter is found faster on any test than 4 per cent, the utility shall refund any overcharge during six months previous or the length of time since installation if it be less than six months, unless inaccuracy can be definitely determined to be for another period.

If meter is found slower than 4 per cent, the utility may, with certain limitations, render bill to the consumer covering the estimated consumption which had not been registered during the previous six months.

If meter is found creeping, an estimate of the amount shall be made and a refund granted.

If a demand meter shows more than 4 per cent error, an adjustment of charges is made, the same as for service meters. The error of the demand meter shall be determined in conjunction with the accuracy of the watt-hour meter when the demand meter is actuated by the watt-hour meter.

Indiana

Rule 19—If on any test a meter is found faster than 4 per cent, the excess charged for a period equal to one-half the time elapsed since the last test, but not to exceed six months, shall be refunded to the consumer.

If a meter is found slower than 4 per cent, the utility may charge consumer for the kilowatt-hours incorrectly metered for one-half the time elapsed since the last test, but not to exceed six months.

If meter is found not registering, the utility may estimate the amount used from previous billing period and charge consumer; such action to be taken only in cases of substantial importance where the utility is not at fault in the use of defective meter.

Massachusetts

Section 120—The refund shall be such amount as, if not agreed upon, shall be determined by the Department upon the customer's application and after opportunity is given the vendor to be heard.

Michigan

Rule 53—When meters are found more than 4 per cent fast, the utility shall refund an amount equal to the excess for the time the error actually existed, or for one-half the time elapsed since the last test, but not to exceed six months.

When meters are more than 4 per cent slow, the utility may bill consumer an amount equal to the loss, for the time the error actually existed, or for one-half the time elapsed since the last previous test, but not to exceed six months.

If meter is found not registering, the utility may estimate the amount used from previous bills and charge the consumer, in cases where a substantial amount is involved and where the utility is not at fault, for allowing the incorrect meter to be in service. No part of a minimum service or demand charge incorrectly measured need be refunded.

Missouri

Rule 31—A meter found in service registering within 4 per cent of correct registration, when tested in accordance with Rule 29, will be regarded as recording within allowable limits.

Montana

Rule 26—When meters are found more than 4 per cent fast, a refund shall be made to the consumer for the excess charged for a period equal to one-half the time elapsed since the last test, but not to exceed six months.

When meters are found more than 4 per cent slow, the utility may charge consumer for the kilowatt-hours incorrectly metered for one-half the time elapsed since the last test, but not to exceed six months.

If a meter is found not registering, the utility shall estimate the amount used from previous bills and charge consumer.

New Hampshire

Rule 8—If a meter is over 4 per cent fast, the utility shall refund to the consumer the excess charged for the previous six months.

If meter is more than 4 per cent slow, the utility shall apply to the Commission for the authority to bill consumer for the electricity used for previous six months.

New Jersey

Rule XXII—When a meter is found more than 4 per cent slow, a refund shall be made to the consumer as follows:

1st—If the date meter first became incorrect can be definitely ascertained, the refund shall be the excess charged for that entire period.

2nd—In all other cases the refund shall be the excess charged during one-half the time elapsed since the last test.

North Dakota

Rule 19—When meters are found more than 4 per cent fast, a refund shall be made to the consumer for the excess charged for a period equal to one-half the time elapsed since the last test but not to exceed three months.

When meters are found more than 4 per cent slow, the utility may charge consumer for the kilowatt-hours incorrectly metered for one-half the time elapsed since the last test, but not to exceed three months.

If a meter is found not registering, the utility shall estimate the amount used from previous bills and charge consumer.

Oklahoma

Rule 36—If a meter is found more than 3 per cent fast, a refund shall be made to the consumer for the excess charged for a period equal to one-half the time elapsed since the last previous test, but not to exceed six months.

If a meter is found more than 3 per cent slow, the utility may charge consumer for the kilowatt-hours incorrectly metered for one-half the time elapsed since the last test, but not to exceed six months, only if excess is more than $0.50.

If a meter is found not registering, the utility may estimate the amount used from previous bills and charge the consumer.

If a meter is found creeping, the utility should estimate the amount used and refund to the consumer.

Oregon

Rule 6-a—When a meter is found more than 4 per cent fast, a refund of the excess shall be made for a period of three months.

Rule 6-b—If a meter does not register at all, or registers less than 50 per cent, an average bill may be rendered, subject to review by the Commission.

Pennsylvania

Rule XXIV—If a meter is found more than 4 per cent fast, the utility shall refund or allow consumer an amount equal to the excess charged from the date of test through entire period of current bill, or to date of trouble when exact time is known.

South Carolina

Rule 18—If a meter is found more than 4 per cent fast, a refund shall be made to the consumer for the excess charged for a period of 60 days and not exceeding 60 days.

If a meter is found more than 4 per cent slow, the utility may collect from the consumer the amount estimated to be due for a period not to exceed 60 days.

West Virginia

Rule 9—When the average error of a meter is more than 2 per cent fast, the utility shall re-calculate the monthly bills for a period equal to one-half the time elapsed since the last test, but it shall not exceed three months, and the excess shall be refunded to the consumer.

When a meter is found more than 2 per cent slow, the utility may re-calculate the monthly bill for a period equal to one-half the time elapsed since the last test but not more than three months, and collect the difference from the consumer.

Testing Fees

California

Rule 15—The following fees shall be charged for request tests if more often than every six months, and the monthly bills are less than $150.00:

Meters up to and including 10 amperes	$1.00
Meters 15 amperes to 25 amperes, inclusive	2.00
Meters over 50 amperes	3.00
Meters with transformers	5.00

If the meter is found to be more than 2 per cent fast or slow, the entire fee shall be refunded.

Colorado

Rule 39—For tests by the Commission the following fee shall accompany application and shall be refunded to the consumer by the utility, if the meter is found to be faster than the prescribed limits:

Single-phase and direct-current meters not over 600 volts and 25 amperes	$2.00
For each additional 50 amperes or fraction thereof	.50
Single-phase meters over 600 volts and polyphase meters not over 25 kw	3.00
For each additional 25 kw	3.00

Connecticut

Rule 5—For Commission tests $1.00 shall accompany petition. If the meter is found to be more than 4 per cent fast the utility will refund said fee to the petitioner.

District of Columiba

Rule 12—The following fee shall be charged for referee tests:

Meters less than 50 amperes	$1.00
All other types	2.00

If a meter is found more than 4 per cent fast at any of light, normal or full loads, the above fee deposited by the consumer will be returned, and the fee shall be paid by the utility owning the meter.

Idaho

If the variation does not exceed 3 per cent the expense of a referee test is borne in some cases by the consumer. If the variation exceeds 3 per cent fast, the expense is borne by the utility.

Illinois

Rule 16—For tests made by the Commission, the following fee shall accompany the application and shall be refunded to the customer by the utility if the meter is found more than 4 per cent fast:

Single-phase or direct-current meters not over 25 amperes and 650 volts	$2.00
For each 50 amperes additional	.50
Single-phase meters above 650 volts and polyphase meters not over 25 kv-a	3.00
For each additional 25 kv-a	.50

The fee for a demand meter test shall be $2.00, to be refunded by the utility if the indicator over-registers more than 4 per cent. No meter shall be disturbed by the utility after notice of application for referee test, unless written authority of consumer or Commission is obtained.

Indiana

Rule 17—For tests by the Commission $2.00 shall accompany the application and shall be refunded to the consumer if the meter is found faster than the allowable limit, and collected from the utility.

Fee for a demand meter test shall be $10 and shall accompany application. Fee shall be refunded to the consumer if the demand is less than fixed by the utility. The amount shall then be collected from the utility.

Maryland

Rule 5-b—For tests by the Commission $1.00 shall accompany the application. If the meter is more than 4 per cent fast, the deposit will be refunded to the consumer and collected from the utility.

Michigan

Rule 51—For tests by the Commission $5.00 shall accompany the application and shall be refunded to the customer and collected from the utility if the meter is found faster than the prescribed limits.

Missouri

Rule 34—The following fee shall be charged for tests made at the Missouri State University:

Single-phase and direct-current meters not over 25 amperes and without instrument transformers	$2.00
For other sizes a proportionately larger fee will be charged.	

If the meter is found fast, the utility will pay the fee plus cost of shipping meter, otherwise such expenses shall be borne by the consumer.

Montana

Rule 25-b—For tests by the Commission $2.00 shall accompany the application. If the meter is found faster than the allowable limit, the fee will be refunded to the consumer and collected from the utility.

New Hampshire

Rule 6—For tests by the Commission $1.00 shall accompany the application. This fee shall cover the test of a meter not over 250 volts and 25 amperes; all other sizes shall have a fee as stated by the Commission. This fee shall be refunded to the consumer and collected from the utility if the meter is found more than 4 per cent fast.

Rule 7—The Commission will test periodically any meters it desires and charge utility $0.50 for the rating given in the above rule.

New Jersey

Rule XXVI—For tests by the Commission $1.00 shall accompany the application and shall be refunded to the consumer and collected from the utility if the meter is found faster than the prescribed limits. The meter shall be opened and sealed by a representative of the utility.

New York

Public Service Commission Law 1910—*Chapter* 480

SCALE OF FEES FOR TESTING METERS

Amperes Rated Capacity	Fee
5 and 10	$1.50
15	2.00
20 and 25	2.50
30, 40 and 50	3.00
60 and 75	3.50
100	4.00

For each additional 25 amperes or fraction thereof, 50 cents.

Public Service Commission Law 1910—*Section* 67

If the meter tested is found to be more than 4 per cent in error, to the prejudice of the consumer, the expense shall be borne by the corporation or the municipality; otherwise the consumer shall bear the expense.

North Dakota

Rule 17-a—For tests by the Commission $5.00 shall accompany the application. If the meter is found faster than the allowable limit, the fee shall be refunded to the consumer and collected from the utility.

Oklahoma

Rule 19-a—The following fee shall be charged for tests made by the Commission:

Single-phase and direct-current meters not over 650 volts and 25 amperes	$2.00
For each additional 50 amperes	.50
Single-phase meters over 650 volts and polyphase meters not over 25 kv-a	3.00
For each additional 25 kv-a	.50

If the meter is found more than 3 per cent fast, average error, the fee will be refunded to the consumer and collected from the utility owning the meter.

Oregon

Rule 23—The following fees are to be deposited when tests are made by the Commission and are to be returned to the consumer and paid by the utility if the meter is found more than 4 per cent fast.

Meters up to 250 volts, 50 amperes	$2.00
Meters up to 100 amperes	4.00
All other meters	8.00

Pennsylvania

Rule XVIII—The following fee shall be charged for tests by the Commission to be paid by the consumer to the Commission if meter is correct, and borne by the utility if the meter is found incorrect.

Single-phase or direct-current meters not over 25 amperes or 600 volts	$1.50
For each additional 50 amperes or fraction thereof.	.50
Single-phase meters over 600 volts and polyphase meters not over 25 kw	2.50
For each additional 25 kw. or fraction thereof	2.50

South Carolina

Rule 17—There will be no charge for request tests except when the test is more often than six months or the consumer's monthly bill is less than $25.00, in which case the following fee will be charged if meter is less than 3 per cent fast:

Single-phase and direct-current meters up to 600 volts and not over 25 amperes	$1.50
Each additional 50 amperes or fraction thereof	.50
Single-phase meters over 600 volts and polyphase meters not over 25 kw	2.50
For each additional 25 kw	2.50

West Virginia

Rule 28-b—The following fee shall be charged for inspections by the Commission and shall be borne by the utility if the meter is found more than 2 per cent fast:

Single-phase and direct-current meters under 250 volts; up to and including 30 amperes	$1.50
30 amperes up to and including 100 amperes	3.00
For each additional 50 amperes or fraction	.75

Polyphase and single-phase or direct-current meters over 250 volts:

5 kw. and under	$1.00
5 kw. to 25 kw.	2.00
25 kw. to 100 kw.	6.00
100 kw. to 500 kw.	15.00
Over 500 kw.	30.00

Wisconsin

Rule 21—For referee tests the following fee shall accompany the application and shall be refunded to the consumer by the utility if the meter is found more than 4 per cent fast:

Single-phase and direct-current meters not over 250 volts and 25 amperes	$2.00
All others not exceeding 100 amperes	4.00
All other capacities	8.00

NEW DEVELOPMENTS
in
ELECTRICAL MEASURING DEVICES

The purpose of the following report on New Developments in Electrical Measuring Devices is to bring to the attention of those interested the results of a recent survey made by the Meter Committee.

No attempt has been made to verify the claims made for the devices described. Therefore, the Committee does not officially approve the various devices, but submits this material as worthy of consideration and investigation.

Single-Phase Watthour Meters

The accuracy of energy measurements has received attention consistent with its important place in the industry. The last few years have shown marked changes in the design of all American watthour meters. The efforts of the Meter Committee, N. E. L. A., to standardize terminal chambers and connections, as to size and position as outlined in Publication No. 278-16, are reflected in the announcements made here by the manufacturers. As to accuracy, the improvements have been along the lines of improved overload accuracy, temperature compensation, voltage variation and other electrical characteristics.

Type MD, Single-Phase, Watthour Meter Made by the Duncan Electric Manufacturing Co.

The Duncan Electric Manufacturing Co. has placed on the market an improved watthour meter known as the Type MD. It supersedes the Type M2 and is available in sizes from 5 to 75 amperes, inclusive. The external appearance of the Type MD meter is somewhat similar to that of the Type M2, differing only in the design of the nameplate and the terminal chamber. In the 5 to 25-ampere sizes the terminal chamber cover is die-cast and is so arranged that it may be swung down to give access to the terminals, or be removed entirely. Recently the design of the terminal chamber sealing screw was modified so as to permit the use of the lead, padlock, or ribbon type seal. This sealing screw, shown in Fig. 1, is loosened by the fingers in the same manner as a wingnut.

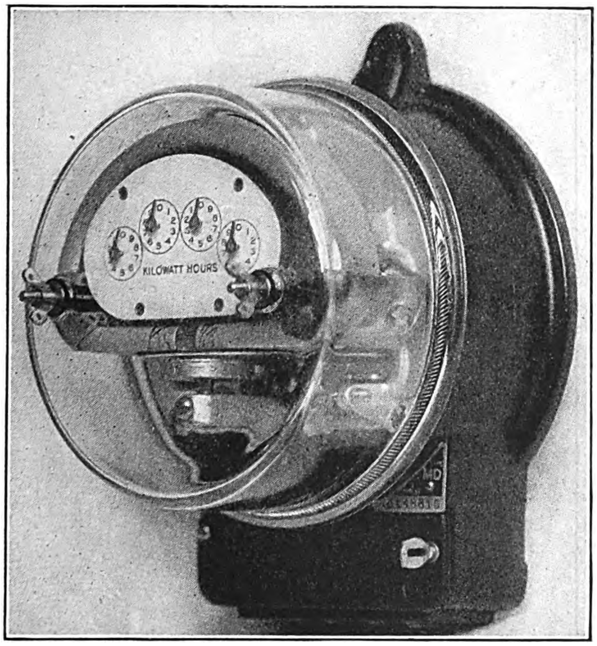

FIG. 1—TYPE MD, 5-AMPERE, SINGLE-PHASE WATTHOUR METER MADE BY THE DUNCAN ELECTRIC MANUFACTURING COMPANY.

In the 5 to 25-ampere sizes the potential and current electro-magnets are mounted on a sub-base, which is dowelled to the meter base as a unit, thus giving better accessibility for repairs. The manufacturer claims that the refinements in the design of the electro-magnets, and the reduction of the full load speed, gives the Type MD meter better performance characteristics than the Type M2 meter. The manufacturer further advises that in the near future the Type MD meter will be compensated for errors due to changes in ambient temperature, this compensation being equally effective at all power factors.

The base of the new 50 and 75-ampere meter, shown in Fig. 2, is a casting. The terminal chamber is designed to comply with the standards agreed upon by the Meter Manufacturers and the N. E. L. A. Meter Committee. In these sizes, as well as in the smaller sizes, the nameplates containing the meter rating, serial number, etc., are two small triangular shaped plates, riveted securely to the base, so as not to be disturbed by the removal of the terminal chamber cover. These sizes have the same full load speed as the 5 to 25-ampere sizes and similar characteristics.

Type I-16, Single-Phase, Watthour Meter Made by The General Electric Co.

The Type I-16 single-phase meter has superseded the Type I-14. It is characterized by its improved overload accuracy and refinement in mechanical design. Both two and three-wire meters of sizes up to and including 50 amperes are available. The meter is normally furnished for use at 60 cycles, but can also be furnished for 40 cycles. Since the improved load characteristics warrant their use on overloads, the series coils are designed to carry at least four times rated current. Two sizes of base

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Publication No. 289-47, Serial Report, Meter Committee.

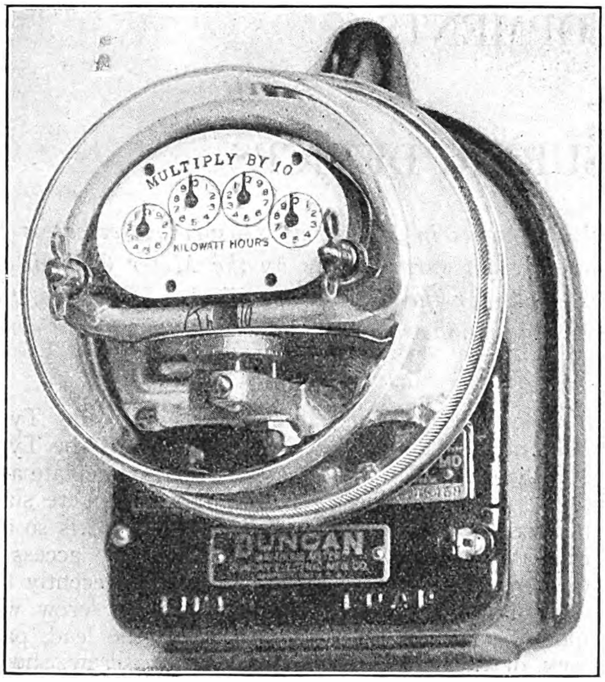


FIG. 2—TYPE MD, 75-AMPERE, SINGLE-PHASE WATTHOUR METER MADE BY THE DUNCAN ELECTRIC MANUFACTURING COMPANY.

are used, one for the 5 and 10-ampere meters, and the other for the 15, 25 and 50-ampere meters.

The cover is made of glass and has attached to its edge a tight fitting steel flange. This flange fits snugly around the meter base, and a slight twist locks it in place, making a dust and tamper-proof joint. The cover is thus fastened without the aid of sealing pins, wingnuts and washers. The terminal chamber cover is removable, but will not fall off. The meter cover and terminal chamber cover may be sealed separately, or a single seal may be used to seal both. Any commonly used type of seal may be used.

The manufacturer makes the following claims for the new electrical element:

1. Rigid mechanical construction
2. Large air gaps
3. Accessibility
4. Removable as a unit
5. Improved electrical performance.

A new magnet with high damping strength is used, and the meter operates at reduced speed. A micrometer full load adjustment moves the damping magnet bodily. A simple micrometer adjusting device, without clamping screws and accessible from the front, gives ample range of adjustment on light load. A lag adjustment is also provided.

The manufacturer claims high accuracy on overloads without any sacrifice in torque, thus insuring equally good accuracy at light loads. All meters are compensated for a temperature range of zero to 100 deg. fahr.

The terminals and bushings of the 5 and 10-ampere sizes are separate and removable; for the 15 to 50-ampere sizes they are assembled in a molded block. The potential test loop is omitted from the two-wire meters. Fig. 3 shows a 5-ampere, 110-volt Type I-16 meter.

Type HC, Single-Phase, Watthour Meter Made by The Sangamo Electric Co.

The Sangamo Electric Co. announces a new type of single-phase watthour meter known as the Type HC. In size, shape, appearance and general construction, it is the same as the Type H, but has improved performance. Aside from slight modifications, the electrical and magnetic circuits are the same as those of the Type H. Important parts, such as the full load and light load adjustments, etc., are interchangeable with those of the Type H, thus eliminating the necessity of adding to the stock of repair parts now on hand.

The manufacturer states that the outstanding changes and improvements in the Type HC may be listed under the following headings:

1. Complete temperature compensation on both inductive and non-inductive loads from 20 to 120 deg. fahr. There is no appreciable variation in accuracy at any power factor for the same temperature range.
2. Straight line accuracy characteristic up to 300 per cent of rated load.
3. The speed of the 60-cycle meter has been decreased so that both 25 and 60-cycle meters have the same disc constant, viz: 1200 watt-seconds for the 5-ampere, 110-volt meter.
4. Direction of rotation has been reversed for the purpose of standardization.
5. The metal cover is stiffer. This added rigidity is obtained by reinforcing the ribs around the studs and around the disc opening.

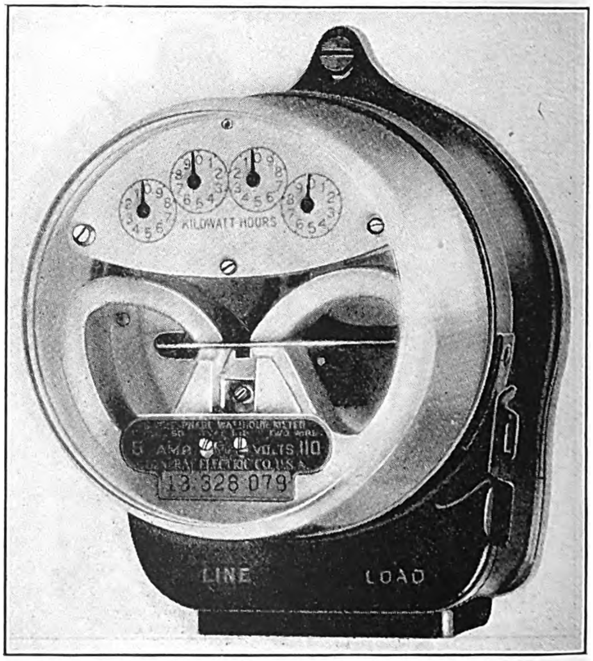


FIG. 3—TYPE I-16, SINGLE-PHASE, WATTHOUR METER MADE BY THE GENERAL ELECTRIC COMPANY.

6. Each permanent magnet is fitted with a flat clamp or locator, which is firmly swaged to the bottom of the magnet. The locator fits over two dowel pins in the grid, the magnet being accurately and positively fixed in position.
7. Although a slight increase has been made in the thickness of the disc, the weight of the moving system remains the same. This is accomplished by making the hub and spindle of duralumin.

Fig. 4 shows the Type HC watthour meter with cover and terminal cover plate removed.

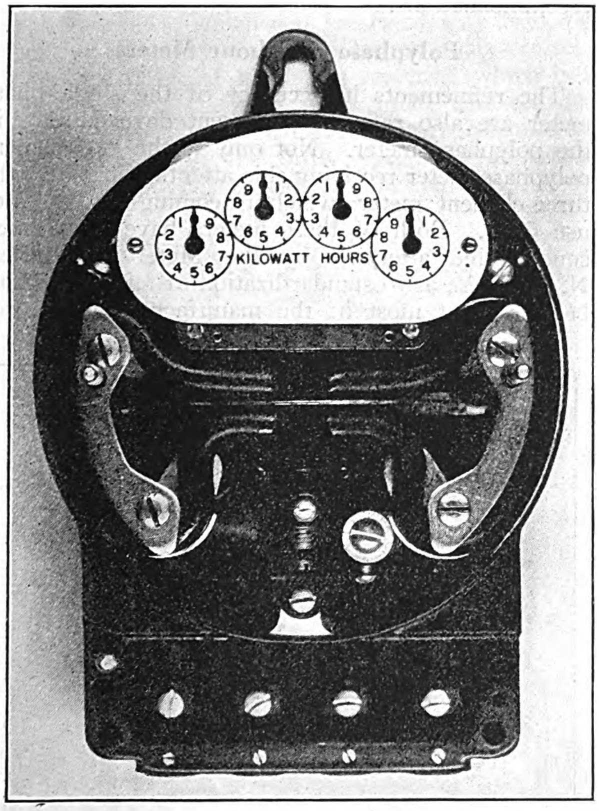


FIG. 4—TYPE HC, SINGLE-PHASE, WATTHOUR METER MADE BY THE SANGAMO ELECTRIC COMPANY—METER COVER AND TERMINAL CHAMBER COVER REMOVED.

Type OB, Single-Phase, Watthour Meter Made by The Westinghouse Electric & Manufacturing Co.

The Westinghouse Electric & Manufacturing Co. announces that it has made some marked improvements in the overload performance of its Type OB meters, previously reported. It is claimed that by making slight internal changes in the electromagnet, the accuracy characteristic has been made practically a straight line from light load to beyond 200 per cent of rated load. The characteristic watthour meter accuracy curve below full load has been retained, and other characteristics of the meter remain the same. The changes do not in any way affect the interchangeability of parts. The manufacturer also claims that the single-phase Type OB meters are now compensated for temperature errors.

The switchboard watthour meters using the Type OB element are available in both the single and polyphase forms. The single-phase meter is the same as the single-phase Type OB house service meter, with the exception that it does not have a terminal chamber. These switchboard meters are rear connected and are supplied with terminal studs which are suitable for steel panel or 2 in. slate panel mounting. The diameter of the single-phase meter is approximately 5 in. Fig. 5 shows a Type OB single-phase switchboard meter.

Two-Element, Three-Wire, Watthour Meters

The two-element, three-wire watthour meter has been developed to measure energy taken from two phases and the grounded neutral of a three-phase four-wire system. This meter also lends itself to the accurate measurement of three-wire, single-phase service, under conditions of unbalanced voltages and loads.

To meet this demand and to comply with the requirements of the user in respect to meter size and cost, the meter manufacturers have placed upon the market special two-element, three-wire meters.

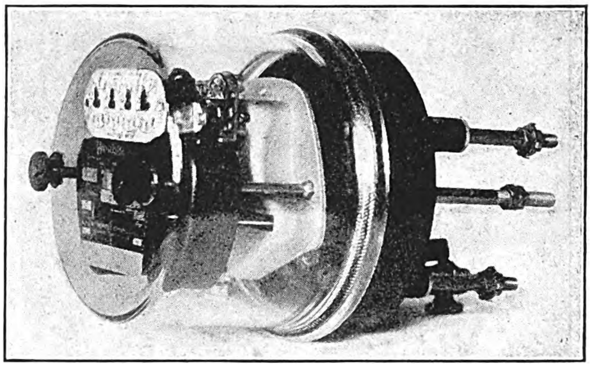


FIG. 5—TYPE OB, SINGLE-PHASE, WATTHOUR METER MADE BY THE WESTINGHOUSE ELECTRIC & MFG. CO.

Type I-18, Two-Element, Three-Wire, Watthour Meter Made by The General Electric Co.

A new two-element, three-wire meter, designated as Type I-18, is shown in Fig. 6. It is intended for metering three-wire service obtained from two-phases and neutral of a four-wire, three-phase system.

It consists of two single-phase I-16 meter elements mounted in one case. Its design features and performance characteristics agree in practically every detail with those of the single-phase Type I-16 meter. Certain new features, such as the cover locking and sealing device, are shown in Fig. 7. This meter has an improved element balancing micrometer adjustment. It is furnished in 5, 10, 15 and 25-ampere sizes.

Type HC, Two-Element, Three-Wire, Watthour Meter Made by The Sangamo Electric Co.

The Type HC is a bottom-connected, two-element, three-wire meter, having a terminal chamber of the

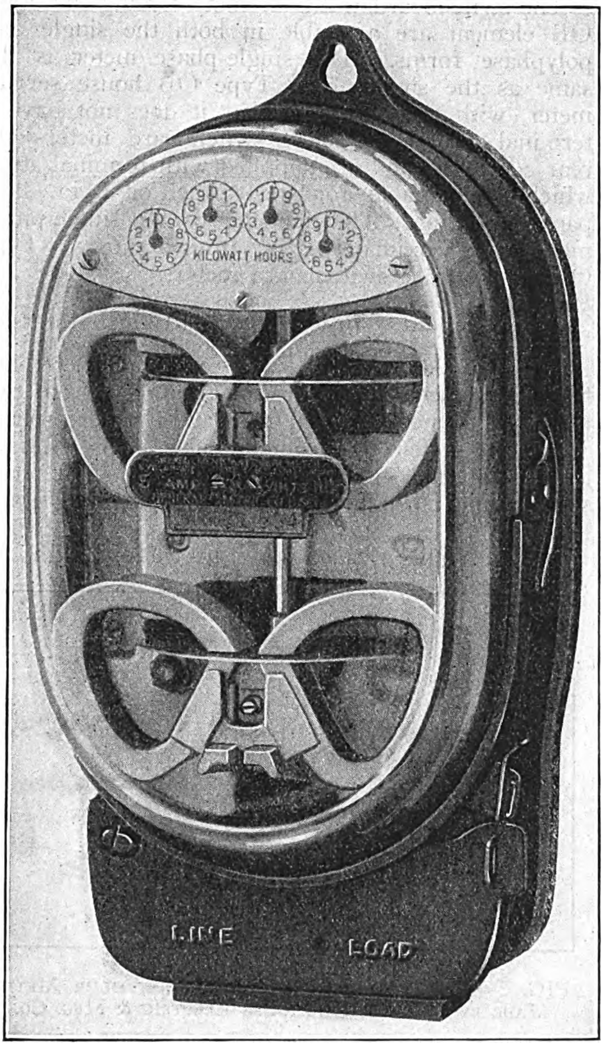


FIG. 6—TYPE I-18, TWO-ELEMENT, THREE-WIRE, WATTHOUR METER MADE BY THE GENERAL ELECTRIC COMPANY.

same dimensions as the corresponding two and three-wire single-phase meters. A base of a certain size is used for the 5 and 10-ampere meters, and a larger base is used for the 15 and 25-ampere meters. The dimensions are in agreement with the recommendations of the Meter Committee, N. E. L. A. on standardization of terminal chambers. Removable terminals are used.

This meter has the latest improvements of the HC type and is claimed to be fully compensated for temperature changes between 20 and 120 deg. fahr. The same full load, light load, inductive load and element balancing adjustments which are used in the polyphase meter are used in the new type meter. Parts will be partially interchangeable. This meter is shown in Fig. 8.

Type OB, Two-Element, Three-Wire, Watthour Meter Made by The Westinghouse Electric & Manufacturing Co.

Fig. 9 shows a two-element three-wire meter built by the Westinghouse Electric & Manufacturing Co., for metering energy taken from two phases and the grounded neutral of a three-phase four-wire system. It has two OB single-phase elements which drive two discs on a common shaft, and is designed to have the same accuracy, performance characteristics and adjustments as the single-phase Type OB meter, with the exception that each electro-magnet is provided with a micrometer phase balancing adjustment, such as used in the Type OB polyphase meter.

The base is made of cast iron. The terminal chamber is located at the bottom of the instrument to conform with Meter Committee, N. E. L. A., recommendations.

Polyphase Watthour Meters

The refinements in accuracy of the single-phase meter are also reflected in recent developments in the polyphase meter. Not only is the two-element polyphase meter receiving this attention, but also the three-element meter, which is coming into greater use daily. Both of these meters have been given considerable attention by the Meter Committee, N. E. L. A., as to standardization of terminal chambers, so that most of the manufacturers are pro-

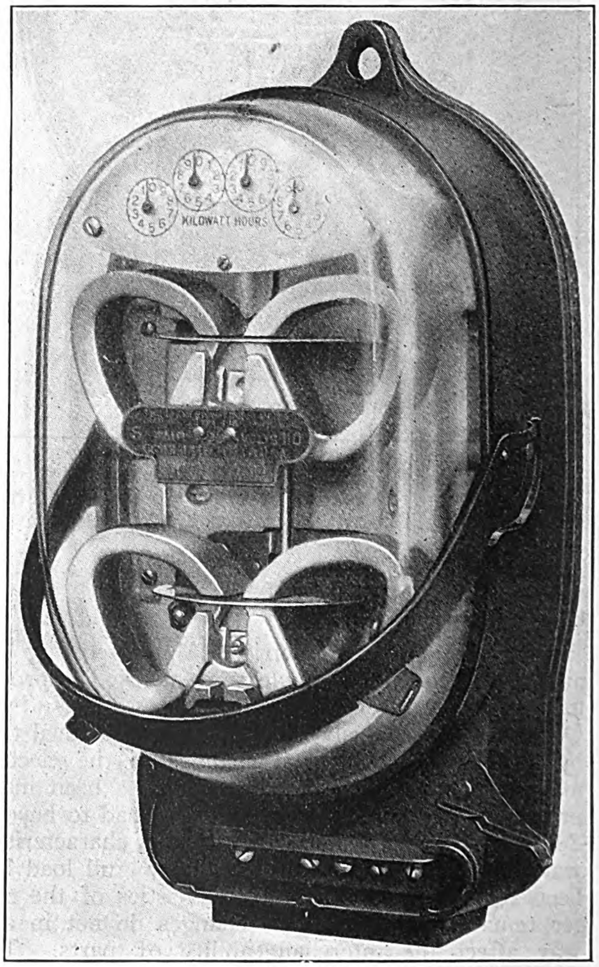


FIG. 7—TYPE I-18, TWO-ELEMENT, THREE-WIRE, WATTHOUR METER—SHOWING DETAILS OF COVER FASTENING DEVICE.

ducing bottom-connected polyphase meters of standard design.

Type MD, Polyphase, Watthour Meter Made by The Duncan Electric Manufacturing Co.

The Type MD polyphase watthour meter was shown to the Meter Committee at the October, 1928, meeting. It is expected that this meter will be in full production some time during the winter. It is of the bottom-connected type, as shown in Fig. 10. The base is a casting, designed in accordance with N. E. L. A. specifications. The terminal chamber cover is also cast and is held in place with two sealing screws, which can be sealed with lead, padlock, or ribbon type seals. The terminals are set in a molded block of insulating material, which is removable from the base as a unit. The terminals are also individually removable for replacement and and arranged in the order specified for bottom-connected polyphase meters. The nameplate is similar to that used on the Type MD single-phase meter, consisting of two triangular plates, bearing the rating, serial number, etc. The two pieces are fastened to the base and are not disturbed by the removal of the terminal chamber cover.

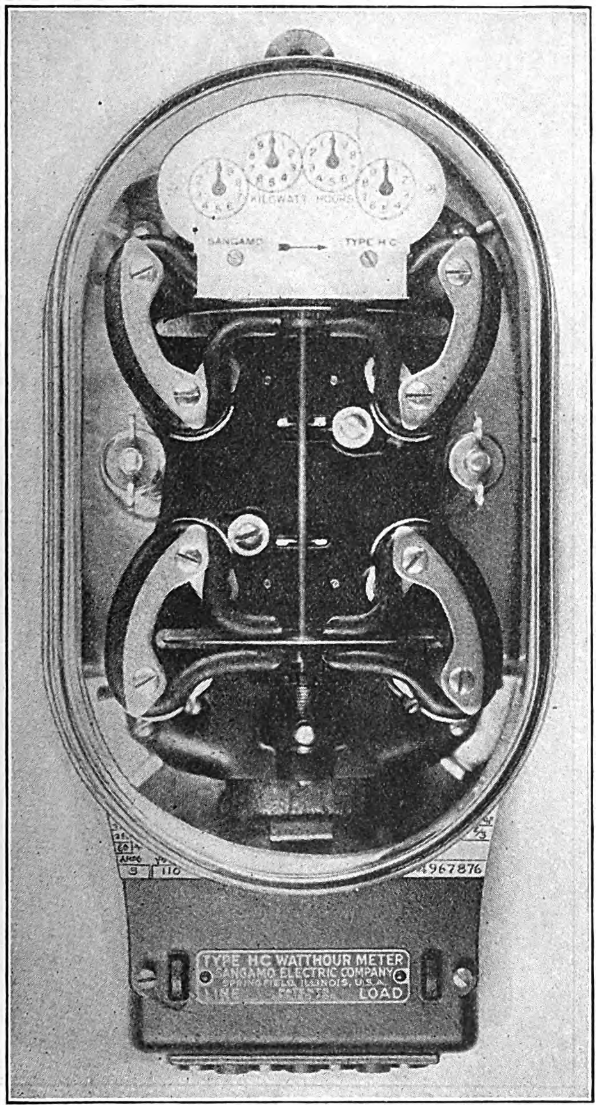

KILOWATT HOURS
SANGAMO
TYPE HC
4967876
TYPE HC WATTHOUR METER
SANGAMO ELECTRIC COMPANY
SPRINGFIELD, ILLINOIS, U.S.A.
LINE
LOAD

FIG. 8—TYPE HC, TWO-ELEMENT, THREE-WIRE, WATTHOUR METER MADE BY THE SANGAMO ELECTRIC COMPANY.

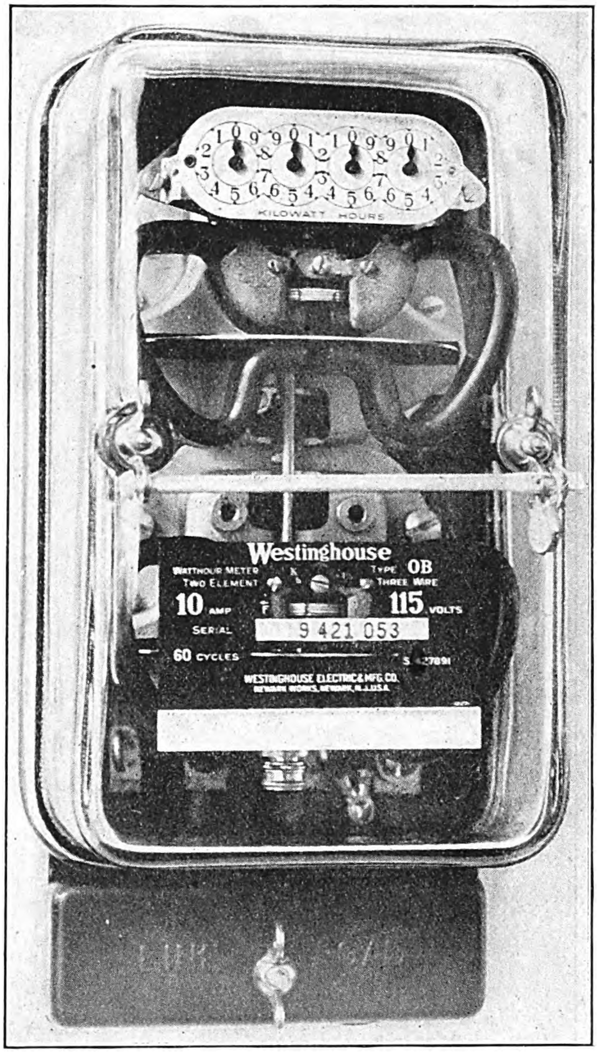

KILOWATT HOURS
Westinghouse
WATTHOUR METER
TYPE OB
TWO ELEMENT
THREE WIRE
10 AMP
115 VOLTS
SERIAL
9 421 053
60 CYCLES
WESTINGHOUSE ELECTRIC & MFG. CO.

FIG. 9—TYPE OB, TWO-ELEMENT, THREE-WIRE WATTHOUR METER MADE BY THE WESTINGHOUSE ELECTRIC & MFG. CO.

The arrangement of the electro-magnets is similar to that of the Type M2P, the preceding type of polyphase meter made by this company, but the leads are fastened to anchoring blocks on each side of the base. From these blocks the leads run to the terminal chamber. The register mechanism, the adjustments and bearings, are the same as in the Type M2P meter.

The manufacturer claims that the meter will be compensated for temperature errors at all power factors.

The single-phase Type MD meter constants will be applicable to the polyphase meter. Self-contained meters of this type will be supplied with current ratings of from 5 to 75 amperes, and voltage ratings of 115, 230 and 460 volts.

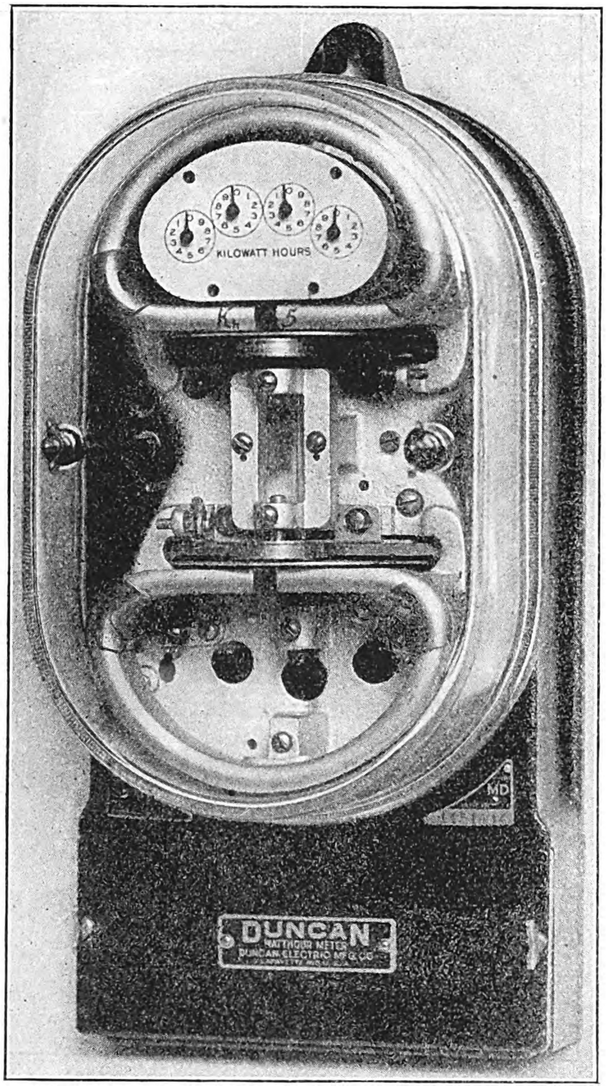


FIG. 10—TYPE MD, TWO-ELEMENT, POLYPHASE WATTHOUR METER MADE BY THE DUNCAN ELECTRIC MANUFACTURING COMPANY.

Types D-14 and D-15 Polyphase, Watthour Meters Made by The General Electric Co.

The General Electric Co. now has in production a new line of bottom-connected polyphase meters, identified as Type D-14 and Type D-15. The Type D-14 meter, shown in Fig. 11, has two elements, while the Type D-15 meter, shown in Fig. 12, has three elements. They supersede the Types D-7 and D-9, and embody all the essential characteristics of the Type I-16 meter, together with some additional features. They are built in sizes of 5, 10, 15, 25 and 50 amperes. As in the Types I-16 and I-18, the base and frame are in one piece, and the meters are provided with a back cover plate. The molded glass cover with steel flange and gasket is held in place by the same novel type of clamp used in Type I-18 meters. The arrangement of terminals and the overall dimensions of the terminal chamber conform to standard practice. The 5 and 10-ampere terminals are inclosed in separate replaceable bushings. The 15- to 50-ampere sizes have a single molded terminal block.

All adjustments, full load, light load, power factor, and balance of elements, are of the micrometer type, accessible from the front of the meter. Potential indicator lamps, for detecting an open potential circuit, are furnished when specified.

The use of the I-16 element provides the same range of accuracy, overload rating and high torque found in that meter. The manufacturer advises that wide temperature changes have no effect on the accuracy of this meter on any load or power factor, as it is completely compensated for temperature. Fig. 13 shows a rear view of the Type D-14 meter with back cover plate removed.

Type HC Polyphase Watthour Meter Made by The Sangamo Electric Co.

The vertical polyphase meter is being modified so that it will be bottom-connected and will have standard dimensions as recommended by the Meter Com-

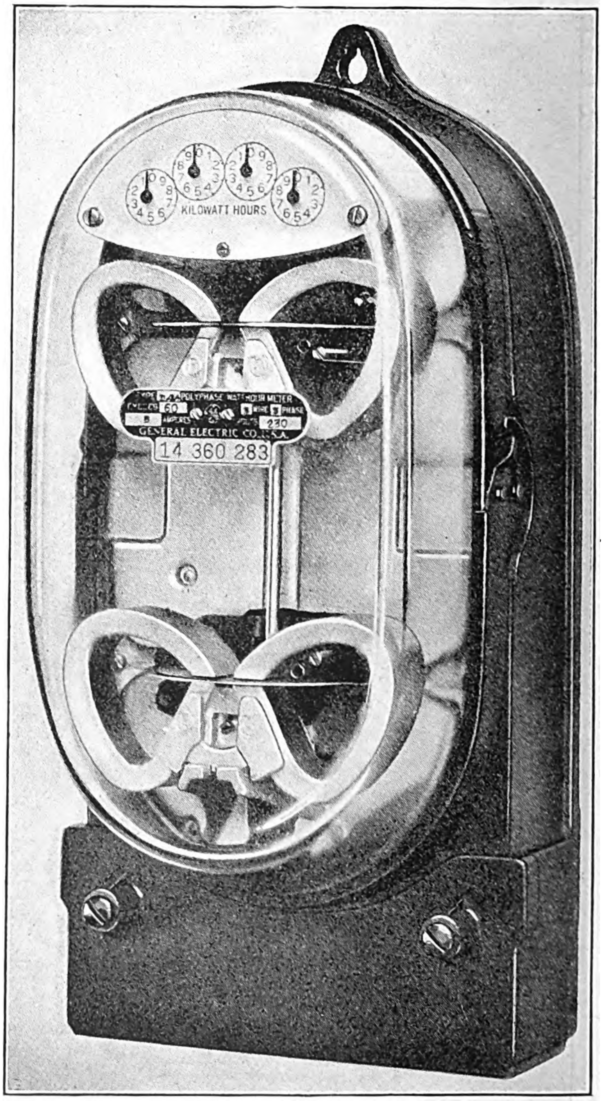


FIG. 11—TYPE D-14, TWO-ELEMENT, POLYPHASE WATTHOUR METER MADE BY THE GENERAL ELECTRIC COMPANY.

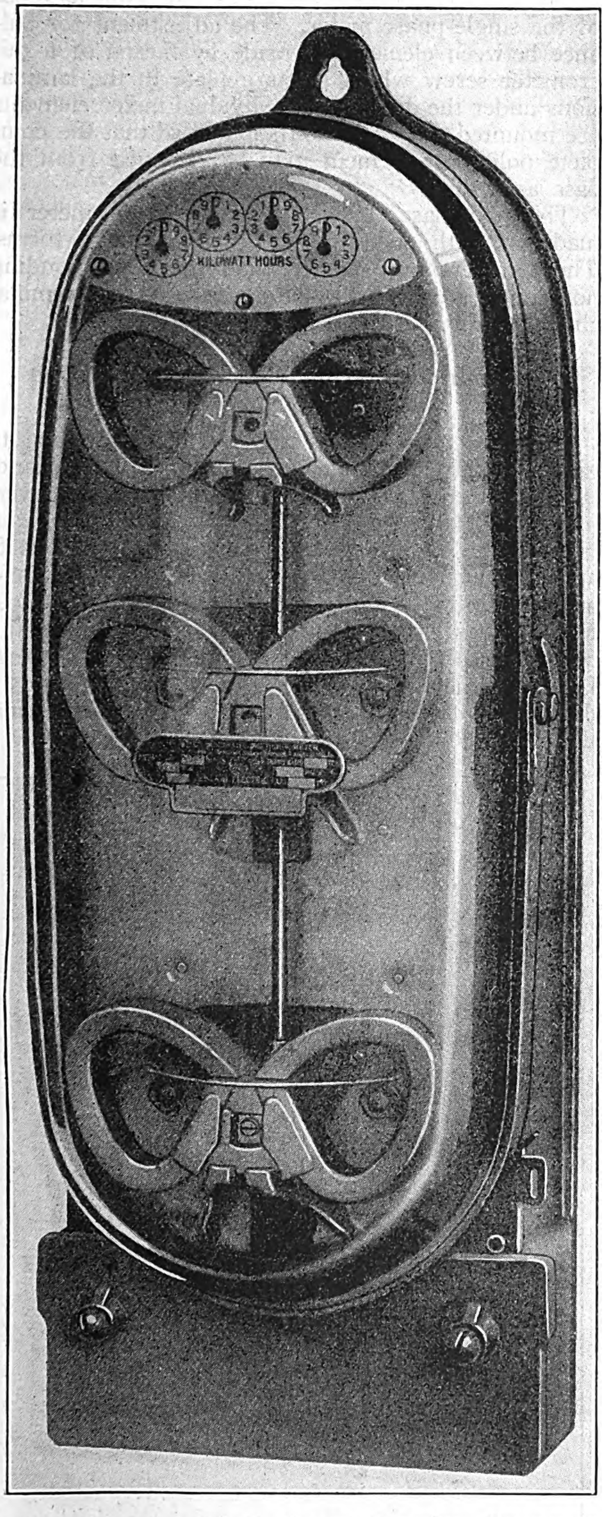


FIG. 12—TYPE D-15, THREE-ELEMENT, POLYPHASE WATTHOUR METER MADE BY THE GENERAL ELECTRIC COMPANY.

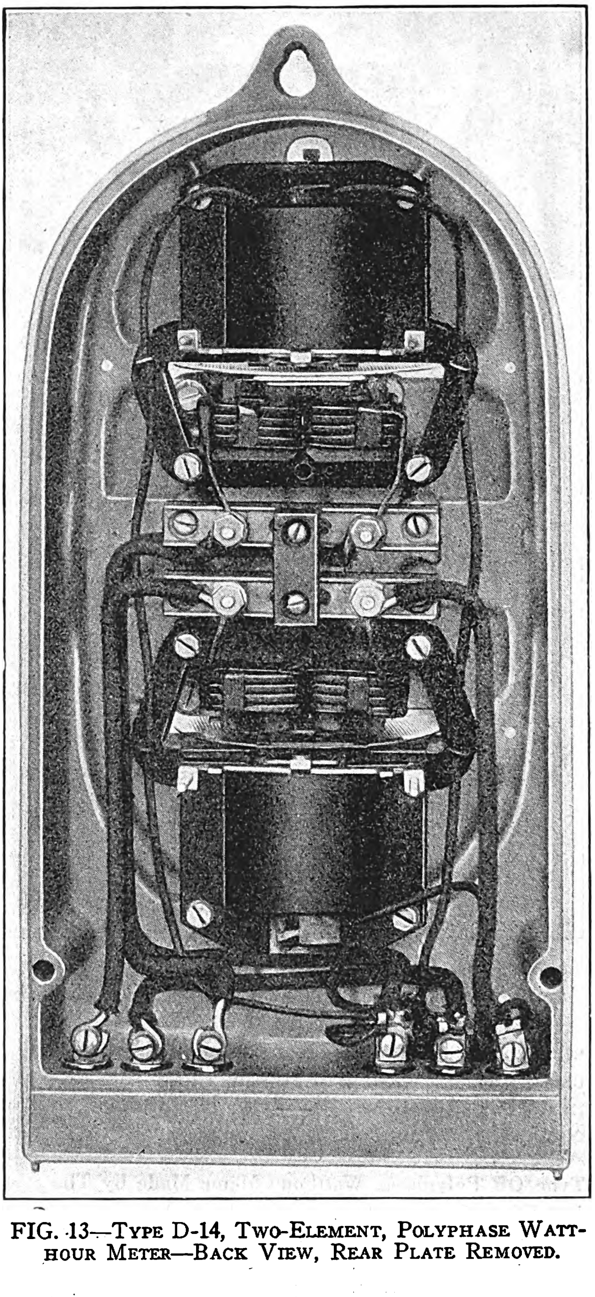


FIG. 13—TYPE D-14, TWO-ELEMENT, POLYPHASE WATTHOUR METER—BACK VIEW, REAR PLATE REMOVED.

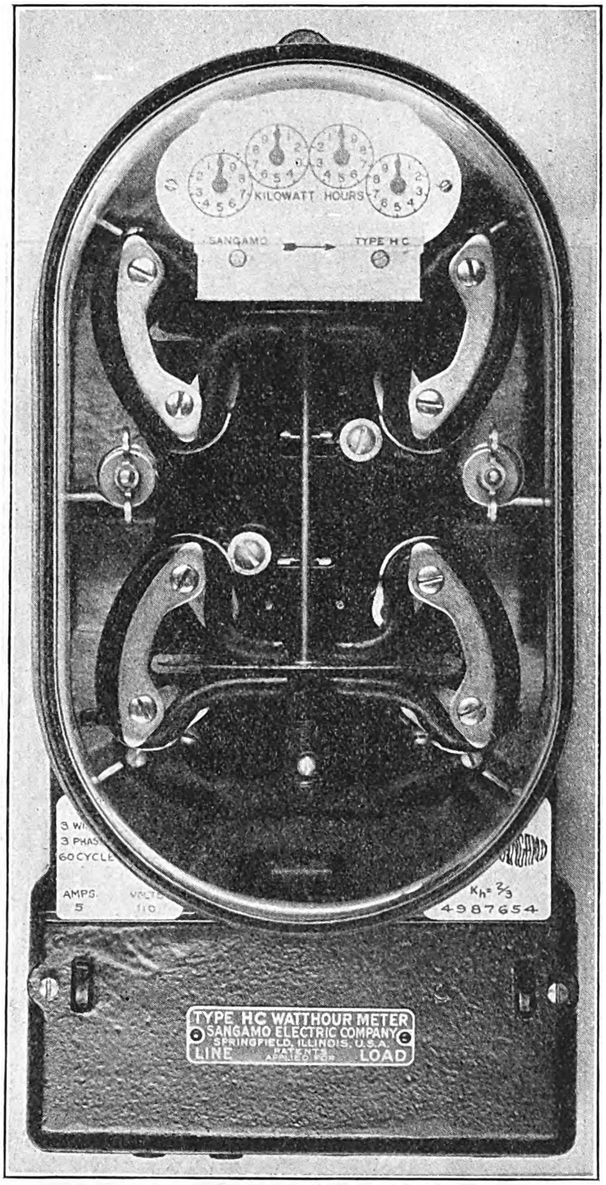

KILOWATT HOURS
SANGAMO
TYPE HC
3 WI
3 PHAS
60 CYCLE
AMPS. 5
VOLTS 110
Kh= 2/3
4987654
TYPE HC WATTHOUR METER
SANGAMO ELECTRIC COMPANY
SPRINGFIELD, ILLINOIS, U.S.A.
LINE
PATENTS APPLIED FOR
LOAD

FIG. 14—TYPE HC, TWO-ELEMENT, POLYPHASE WATTHOUR METER MADE BY THE SANGAMO ELECTRIC COMPANY.

mittee, N. E. L. A. Removable terminals will be used, and the base will be the same for all capacities. Fig. 14 shows the Type HC vertical, bottom-connected, two-element, polyphase watthour meter.

Type OB Polyphase, Watthour Meter Made by The Westinghouse Electric & Manufacturing Co.

The Type OB polyphase meters are manufactured in both the two- and three-element types, Fig. 15 and 16, respectively. They are bottom-connected and have standard terminal chambers. The base and terminal assembly consists of iron castings somewhat similar to those used in former designs, with the exception that the terminal chamber is at the bottom. The covers are made of glass and are rectangular in shape. The meter is mounted on the wall or the support with two screws, similar to the manner of mounting the single-phase Type OB meter.

The micrometer adjustments are the same as those of the single-phase meter. The adjustment for balance between elements is made by means of a micrometer screw which shifts a plate in the laminations under the disk. The individual meter elements are mounted on a common support so that the complete polyphase element may be removed from the base as a unit.

The polyphase Type OB switchboard meter is made in both the two and three-element forms. These meters are smaller than the corresponding house meter due to the elimination of the terminal chamber, Fig. 17 and 18.

Watthour Meters for Use With Instrument Transformers

Standard type current transformers designed to give 5 amperes secondary current at full load cannot be overloaded for any length of time without overheating. This makes it impossible to take advantage of the long range accuracy of the modern 5-ampere watthour meter. Therefore, a 2½-ampere, or the so-called "Instrument Transformer Watthour Meter," has been recently developed. With this type of meter accurate registration can be obtained from light load to 200 per cent of normal load of the meter, namely 5 amperes, which is the normal secondary current of the current transformer.

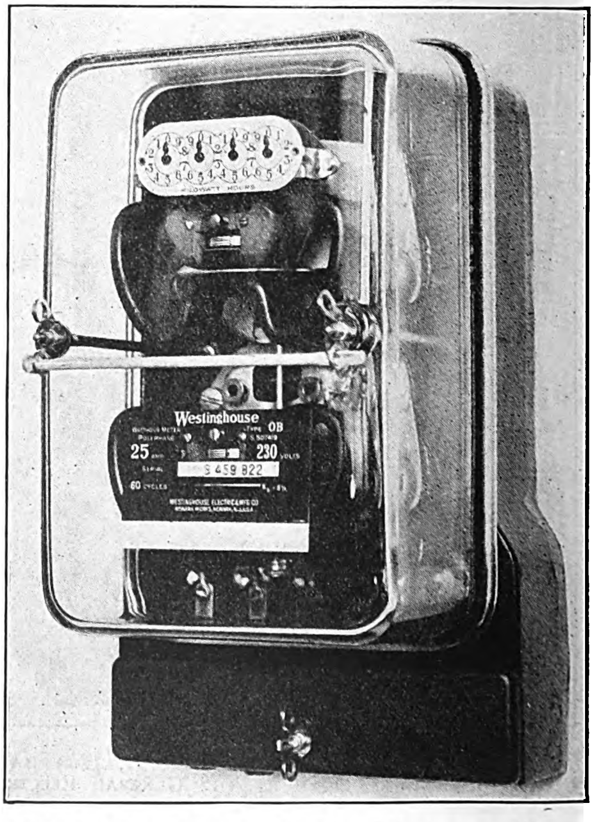

KILOWATT HOURS
Westinghouse
Type OB
25
230
S 459 822
60 CYCLES

FIG. 15—TYPE OB, TWO-ELEMENT, POLYPHASE WATTHOUR METER MADE BY THE WESTINGHOUSE ELECTRIC & MFG. CO.

This meter also makes possible the more accurate determination of the maximum demand. As the speed of the 2½-ampere meter is approximately twice that of the 5-ampere meter, the demand determination automatically becomes 100 per cent more accurate.

The General Electric Co. announces such a line of watthour meters. The increase in the number of turns of the current or series winding has doubled the torque without sacrifice in accuracy over the working range of the meter and current transformer combination. The disc speed is twice that of the self-contained meter, hence the test constant has been halved. The foregoing applies to the Types I-16, D-14 and D-15 meters. The Type I-18 is not furnished for use with instrument transformers.

The Westinghouse Electric & Manufacturing Co. also announces a similar line of instrument transformer meters, which can be obtained in either the house or switchboard types.

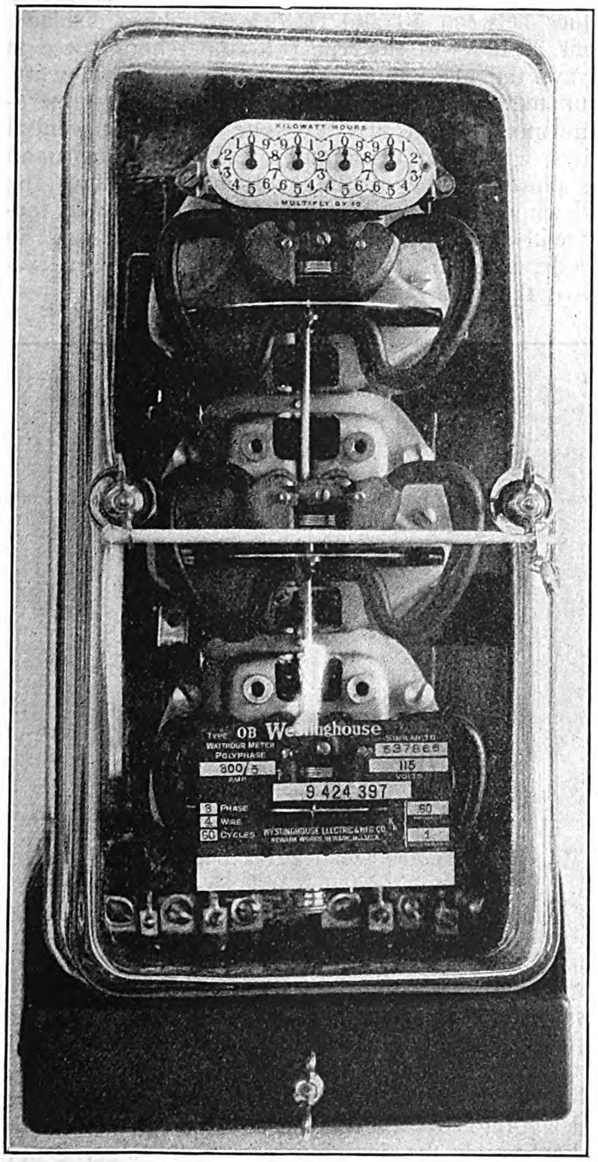


FIG. 16—TYPE OB, THREE-ELEMENT, POLYPHASE WATTHOUR METER MADE BY THE WESTINGHOUSE ELECTRIC & MFG. CO.

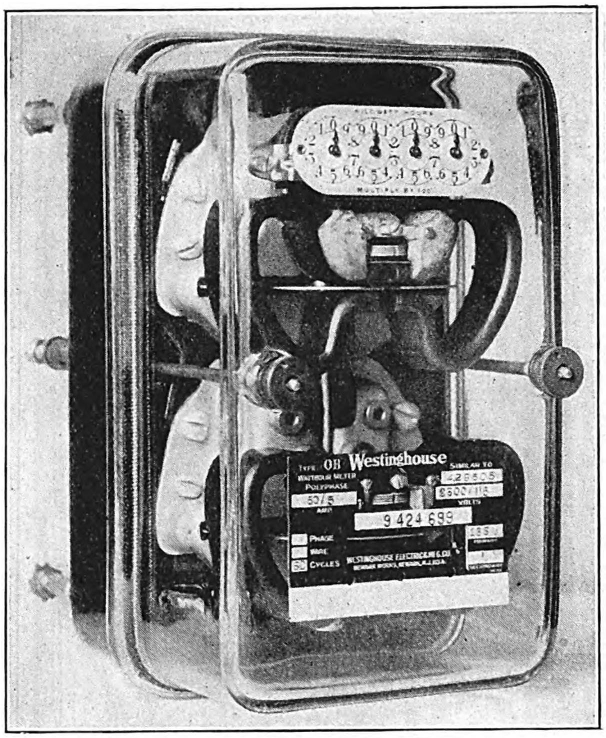


FIG. 17—TYPE OB, TWO-ELEMENT, POLYPHASE WATTHOUR METER MADE BY THE WESTINGHOUSE ELECTRIC & MFG. CO.—SWITCHBOARD TYPE.

Volt-Amperehour Meters

To encourage the consumer to improve the power factor of his electrical load, contracts have been offered by some utilities which base the charge on the volt-amperehour.

The Trivector Volt-Amperehour Meter Made by Landis & Gyr, Inc.

The new Trivector meter developed by Landis & Gyr, Inc., combines in one unit a watthour meter, a reactive volt-amperehour meter, and a special gear mechanism which the manufacturer claims is capable of computing the true volt-amperehours of a load regardless of power factor variations.

A watthour meter will register volt-amperehours within commercial accuracies over a range of 10 deg. phase variation, or from 0 to 10 deg. phase displacement, because the cosine of angles within this range vary only slightly. Likewise a reactive volt-amperehour meter will register correct volt-amperehours of a load varying from 80 deg. to 90 deg. in phase displacement, because the sine of angles within that range vary but slightly. The special gear mechanism of the Trivector meter is so constructed that during the periods in which the power factor falls within the limits mentioned above, the volt-amperehour dial is driven directly by the proper unit and registers the correct volt-amperehours. Referring to the schematic diagram, Fig.

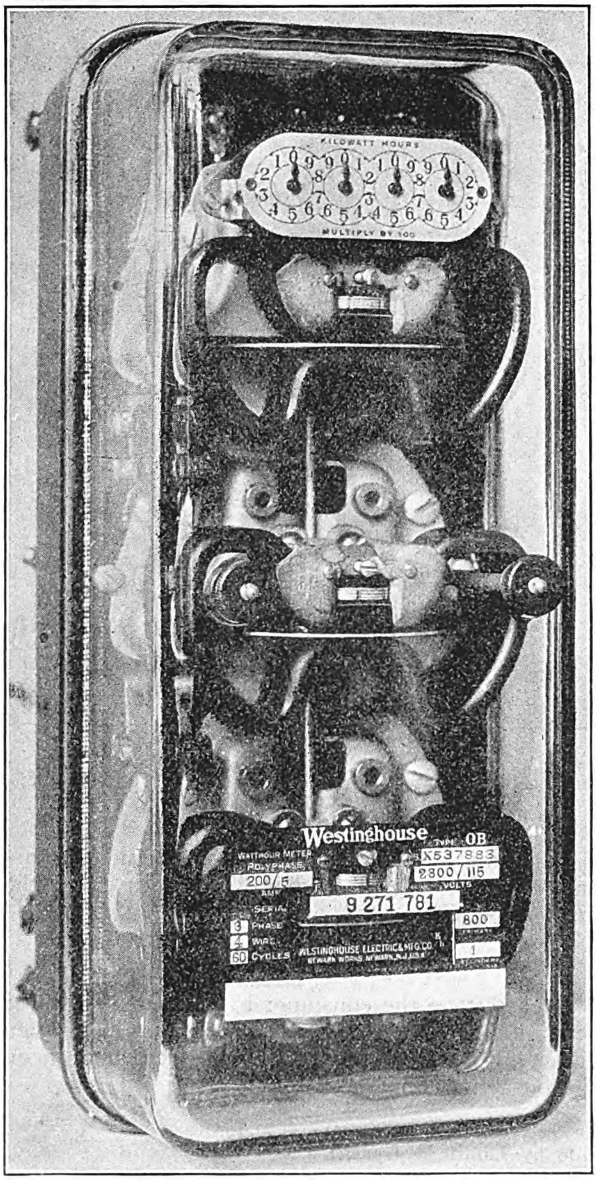


FIG. 18—TYPE OB, THREE-ELEMENT, POLYPHASE WATTHOUR METER MADE BY THE WESTINGHOUSE ELECTRIC & MFG. CO.—SWITCHBOARD TYPE.

19, the main shaft, 14, of the gear train of the watthour meter is geared to the volt-amperehour register through a ratchet, 18. In like manner the gear train shaft, 15, of the reactive volt-amperehour meter is connected to the main shaft of the volt-amperehour register, 30, through ratchet 18′. Due to the ratchet arrangement, the meter running at the greater speed actuates the volt-amperehour register. Besides being geared through ratchets to the volt-amperehour register, as already described, the watthour and the reactive volt-amperehour registers are coupled together through three sets of differential gears, shown at 19, 20 and 21 in Fig. 19. The resultant torque of each of these differential units is transmitted through a ratchet to the main volt-amperehour register shaft, 22. The gear ratios along the connecting linkage are so selected that the resultant speed of each will register true volt-amperehours for a separate range of power factor values between 10 and 80 deg. of phase displacement. Therefore, as true volt-amperehour speed is always the maximum speed, either the main watthour meter direct drive, the reactive volt-amperehour meter direct drive, or one of the differential drives will be at maximum speed, depending upon the power factor of the load, and will drive the volt-amperehour register. The value of power factor will always determine which gear train will do the driving, this factor varying as the power factor of the load varies.

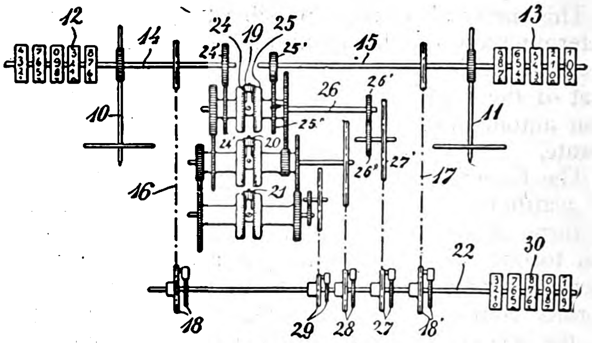


FIG. 19—SCHEMATIC DIAGRAM OF THE GEAR MECHANISM OF THE TRIVECTOR VOLT-AMPEREHOUR METER MADE BY LANDIS & GYR, INC.

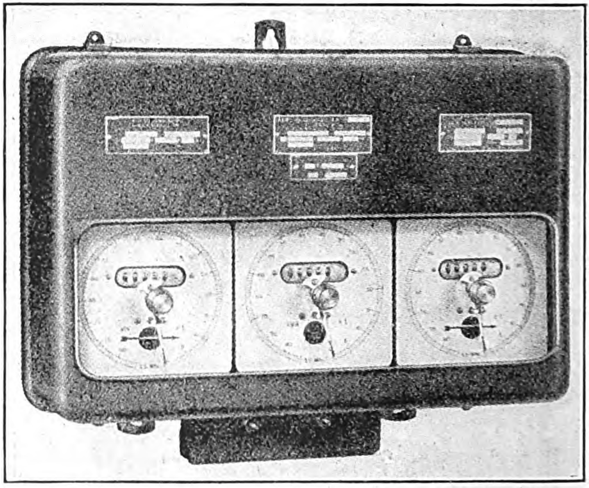


FIG. 20—TRIVECTOR VOLT-AMPEREHOUR METER MADE BY LANDIS & GYR, INC.

The meter shown in Fig. 20 will register volt-amperehours, watthours and reactive volt-amperehours, and the maximum demand of each. It is designed to register these only for a lagging power factor range of from unity to zero. However, with suitable modifications, it can be made to register the volt-amperehours for all power factors both leading and lagging. In the latter case two registers would make possible the distinguishing of the lagging and leading values separately. This meter is very flexible in its application. It is possible to modify it to furnish many combinations of registrations.

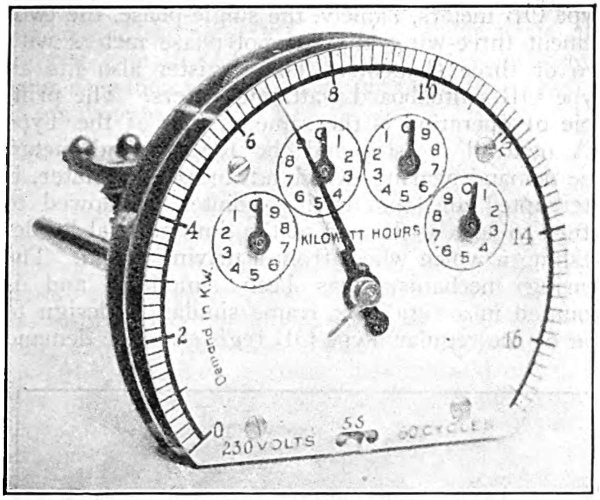


FIG. 21—DEMAND REGISTER MADE BY THE DUNCAN ELECTRIC MANUFACTURING CO.

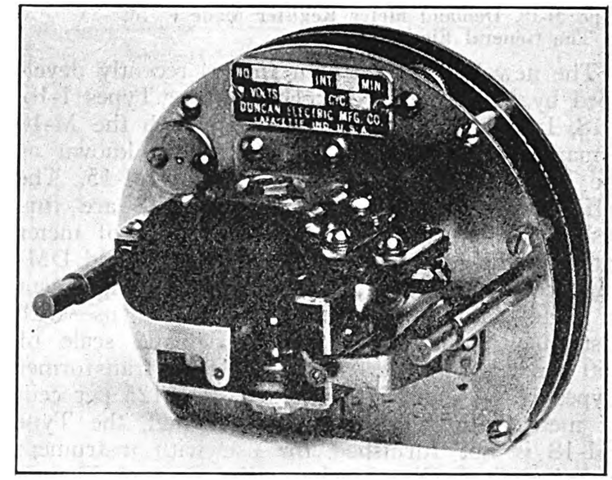


FIG. 22—DUNCAN DEMAND REGISTER—REAR VIEW.

Demand Registers

The demand registers of the various manufacturers have been remodeled to cover the working range of their new types of watthour meters, and to be mechanically applicable to all the various types manufactured by them.

Demand Register Made by The Duncan Electric Manufacturing Co.

The Duncan Electric Manufacturing Co. has recently announced some improvements in its block interval type of demand register. This register is similar to the one which it placed on the market about two years ago, differing only in a few details of mechanical design which provide more rugged construction and improved accuracy. The demand scales now supplied conform to the latest N. E. L. A. Meter Committee recommendations in regard to overloads. The demand scales are about 7¾ in. in length and occupy approximately 250 deg. of the dial face. The time interval is controlled by a small synchronous motor having a speed of 1200 r.p.m. Front and rear views of this register are shown in Fig. 21 and 22.

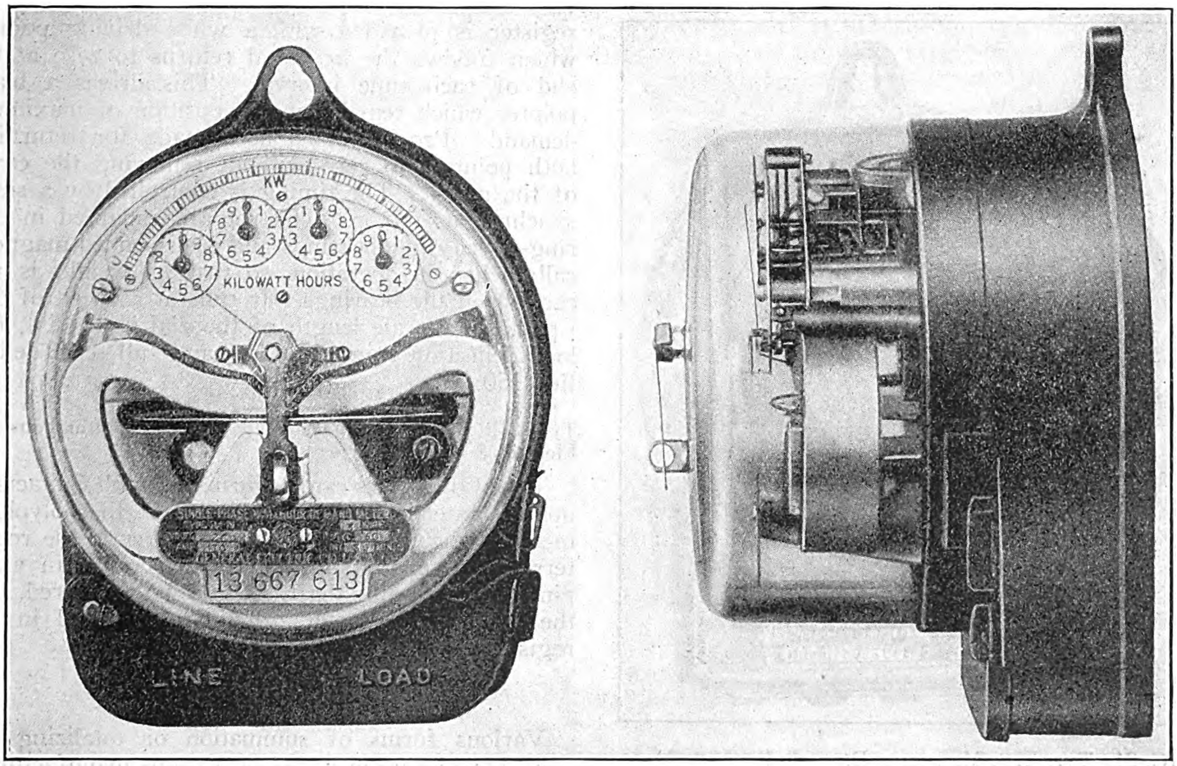


FIG. 23—TYPE IM-16 WATTHOUR DEMAND METER MADE BY THE GENERAL ELECTRIC COMPANY—FRONT AND SIDE VIEWS.

Type M-10, Demand Meter Register Made by The General Electric Co.

The new line of watthour meters recently developed by the General Electric Co., the Types I-16, I-18, D-14 and D-15, are available with the M-10 demand register equipment. They are known as the Types IM-16, IM-18, DM-14 and DM-15. The self-contained Types IM-16 and IM-18 are furnished with a full scale of 300 per cent of meter rating. The self-contained Types DM-14 and DM-15 have a full scale demand rating of 250 per cent of meter rating. The Type IM-16 for use with instrument transformers has a demand scale of 150 per cent of meter rating, while the transformer Types DM-14 and DM-15 scales are 125 per cent of meter rating. As previously stated, the Type IM-18 is not furnished for use with instrument transformers. Fig. 23 shows the General Electric Type IM-16 watthour demand meter.

Type HB Maximum Demand Register Made by The Sangamo Electric Co.

The Type HB demand attachment previously announced has been changed to meet the N. E. L. A. Meter Committee specification of a 300 per cent load value scale on a 300 deg. dial. Fig. 24 illustrates a Sangamo Type HC, single-phase watthour meter equipped with a Type HB maximum demand register.

Type OB Demand Registers Made by The Westinghouse Electric & Manufacturing Co.

The Type OB demand register shown in Fig. 25 is designed to fit the complete line of Westinghouse Type OB meters, namely, the single-phase, the two-element three-wire, and the polyphase meters with two or three elements. This register also fits all Type OB switchboard watthour meters. The principle of operation is the same as that of the Type OA demand register and the RA demand meter. The demand gearing, which advances the pointer, is interrupted and the driving pointer is allowed to return to zero at the end of the time interval by demeshing a worm wheel from a driving worm. The gearing mechanism has been simplified and is mounted in a rigid box frame similar in design to that of the regular Type OB register. The demand register is provided with a white driving pointer which follows the load and returns to zero at the end of each time interval. This drives a black pointer which remains in the position of maximum demand. Provision has been made for returning both pointers to zero without removing the cover of the meter. The timing is controlled by a small synchronous motor. The rotor is mounted in two ring-jewel guide-bearings and is suspended magnetically when in operation, so that its weight is not carried on the bearings. It runs at a speed of 600 r.p.m. The scale length of the dial is 3⅝ in., full load deflection being 120 deg. and full scale deflection 150 deg.

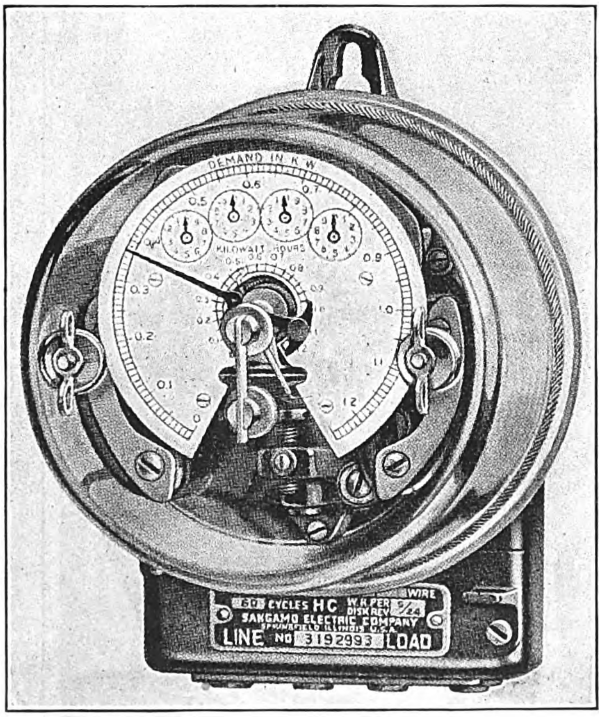


FIG. 24—TYPE HB, MAXIMUM DEMAND REGISTER MADE BY THE SANGAMO ELECTRIC COMPANY MOUNTED ON A TYPE HC SINGLE-PHASE WATTHOUR METER MADE BY THE SAME MANUFACTURER.

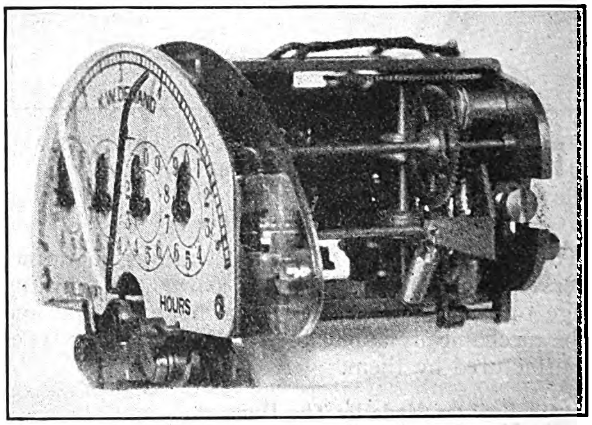


FIG. 25—TYPE OB, DEMAND REGISTER MADE BY THE WESTINGHOUSE ELECTRIC & MFG. CO.—SIDE VIEW, SHOWING DETAILS OF MECHANISM.

Type OB Demand Contacts Made by The Westinghouse Electric & Manufacturing Co.

Type OB meters can be furnished with contacts to operate external demand devices. In the polyphase meters the contacts are mounted either in the registers or in separate assemblies driven by an extra pinion on the disc shaft, as may be preferred. In the single-phase meters, they are mounted in the registers.

Load Totalizing Meters

Various forms of summation or totalizing devices have been developed by various manufacturers to measure the consumption on two or more independent circuits, and also to combine the maximum demands of these circuits. It is desirable to do this without complicating the metering equipment, endangering its accuracy, or unduly increasing the cost of maintenance.

Totalizing Meter Made by Landis & Gyr, Inc.

A meter for totalizing the readings of two independent circuits has been in production for a number of years by Landis & Gyr, Inc. The manufacturer claims that this device will measure the combined consumption of a three-phase, three-wire, and a three-phase, four-wire circuit, and will give the combined periodic maximum demand on these circuits. The record can be registered on a demand indicator or on a chart by adding the usual attachments in a manner similar to that done with watthour meters.

A device is needed to obtain the same data for a combination of more than two circuits, including both alternating-current and direct-current circuits. To meet this latter requirement, this company has developed a new totalizing device, which is now in production, and is illustrated in Fig. 26.

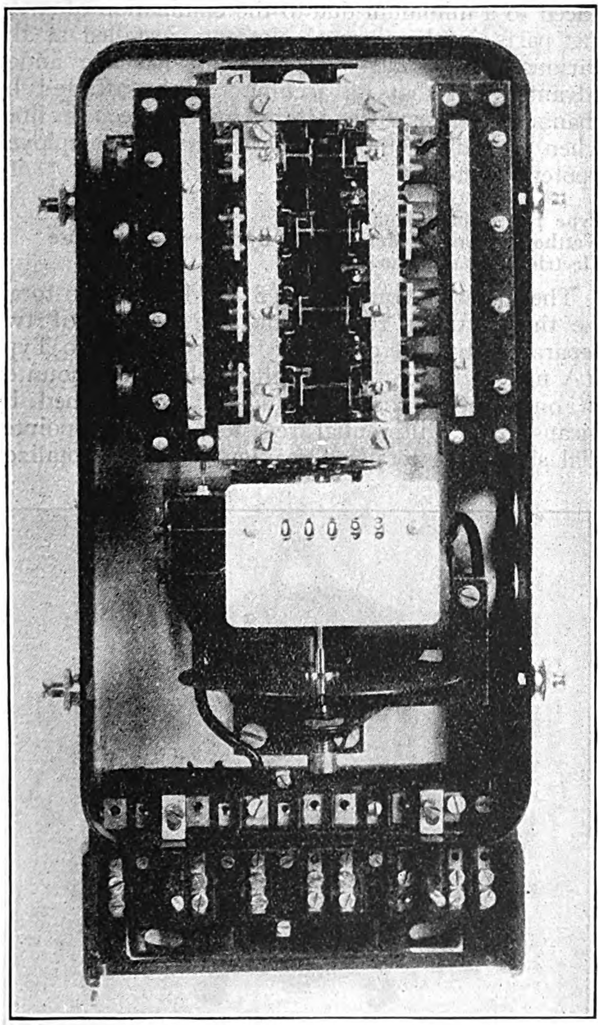


FIG. 26—TOTALIZING METER MADE BY LANDIS & GYR, INC.

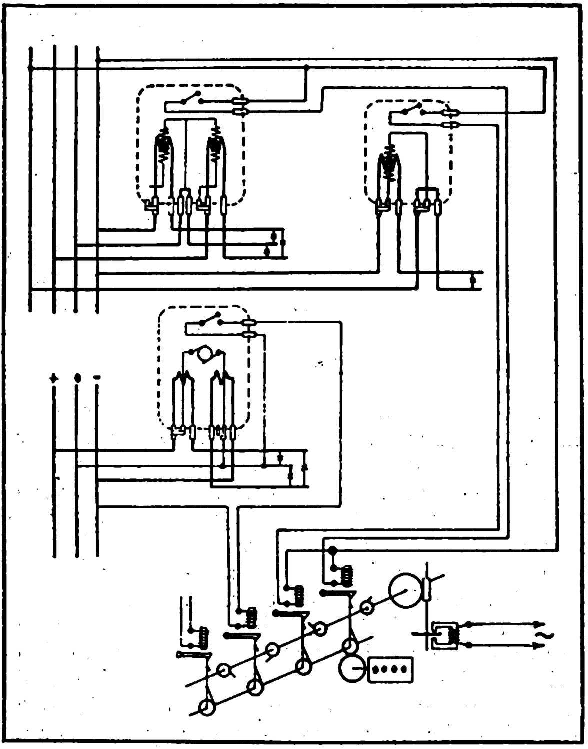


FIG. 27—SCHEMATIC DIAGRAM OF THE TOTALIZING METER MADE BY LANDIS & GYR, INC.

The principle of operation of this device is shown schematically in Fig. 27. Three circuits and corresponding meters are shown, namely, a polyphase circuit and its meter, a single-phase circuit and its meter and a direct-current circuit and its meter. The totalizing equipment is connected to totalize on one register the load of these three circuits.

The watthour meters have contact devices operating from their registers. These devices make contact after a given quantity of energy have been registered on their respective meters. It is necessary that this quantity of energy have the same value for every meter belonging to the same totalizing unit. Each of these contact making devices is connected through an individual circuit to a relay which is located in the totalizing device.

The totalizing apparatus is equipped with a shaft continually rotated by an induction motor. On this shaft are located several discs, each of which is equipped with one tooth. The discs are so assembled that the teeth are located at equal intervals around the periphery when viewed along the shaft. For each disc there is a corresponding relay. The shaft and discs rotate freely as long as the relays are de-energized. As soon as one of the relays becomes momentarily energized, it attracts its armature and releases a lever. As the lever is released, it moves forward under spring action and pushes a pawl which engages into a tooth in a ratchet wheel and turns the wheel. This movement is transmitted, through suitable gearing, to the register. The tooth of the rotating disc, corresponding to the lever that has been released, then pushes the lever back to its original position where it is held by the armature of the relay, which, by this time, is again de-energized.

Each relay of the totalizing device controls an identical mechanism, and all ratchet wheels, which are actuated by the pawls, are connected with the register of the totalizing meter in such a manner that the excitation of each relay causes a definite advance of the register. If the excitation of the different relays is now so arranged that each of them is energized after a predetermined quantity of consumed energy has passed through its corresponding meter, then the register of the totalizing meter will give the correct sum of all the energy consumed in the different circuits.

The construction of the totalizing meter is such that the relays require a very small amount of energy for their excitation. Their current consumption is extremely small, therefore the distance between the different meters and the totalizing apparatus is of no importance. This device can be used for totalizing the registration of several meters located at some distance from each other.

The torque of the rotating shaft is sufficiently high to assure reliable performance of the totalizing device. The peripheral arrangement of the disc teeth as outlined above makes it impossible to lose the registration of a meter should any two contacts, located on two of the meters being totalized, function at the same instant.

The totalizing meter can be furnished with different types of demand attachments, such as a demand indicator or a chart for recording the demand (the maxigraph). In this way, a periodic demand reading may be obtained in addition to the totalized watthour registration of a number of circuits. This totalizing device can also be furnished with two or three gear ratios. Direct or alternating-current can be used to energize the relays, and it is not necessary that all relays be energized from the same source of potential, as the relay circuits are entirely independent of each other.

Thermal Converter Made by The Lincoln Meter Co., Ltd.

Thermo-couples are used in a device developed by the Lincoln Meter Company, Ltd., of Canada for totalizing the loads of several circuits. Fig. 28 and 29 show this instrument with the cover on and off respectively. Fig. 30 shows one of the thermal elements before the assembling of the current and potential windings.

Any number of loads may be totalized by associating a thermal element with each load. The various e.m.f's. generated by the thermo-couples are connected in series and are measured by a suitable d-c. millivoltmeter. A recording potentiometer, such as the Leeds and Northrup instrument, is preferable to a millivoltmeter, as it eliminates potential drops over the connecting leads. The distance over which such totalizing can be accomplished accurately depends upon the number of loads to be totalized and the loading of each thermal converter. Total distances up to ten miles have been covered satisfactorily, and loads have been measured up to 145,000 kw. It is claimed that maintenance has been reduced to a minimum due to the elimination of moving parts in the thermal elements installed at the various load points. This device has the added advantage in that its accuracy is not affected by changes in resistance of the interconnecting lines when the null method of measurement is employed (potentiometer).

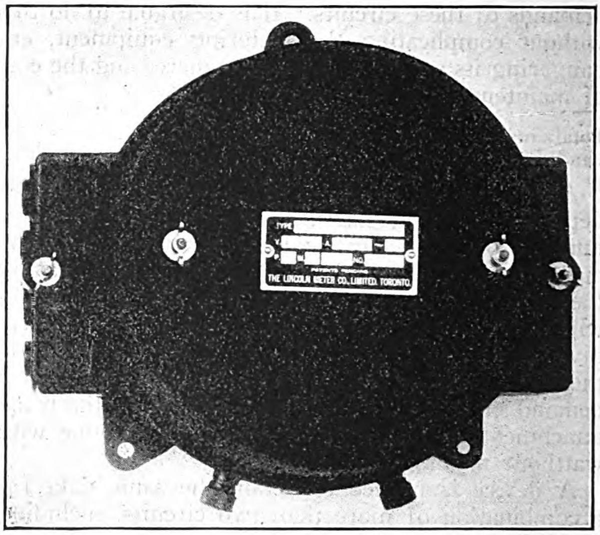


FIG. 28—THERMAL CONVERTER TYPE OF TOTALIZING METER MADE BY THE LINCOLN METER COMPANY, LTD.

Type RA Duplex Totalizing Watthour Demand Meter Made by The Westinghouse Electric & Manufacturing Co.

The meter shown in Fig. 31 is designed to totalize the watthour reading and the demand of two separate polyphase circuits. It consists of two Type RA meters having two or three elements, mounted in one case. The totalizing is accomplished by means of a differential register. A four-pointer dial shows the totalized reading while the totalized

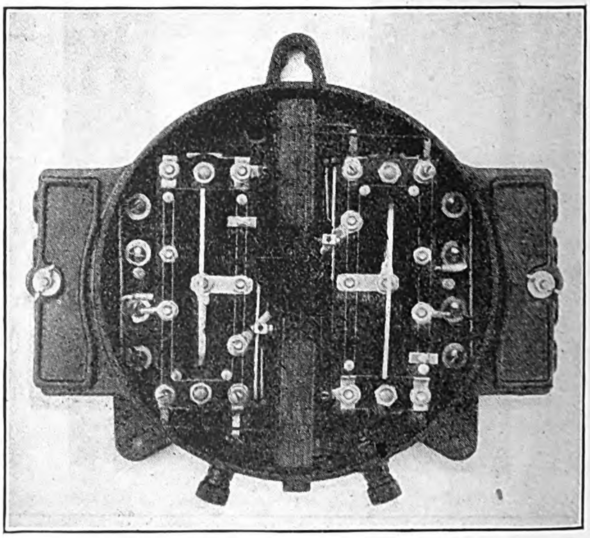


FIG. 29—LINCOLN TOTALIZING METER—COVER REMOVED.

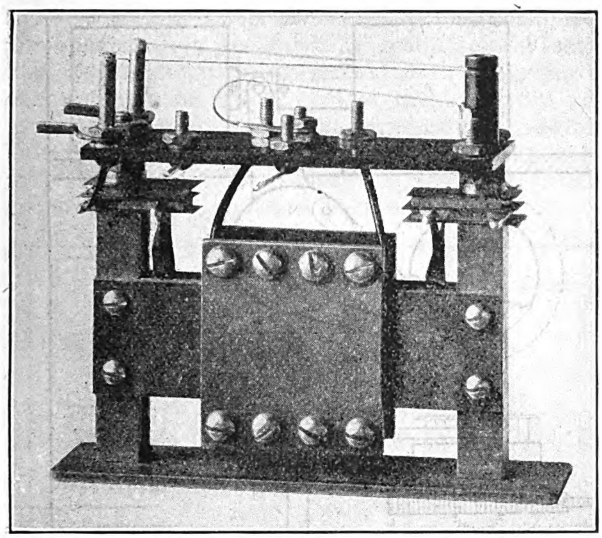


FIG. 30—THERMAL ELEMENT OF THE LINCOLN TOTALIZING METER—BEFORE ASSEMBLING THE CURRENT AND POTENTIAL WINDINGS.

demand is recorded on one RA chart. A second register is used to record the energy integrated on one of the circuits, thus making it possible to obtain the watthour reading of both circuits separately in addition to the totalized results. It is necessary to use instrument transformers of the same ratio on both elements or to compensate for the difference in the transformer ratios by special gearing in the register.

Type DT Totalizing Relay Made by The General Electric Co.

The Type DT Relay is designed to totalize the measurements obtained on a number of watthour meters and to transmit this total registration to a suitable recording device. The relay is made with two, four, six or eight elements.

The four-element relay shown in Fig. 32 has four sets of solenoids (A - B in Fig. 33) each of which may be operated from one of four watthour meters. The four sets of solenoids, when energized by impulses transmitted by the watthour meters, move crown wheels E, F, G and H (Fig. 33). This motion is transmitted to ring gears L and M and then to gears O and P. Gears O and P transmit their movement to crown wheels Q and R and finally to gear S, which is mounted loosely on contact shaft I. Gear S is connected to gear K, which is rigidly connected to shaft I by means of a spiral spring. As gear S advances, gear K becomes free to move and advances under the action of the spring until a pin attached to gear K rests against a pin attached to gear S. This motion is transmitted to contact cams T and the contacts transmit the impulses to the demand meter. In the four-element relay, one impulse is sent to the demand meter for every four impulses received from the watthour meters (one impulse from each of the four watthour meters, four impulses from any one of the watthour meters, or any other combination resulting in a total of four impulses).

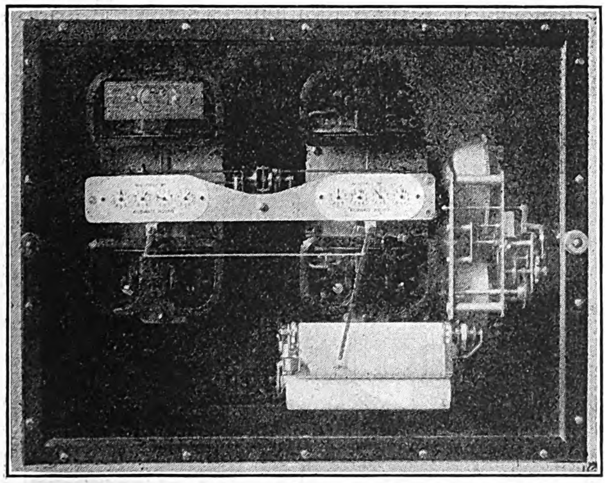


FIG. 31—TYPE RA DUPLEX TOTALIZING WATTHOUR DEMAND METER MADE BY THE WESTINGHOUSE ELECTRIC & MFG. CO.

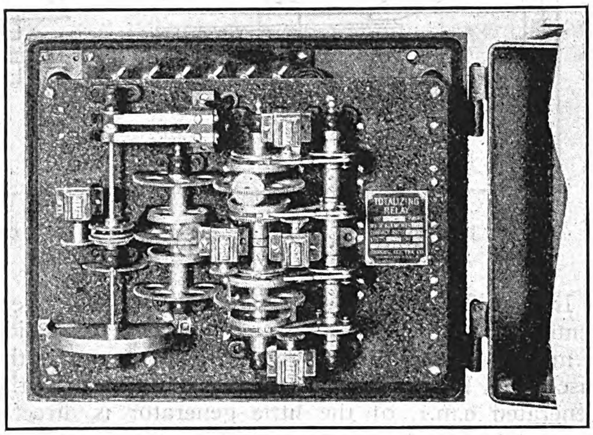


FIG. 32—TYPE DT TOTALIZING RELAY MADE BY THE GENERAL ELECTRIC COMPANY—FOUR-ELEMENT DEVICE.

Shaft N, carrying an aluminum disc running between the poles of a permanent magnet, is geared to shaft I and reduces its speed of rotation through the braking action of the disc, thus enabling the demand meter to record all impulses. With this arrangement, even if a very large number of impulses are received from the four watthour meters within a very short time, shaft I will turn under the action of the spiral spring, but will be sufficiently retarded by the drag magnet to permit the successive transmission of the impulses to the demand meter at the proper rate to insure correct recording.

Totalizing Equipment Made by The Aron Meter Works

The device described has been developed, primarily, to fill the demand for a reliable and simple means of totalizing the output of a number of generators or generating stations, irrespective of the distance between the units or stations. The essential parts of this equipment are the transmitter and the receiver.

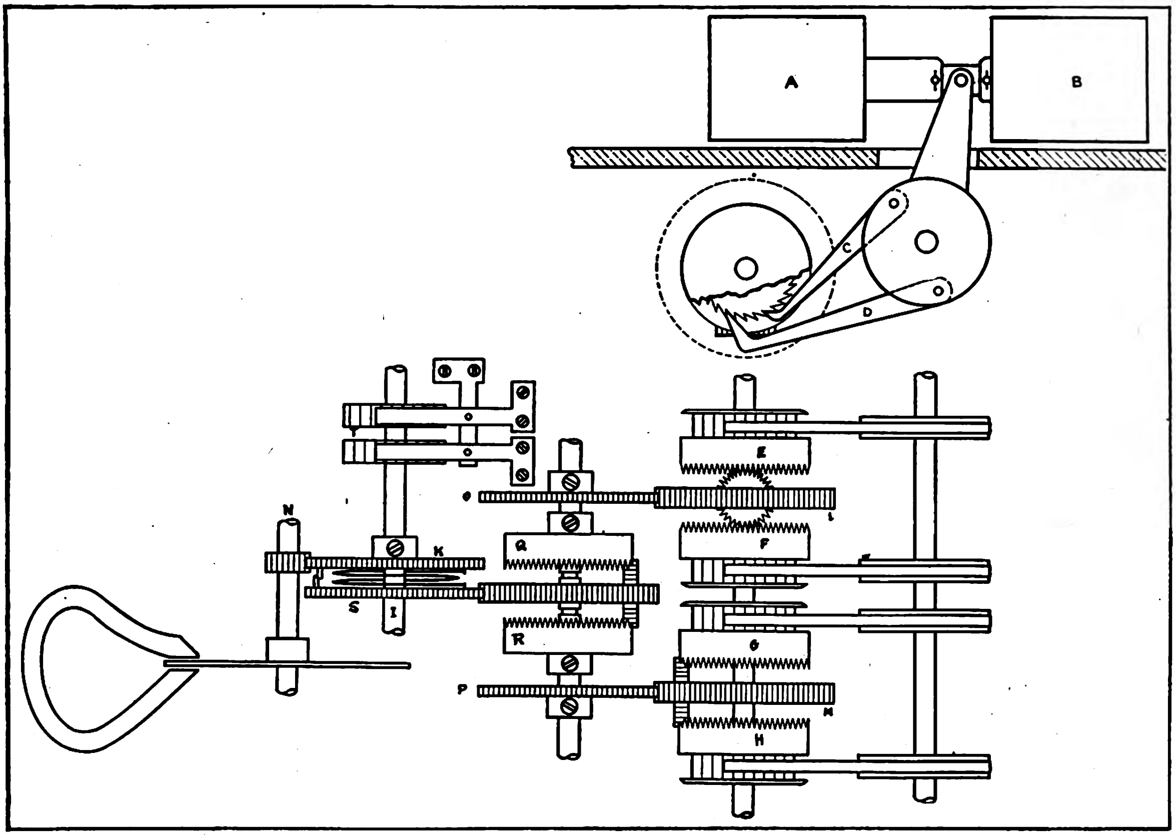


FIG. 33—SCHEMATIC DIAGRAM OF THE GEAR MECHANISM OF THE FOUR-ELEMENT TYPE DT TOTALIZING RELAY.

In Fig. 34 is shown the transmitter, which is essentially a watthour meter, on the shaft of which is mounted a small direct-current generator. As the disc speed is proportional to the power, and as the generated e.m.f. of the little generator is directly proportional to the disc speed, the e.m.f. generated is directly proportional to the power being measured. The receiver, therefore, is calibrated in kilowatts, or megawatts, and takes the form of a suitable millivoltmeter to indicate or to record graphically the e.m.f. of the transmitter. In Fig. 35 are shown four forms the receiver can take.

In Fig. 36 is shown the wiring diagram of the Aron Totalizing Equipment consisting of a transmitter, four indicating receivers, and one recording receiver. The indicating receiver located near the transmitter is intended to give the operator at the sending end an indication of what is being transmitted. The other four receivers are supposed to be installed in various locations to show the load to interested persons.

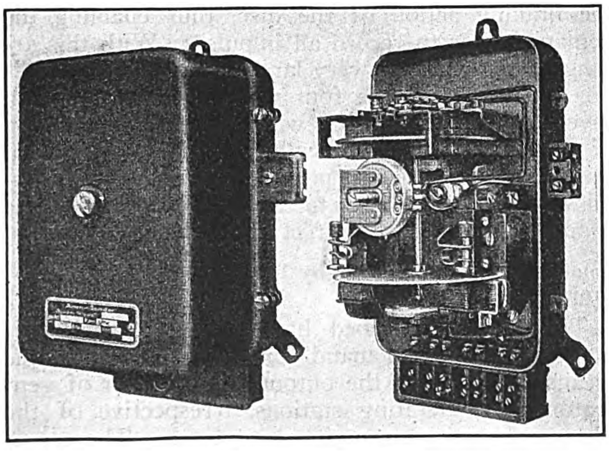


FIG. 34—TRANSMITTER OF TOTALIZING EQUIPMENT MADE BY THE ARON METER WORKS.

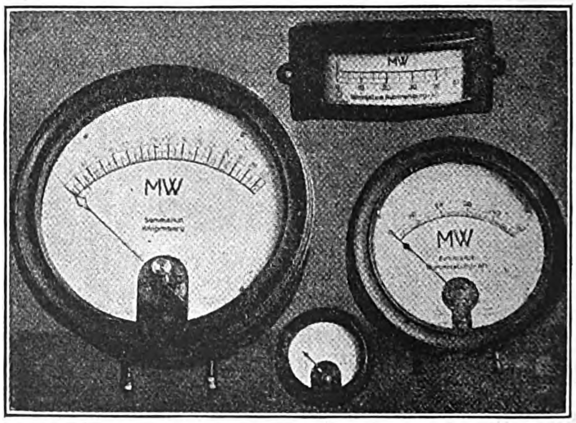


FIG. 35—RECEIVERS OF TOTALIZING EQUIPMENT MADE BY THE ARON METER WORKS.

For totalizing purposes a number of transmitters are connected in series. The manufacturer states that, as the quantity transmitted is of the order of one milliampere (d-c.) at less than 10 volts, the usual telephone or telegraph wires can be used and long distances may exist between the various transmitters. He also states that the telephone or telegraph wires used for this purpose can also be utilized for communication purposes without any interference between the two functions.

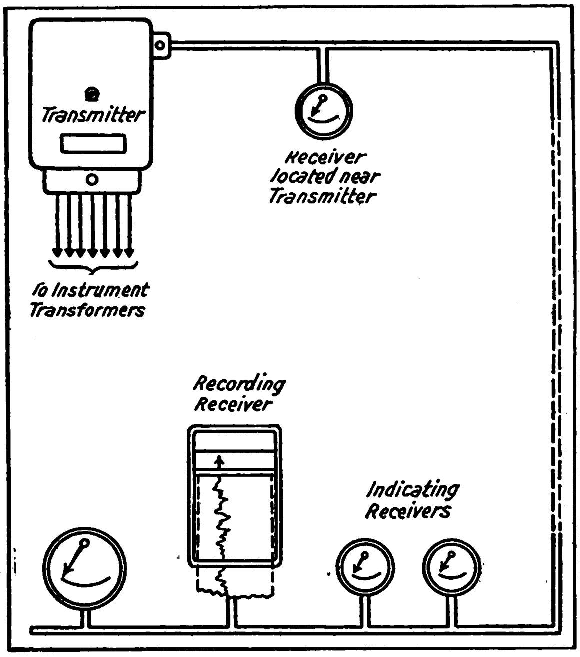


FIG. 36—Diagram of Connections of Totalizing Equipment Made by the Aron Meter Works.

The following advantages are claimed for this device by its manufacturer:

1. As the quantity transmitted and detected by the receiver is a direct-current, energy coming from sources which are not in synchronism can be totalized on one and the same receiver.
2. As the transmitter coils have impedances comparable to that of the usual type of watthour meter, the device can be connected to existing current and potential transformers without overburdening them.
3. The current to be transmitted being very small, wire of very small cross-section can be used. Furthermore, the resistance change with temperature of the transmitting wires can be rendered negligible by the use of a series resistor made of zero temperature coefficient wire. This is possible because the current to be transmitted is of the order of one milliampere. Such temperature compensation would be impossible if the currents to be measured were to be transmitted as obtained from the current transformers.
4. As the quantities to be measured are converted at the transmitter, no auxiliary equipment such as batteries or relays are required.
5. The accuracy of the system is of the order of that of the usual type of switchboard instruments.

Although a transmitter of the watthour meter type has been described, the manufacturer states that any of the usual electrical quantities such as amperes, volts, watts, volt-amperes, etc., can be taken care of by suitable design of the driving element of the transmitter. The small d-c. generator mounted on the shaft of the transmitter and the receiver are, of course, common to all applications. All that is necessary is to change the scale marking of the receiver to agree with units to be totalized or transmitted.

Instrument Transformers

The insistent demand of the industry for more accurate metering of electricity has not only promoted a marked improvement in watthour meter construction but has also resulted in a decided advance in the art of building instrument transformers. This applies chiefly to the current transformer.

The characteristic curves shown in this section have been submitted by the manufacturers of the several makes of transformers. No attempt has been made to verify them. A study of these curves indicates that a marked improvement has been accomplished in the light load performance of those transformers. Better performance is also obtained at heavier secondary burdens.

Types KF-85, and KF-58 Instrument Current Transformers Made by The General Electric Co.

The General Electric Co. announces two new types of instrument current transformers for indoor use. The Type KF-85 is designed for 7500-volt circuits and the Type KF-58 for 15,000-volt circuits. These will supersede the Types KC-85 and KC-58 respectively. The new transformers have improved ratio

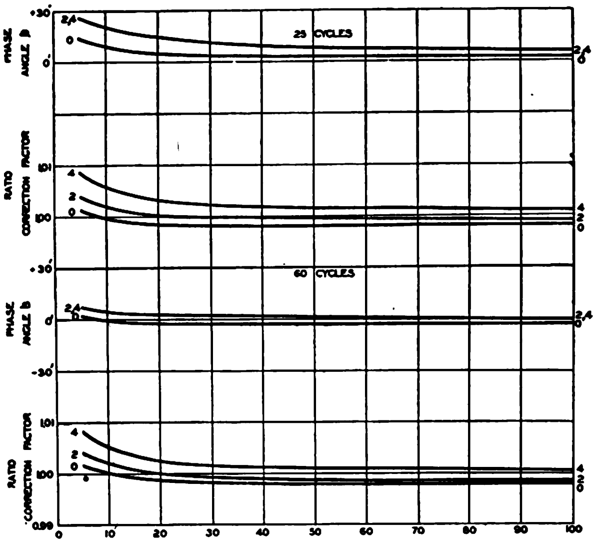


FIG. 37—Characteristic Curves of Type KF-85 and KF-58 Current Transformers Made by the General Electric Company.

and phase angle characteristics as shown by Fig. 37. In this figure, curves obtained at three different burdens are shown. The values of these burdens are given in the following table:

Burden No.	Volt-Amps.	Watts	Power Factor	Effective Ohms	Micro-henrys
0	6.0	6.0	1.00	0.240	......
2	19.2	17.05	0.89	0.682	936.0
4	45.1	24.28	0.54	0.971	4035.0

The mechanical features and appearance of these transformers are unchanged, as shown by Fig. 38 and 39.

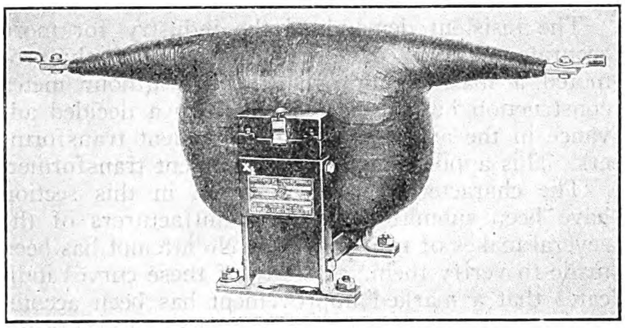


FIG. 38—TYPE KF-58 CURRENT TRANSFORMER MADE BY THE GENERAL ELECTRIC COMPANY.

In this new line of current transformers a very high degree of accuracy has been obtained by the use of certain corrective methods. Not only has the ratio error been minimized and the phase angle been reduced, but the slopes of the curves have been greatly reduced as well.

The principle upon which the ratio corrector operates is that of automatically changing the effective secondary turns as the load increases or decreases. For example, assume a ratio correction factor of 1.010 for 10 per cent load and of 1.000 for 100 per cent load. This indicates that at 10 per cent load the secondary current will be 1 per cent too small and at 100 per cent load it will be correct. Therefore, if we could remove 1 per cent of the secondary turns at 10 per cent load and gradually add them back as the load increased to 100 per cent, the curve would be flat and correct at all points from 10 per cent to 100 per cent load.

A special form of iron core has been designed. This, together with the ratio and phase angle corrector, is shown schematically in Fig. 40. Enough secondary turns are dropped to place the curves correctly. Then enough corrective turns are added, be-

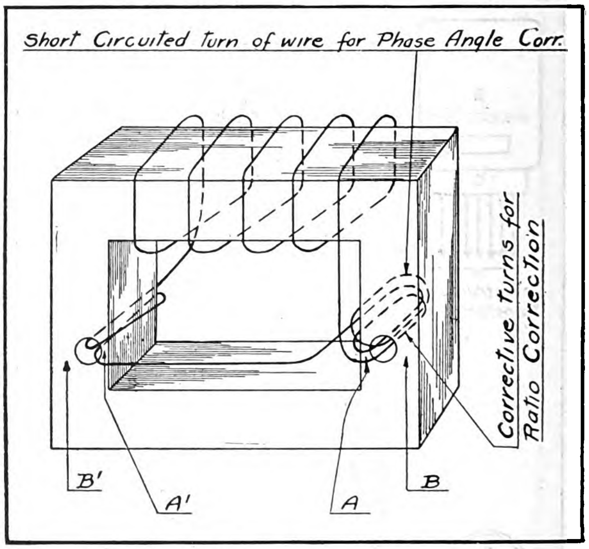
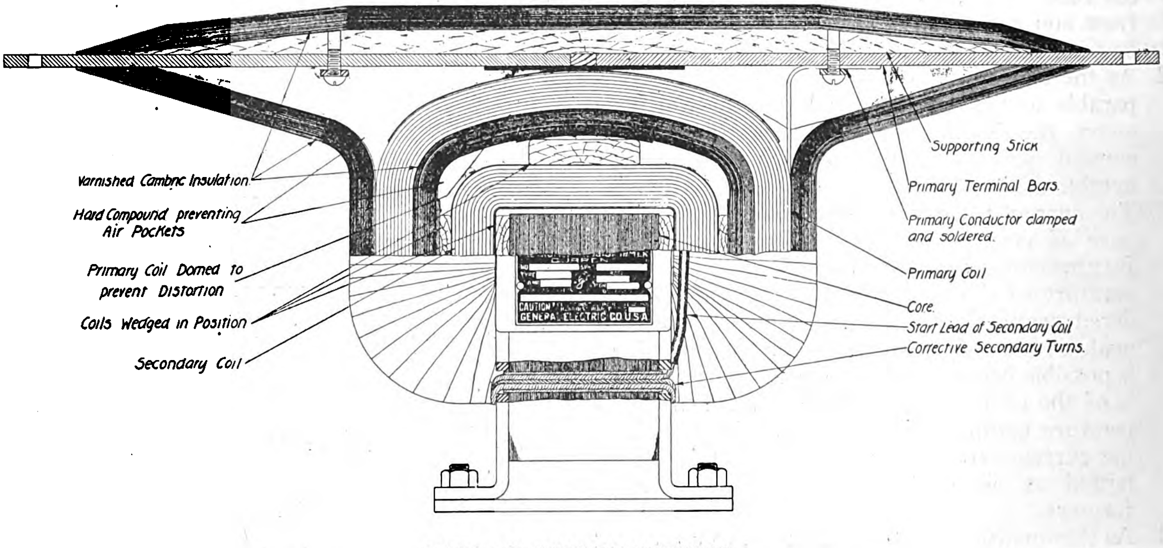

Short Circuited turn of wire for Phase Angle Corr.
Corrective turns for Ratio Correction
B'
A'
A
B

FIG. 40—SCHEMATIC DIAGRAM OF RATIO AND PHASE ANGLE CORRECTOR OF KF CURRENT TRANSFORMERS.


Varnished Cambric Insulation
Hard Compound preventing Air Pockets
Primary Coil Domed to prevent Distortion
Coils Wedged in Position
Secondary Coil
Supporting Stick
Primary Terminal Bars
Primary Conductor clamped and soldered
Primary Coil
Core
Start Lead of Secondary Coil
Corrective Secondary Turns
CAUTION
GENERAL ELECTRIC CO U.S.A.

TYPE KF-58 CURRENT TRANSFORMER

FIG. 39—CONSTRUCTION DETAILS OF THE TYPE KF-58 CURRENT TRANSFORMER.

ing wound through the holes, passing transversely through the core to properly straighten out or flatten the curves. From the sketch it will be noted that holes, passing transversely through the core, divide the flux path into two sections, A and B, and A′ and B′. At lower values of primary current (low load), the flux will divide in a certain proportion between the paths A and B and A′ and B′. As the primary current increases, a greater proportion of the flux will pass through paths B and B′ because of a change in the relative permeability of these parts, thus causing the corrective turns to have less and less effect as the current increases. Therefore, at full rated primary current, the distribution of the flux in these sections of the core is such that the corrective turns have very little effect, while at lower primary currents, where the ratio curve would naturally begin to turn up, the flux distribution changes so that the corrective turns have an increasingly greater effect. Thus, by the proper selection of the number of corrective turns, and with the correct proportioning of the sections A and B and A′ and B′, the ratio curve can be flattened to practically a straight line.

The phase-angle corrector consists of a short-circuited turn of wire around section A or A′ or both. This corrector is similar in its action to that of the lag plate of an ordinary watthour meter. The action of the flux due to the current induced in this wire has the effect of lagging the main flux slightly. This lagging of the main flux throws the reversed secondary current nearer in phase with the primary current, thus reducing the phase angle of the current transformer. The magnitude of the effect of this phase-angle corrector varies in the same manner and for the same reason as the ratio corrector described above. As in the case of the ratio corrector, the effect is greater at light loads than at full loads, tending to straighten the phase-angle curve and to reduce the angle.

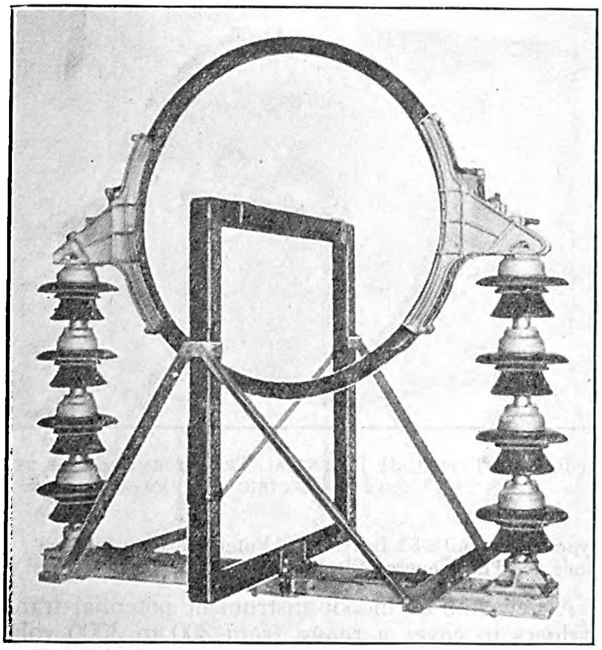


FIG. 41—AIR-INSULATED CURRENT TRANSFORMER MADE BY THE NIAGARA ELECTRIC IMPROVEMENT CORPORATION.

High-Voltage, Air-Insulated, Current Transformer Made by The Niagara Electric Improvement Corp.

The air-insulated current transformer has found its place in the development of high tension distribution systems. A high-voltage, air-insulated current transformer made by the Niagara Electric Improvement Corp. is shown in Fig. 41. The primary coil of this transformer is supported on conventional type high-tension insulators providing the necessary clearance between the primary and the core on which the secondary coil is wound.

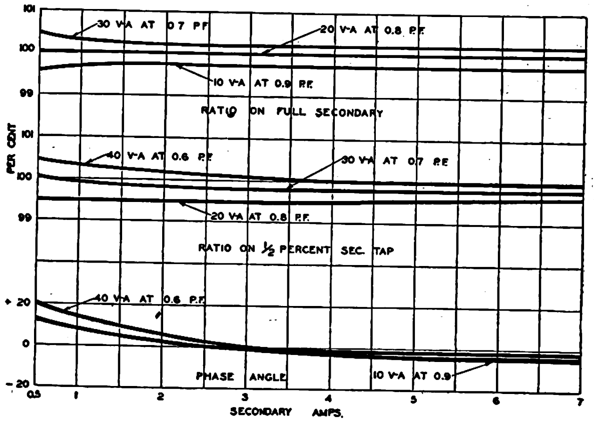


FIG. 42—CHARACTERISTIC CURVES OF AIR-INSULATED CURRENT TRANSFORMERS.

The manufacturer makes the following claims for these transformers:

1. Easy adaptability to outdoor bus and switch structures permits simplified current transformer installation.
2. Simplicity of design affords complete accessibility and visibility of parts.
3. Non-deteriorating air insulation between primary and secondary insures continuous and uninterrupted operation.
4. Windings will not be distorted under extreme overload and short circuit conditions.
5. Excellent accuracy resulting from a small ratio error and phase angle, which is desirable for all kinds of power measurements.

Fig. 42 shows the characteristic curves for this type of transformer as submitted by the manufacturer.

The manufacturer also claims that normal ratio is maintained up to ten times the rated current capacity, insuring dependable relay operation. The thermal capacity of windings is much in excess of that required by the A. I. E. E. specification. The guaranteed overload ratings are listed below:

80 times full load rated current for one (1) second.

55 times full load rated current for two (2) seconds.

45 times full load rated current for three (3) seconds.

40 times full load rated current for four (4) seconds.

35 times full load rated current for five (5) seconds.

Due to the open construction, the ratio can be varied by adding more turns to boost or buck the secondary current. The phase-angle also can be varied by short-circuiting loops placed at proper points.

Type NA Current Transformer Made by The Westinghouse Electric & Manufacturing Co.

The Westinghouse Electric & Manufacturing Co. placed on the market recently a current transformer in which the new "Hipernik" steel is used in place of the usual silicon steel. Hipernik steel was developed by Westinghouse research engineers who claim that it has three times the permeability of silicon steel with but half the losses. These characteristics are desirable for good transformer design. So far, this material has been used in the 7500-volt transformer only. The new current transformer is known as the Type NA, and is obtainable in all standard current capacities. The new design shows decided improved performance in respect to ratio and phase-angle as compared with the Type KA which it supersedes. Fig. 43 and 44 show the performance characteristics of the Type NA current transformer as submitted by the manufacturer.

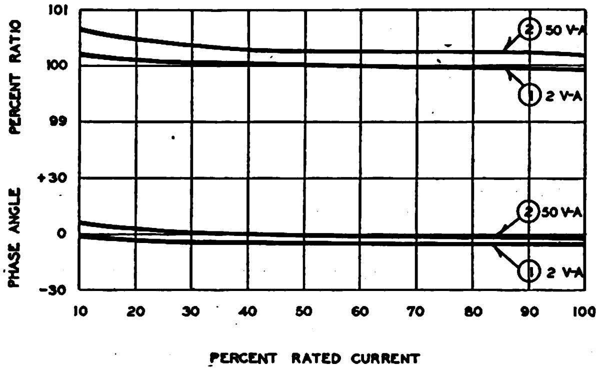


FIG. 43—Characteristic Curves of Type NA Current Transformers Made by the Westinghouse Electric & Manufacturing Co.—Effect of Secondary Burden Variation.

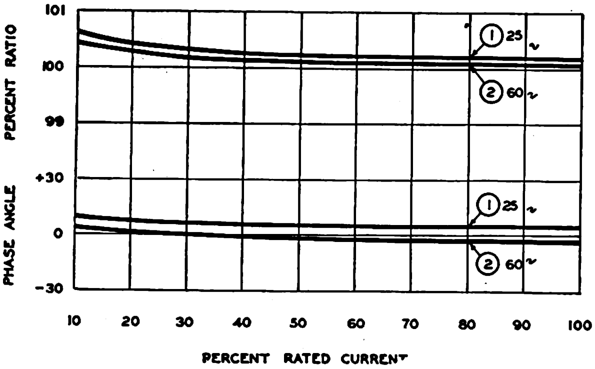


FIG. 44—Characteristic Curves of Type NA Current Transformer—Effect of Frequency Variation.

The mechanical improvements include a secondary terminal block provided with a sealable cover and equipped with an automatic short-circuiting device. The primary terminals are located along the center line of the windings and are equipped with two-bolt pressed-tube terminals. The inside bolt holes of the primary terminals have been placed 12½ inches apart on transformers of all capacities, making them interchangeable with each other and with the Type KA units. The two sets of bolt holes also assist interchangeability with other types of current transformers.

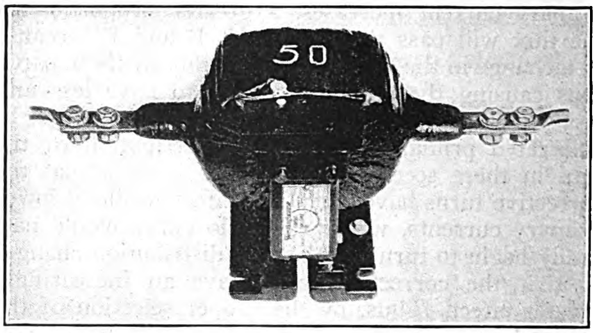


FIG. 45—Type NA Current Transformer Made by the Westinghouse Electric & Mfg. Co.

The mounting feet are designed for flat surface or transverse pipe framework mounting. The 50-ampere size transformer is shown in Fig. 45.

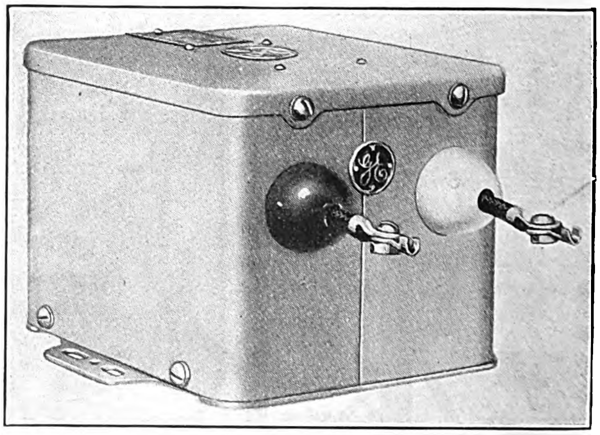


FIG. 46—Type E-31 Potential Transformer Made by the General Electric Company.

Types E-31 and E-32 Instrument Potential Transformers Made by The General Electric Co.

A new line of indoor instrument potential transformers to cover a range from 200 to 3000 volts, 60 cycles, has been developed by the General Electric Company. Transformers not provided with

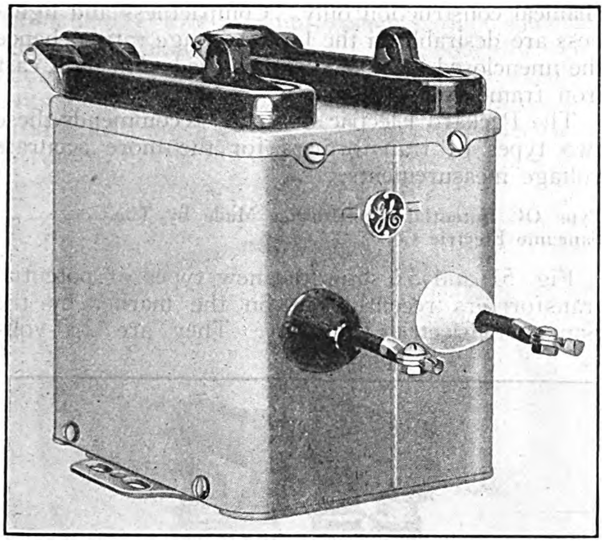


FIG. 47—TYPE E-32 POTENTIAL TRANSFORMER MADE BY THE GENERAL ELECTRIC COMPANY.

fuses are designated Type E-31, Fig. 46, and those provided with fuses are designated Type E-32, Fig. 47. They are rated 100 volt-amperes under the General Electric standard of rating instrument transformers, and are compensated for 50 volt-amperes at 115 volts secondary. The thermal rating (maximum allowable burden) is 300 volt-amperes.

The windings of these transformers are heavily insulated. Varnished cambric is used between end layers. The insulation of the primary conductors and sections of the primary coil is such as to produce unusually high factors of safety.

The core and windings are enclosed in a heavy metal casing. The secondary leads are brought out through a metal connection box of standard design which can be mounted in any one of the four quadrant positions by simply changing the position of two screws. This facilitates the installation of the conduit wiring. If this is not desired, the connection box can be readily removed. The primary bushings are made of a single piece of porcelain, and are fastened to the casing by a steel clamping ring.

These transformers have subtractive polarity. The primary polarity markings are made permanent by the use of white, and brown bushings, and one secondary lead is painted white. In addition polarity markings are embossed on the metal casing near the primary bushing and on the metal connection box near the secondary lead.

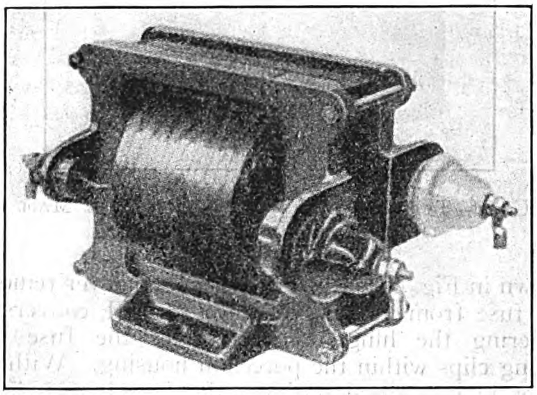


FIG. 49—TYPE PS POTENTIAL TRANSFORMER MADE BY THE PACKARD ELECTRIC COMPANY.

The Type E-32 transformer has fuse supports and housings of special design which facilitate inspection and renewal. This type of transformer with its special hinged cover fuse equipment is

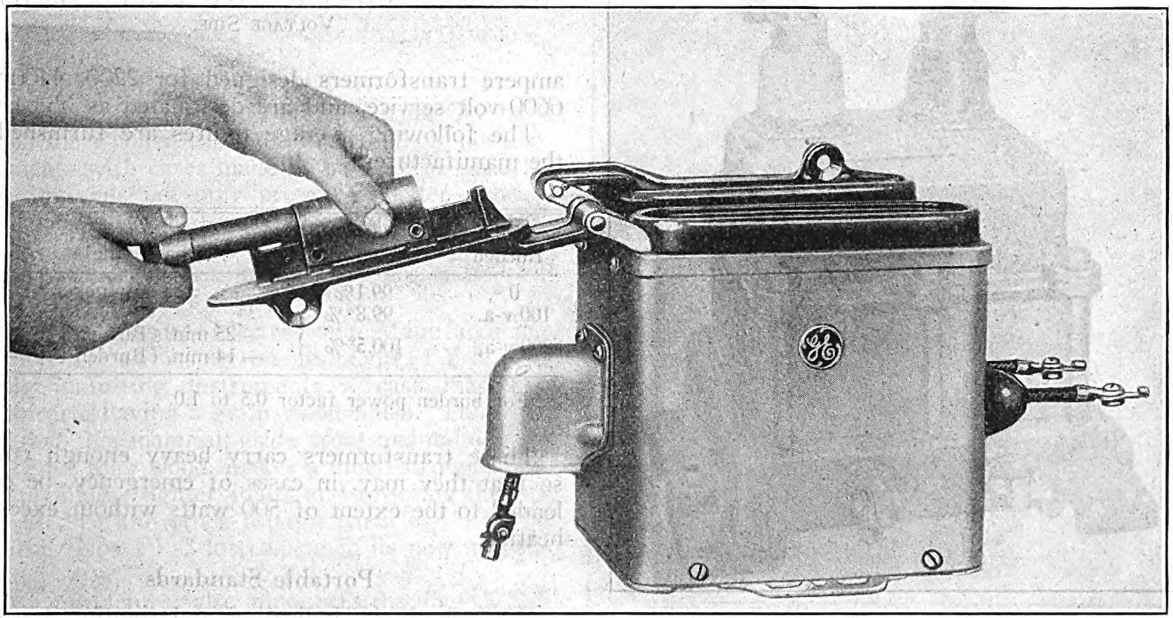


FIG. 48—TYPE E-43 POTENTIAL TRANSFORMER—METHOD OF REMOVING FUSE FROM FUSE HOLDER.

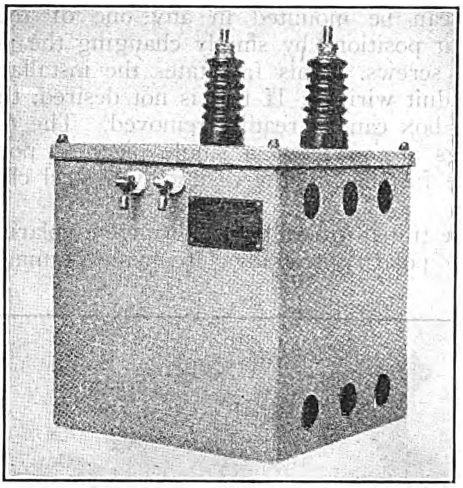


FIG. 50—Type PD Potential Transformer Made by the Packard Electric Company.

shown in Fig. 48. Raising the hinged cover removes the fuse from its clips in the block and, conversely, lowering the hinged cover forces the fuse into spring clips within the porcelain housing. With the cover in its normal position, the fuse is completely enclosed.

Types PS and PD Potential Transformers Made by The Packard Electric Co.

This company has developed two new lines of indoor dry type potential transformers. The Type PS, Fig. 49, is designed for use on the several standard primary voltages up to and including 6900 volts. The Type PD, Fig. 50, is available for 11,500 and 13,800-volt service.

The difference between these two types is in mechanical construction only. Compactness and lightness are desirable in the lower voltage rating, hence the unenclosed Type PS is furnished with light cast iron frame and feet.

The Packard Electric Company recommends these two types of transformers for the more accurate voltage measurements.

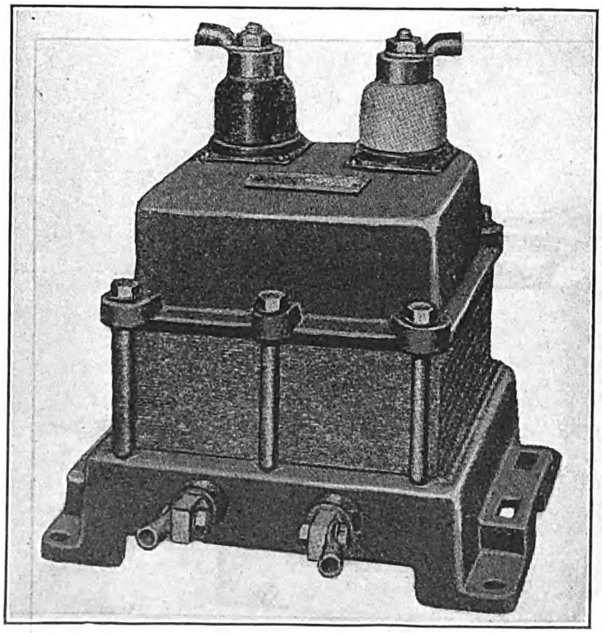


FIG. 51—Type OC Potential Transformer Made by the Sangamo Electric Company—Not Fused.

Type OC Potential Transformer Made by The Sangamo Electric Co.

Fig. 51 and 52 show the new types of potential transformers recently put on the market by the Sangamo Electric Company. They are 200-volt-ampere transformers designed for 2200, 4400 and 6600-volt service, and are designated as Type OC.

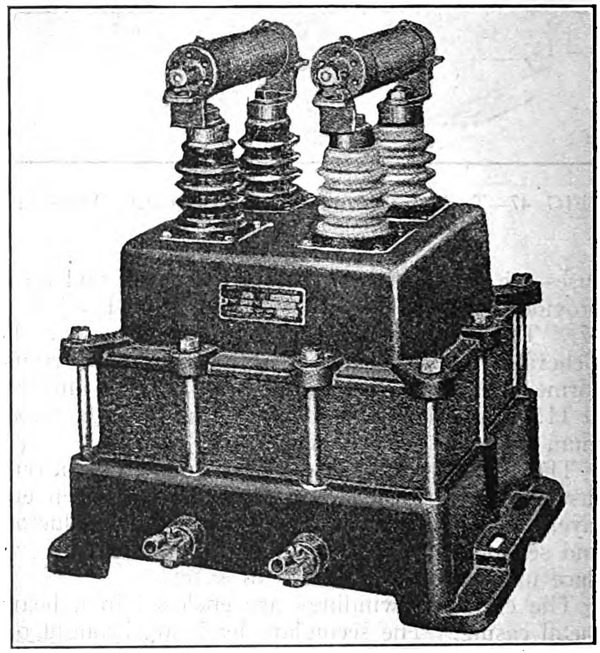


FIG. 52—Type OC Potential Transformer Made by the Sangamo Electric Company—Fused on the High Voltage Side.

The following average figures are furnished by the manufacturer:

Secondary Burden	Ratio Factor	Phase Angle
0	99.1%	+ 3 minutes
100 v-a.	99.8*%	—
200 v-a.	100.5*%	— 25 min. (Burden P.F. = 1.0) — 14 min. (Burden P.F. = 0.5)

*For burden power factor 0.5 to 1.0.

These transformers carry heavy enough copper so that they may, in cases of emergency, be overloaded to the extent of 500 watts without excessive heating.

Portable Standards

While both the indicating and rotating types of portable standards have received their share of attention in the way of improvements, their general appearance remains the same. Consequently few announcements have been received of new developments in this line. A number of manufacturers of portable instruments, such as the Weston Electrical Instrument Corp., the General Electric Co., and the Westinghouse Electric and Manufacturing Co., have replaced the wooden cases of some of their portable instruments with cases made of bakelite or micarta. These materials not only present a better appearance than wood, but also are more durable.

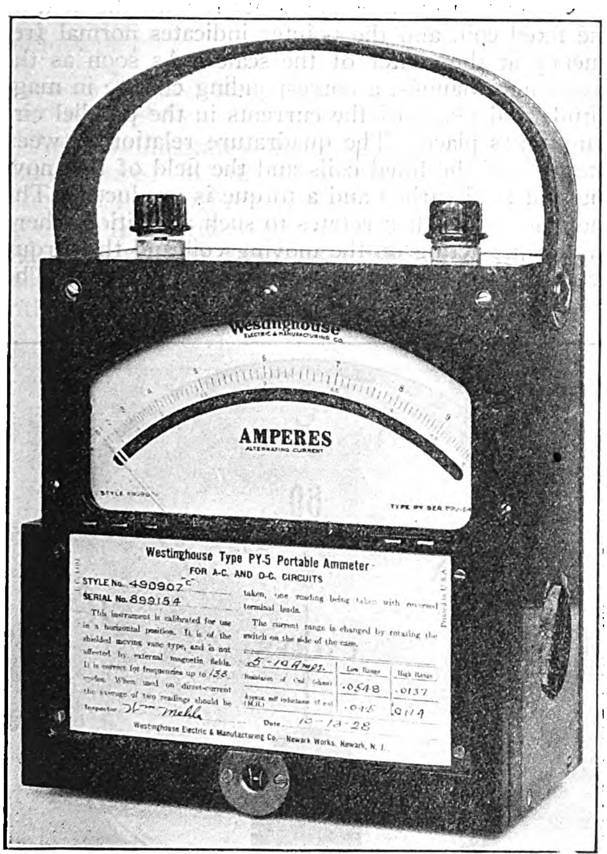

Westinghouse
AMPERES
Westinghouse Type PY-5 Portable Ammeter
FOR A-C. AND D-C. CIRCUITS

FIG. 53—TYPE PY-5 AMMETER MADE BY THE WESTINGHOUSE ELECTRIC & MFG. CO.—MOUNTED IN MICARTA CASE.

Portable Instruments Made by The Westinghouse Electric & Manufacturing Co.

The Westinghouse Electric and Manufacturing Company is now using on its Type PY-5, a-c. portable indicating instruments a case made of sheet micarta having a grain wood finish. This firm claims that this material, aside from maintaining its finish better than wood, makes a much stronger box which maintains tighter joints and prevents the entrance of dust and other foreign particles. Fig. 53 shows the Type PY-5 instrument in its new micarta case.

This manufacturer also announces the Type PX-5 line of portable direct-current instruments furnished in a case similar to that of the PY-5.

Type OB Portable Watthour Meter Made by The Westinghouse Electric & Manufacturing Co.

The Type OB portable watthour meters are now available in either two or five current ranges. The five current range meter is wound for 1, 5, 10, 25 and 50 amperes. The case is of one-piece micarta with mahogany finish, Fig. 54. The meter weighs eight pounds, and its dimensions, less handle, are 4¾ in. by 6½ in. by 6½ in.

Frequency Meters, Indicating and Graphic

Modern practice in station operation, incident to the development of large electrical systems involving the interconnection of large capacity units, have created a demand for more accurate frequency

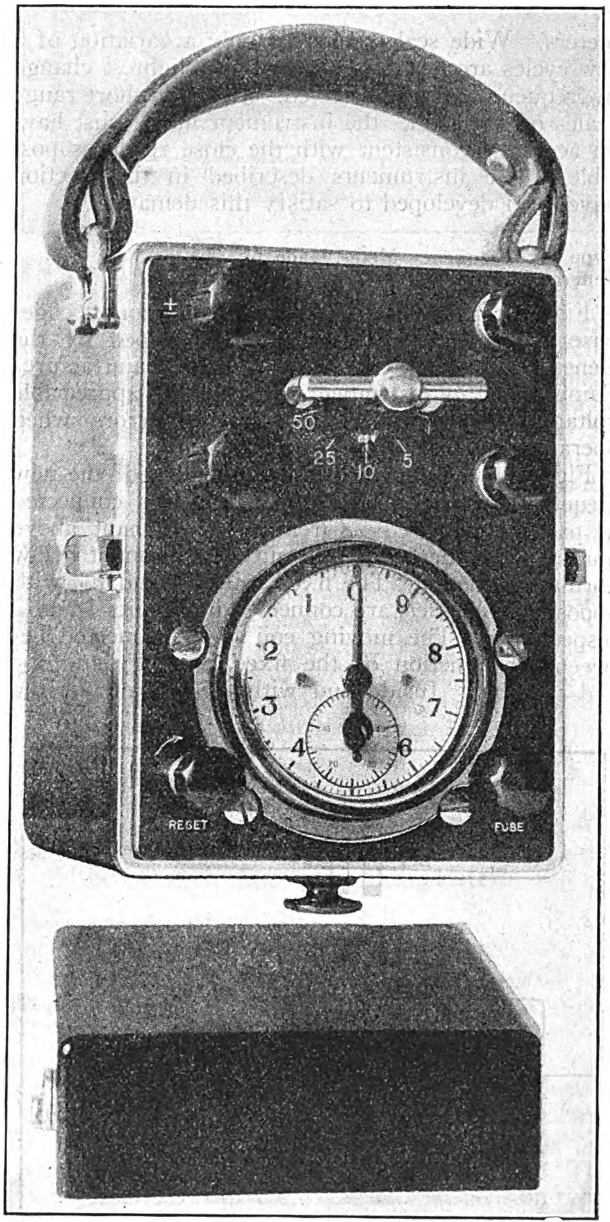


FIG. 54—TYPE OB PORTABLE WATTHOUR METER MADE BY THE WESTINGHOUSE ELECTRIC & MFG. CO.

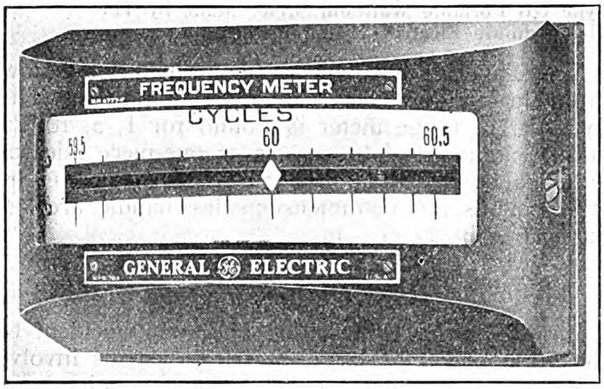


FIG. 55—Type H-8 Frequency Meter Made by the General Electric Company.

meters. Wide scales covering only a variation of a few cycles are desirable, so that the slightest change in frequency may be detected. To make short range scales of any value, the instrument itself must have an accuracy consistent with the close readings possible. The instruments described in this section have been developed to satisfy this demand.

Type H-8 Frequency Meter Made by The General Electric Co.

Fig. 55 shows the Type H-8, a horizontal edgewise frequency meter, recently developed by the General Electric Company. The manufacturer claims that this instrument is free from appreciable voltage, wave-form, or temperature errors when operating under extreme conditions.

Fig. 56 shows the circuit arrangement of the new freqency meter. Two resonant circuits connected in parallel are used. Circuit 1 is resonant above normal frequency, while circuit 2 is resonant below normal frequency. The fixed coils, F_1 and F_2, with opposing polarities, are connected in circuits 1 and 2 respectively. The moving coil M is connected between the junction of the fixed coils, F_1 and F_2, and the line. Inside and within the plane of the moving coil is an iron vane. The resistance of circuit 1 is approximately equal to that of circuit 2, therefore, the currents in the two parallel circuits are equal at normal frequency.

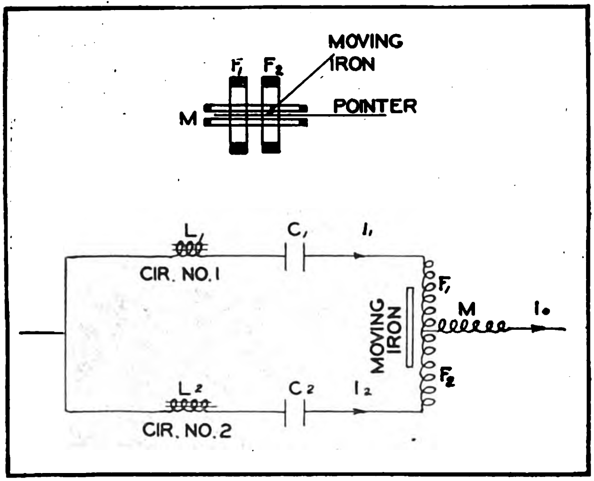


FIG. 56—Schematic Diagram Showing the Internal Connections of the Type H-8 Frequency Meter.

At normal frequency the field of the fixed coils is in quadrature with the field of the moving coil. Therefore, no torque is exerted on the moving coil. The moving iron vane aligns itself with the field of the fixed coil, and the pointer indicates normal frequency at the center of the scale. As soon as the frequency changes, a corresponding change in magnitude and phase of the currents in the parallel circuits takes place. The quadrature relation between the field of the fixed coils and the field of the moving coil is disturbed and a torque is produced. The moving system then rotates to such a position where the torque acting on the moving coil and the torque acting on the iron vane are equal and opposite. The deflecting torque is proportional to the difference of the squares of the currents in the two parallel circuits. Due to this fact, the instrument is referred to as a "differential" frequency meter. The restoring torque (control torque) is proportional to the square of the resultant current.

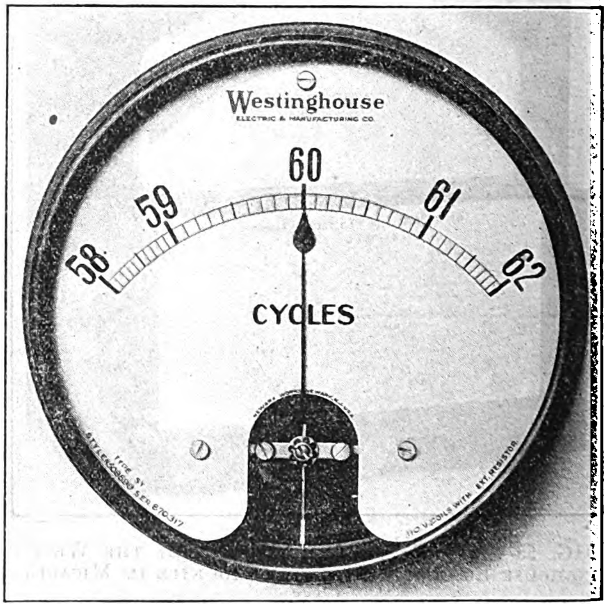


FIG. 57—Type SY Frequency Meter Made by the Westinghouse Electric & Mfg. Co.

The normal position of the pointer, at the center of the scale, is fixed by the position of the iron vane on the moving coil shaft. The scale characteristic is determined by the angle between the iron vane and the shaft.

The Type H-8 instruments are supplied with an external resistor for use on 110-volt circuits. For higher voltages, potential transformers are necessary. The following scale ranges are available: 59.5 to 60.5 cycles; 59 to 61 cycles; 55 to 65 cycles; 45 to 55 cycles; and 22.5 to 27.5 cycles.

Type SY Indicating Frequency Meter Made by The Westinghouse Electric & Manufacturing Co.

The Westinghouse Electric and Manufacturing Company has now on the market the Type SY frequency meter for use on switchboards. This is a short-range scale instrument of the resonant type, Fig. 57. The manufacturer advises that it has a torque equal to that of switchboard ammeters and voltmeters.

Frequency Recorder Made by The Esterline-Angus Co.

Fig. 58 illustrates the new frequency recorder manufactured by the Esterline-Angus Company. Single instruments are available in any of five types of cases for portable use and for wall or switchboard mounting. Twin cases are furnished in the wall or switchboard type mountings for combination with another frequency recorder or meter elements of other types. The weight of a single instrument is about 25 lb., and that of the twin type about 45 lb. The electrodynamic principle is employed. The scale of this instrument is 55 to 65 cycles and is distributed practically uniformly across a chart 4½ in. wide. The scale and record chart have ten main divisions, one for each cycle. Each main division is divided into four smaller divisions of ¼-cycle each.

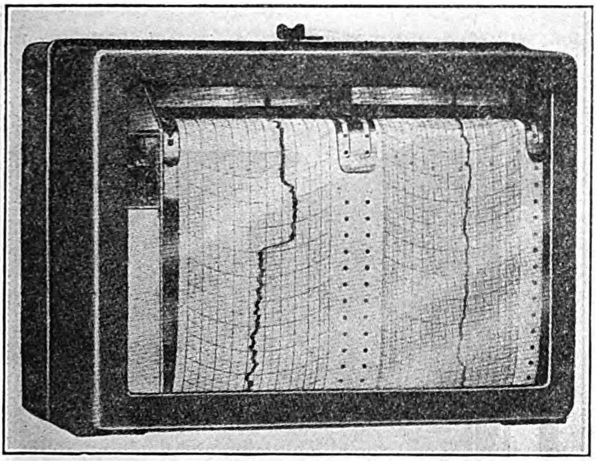


FIG. 58—FREQUENCY RECORDER MADE BY THE ESTERLINE-ANGUS COMPANY—MOUNTED IN A TWIN CASE WITH ANOTHER INSTRUMENT OF THE SAME MANUFACTURER.

This instrument can be furnished with spring-wound clocks for driving the chart at either ¾, 1½, 3, 6 or 12 in. per hour.

Type R Graphic Frequency Recorder Made by The Westinghouse Electric & Manufacturing Co.

The Westinghouse Electric and Manufacturing Company has on the market a recording frequency meter of the short-range type, Fig. 59. To measure frequency, this instrument uses the centrifugal force developed by a flyball governor driven by a synchronous motor. Any variation of the frequency produces a change in centrifugal force proportional to the difference of the square of the frequencies before and after the change. The force developed is transmitted through a mechanical linkage to a pivoted beam. Electrical contacts are located at the free end of this beam and a balance weight, linked to the pen carriage, rides on top of it. As the centrifugal force varies, the closing of one or the other of the electrical contacts causes a control motor to move the balancing weight and pen, maintaining a balance of force and weight and graphically recording the frequency variations.

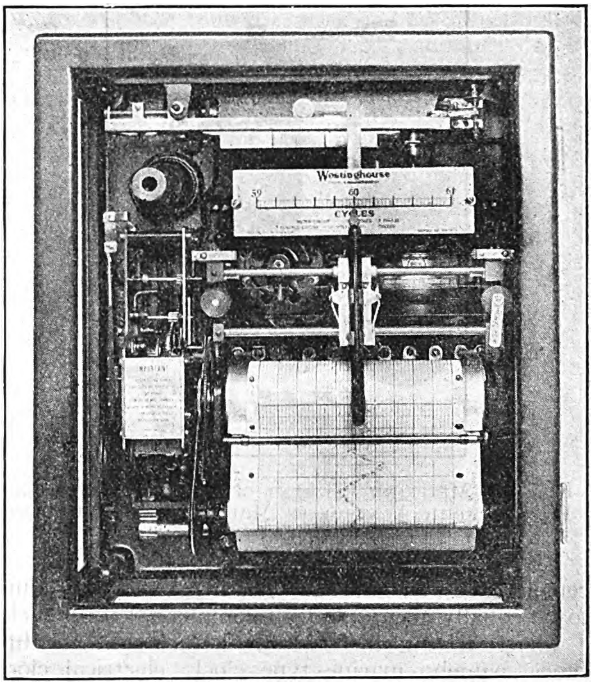


FIG. 59—TYPE R FREQUENCY RECORDER MADE BY THE WESTINGHOUSE ELECTRIC & MFG. CO.

The manufacturer claims that this instrument is very accurate, sensitive, and rugged. The instrument illustrated has a scale of 59 to 61 cycles and a 5¼ in. chart traveling at the rate of 4 in. per hour.

Other Graphic Instruments

While the changes in the general line of graphic instruments has not been of a radical nature, they should be of some interest to the industry.

Three-Phase, Four-Wire, Graphic Wattmeter Made by The Esterline-Angus Co.

The Esterline-Angus Company is prepared to meet the increasing demand for a graphic wattmeter for use on three-phase, four-wire circuits. The metering element is of the electrodynamic type, having three stationary current coils and two potential coils as shown in Fig. 60. The current coils have a normal rating of 5 amperes but will carry 35 per cent overload continuously without overheating. The moving element is of the usual wire suspension type. The potential circuit is furnished with external resistors for use on 115, 230 or 575 volts, and is designed to operate satisfactorily on voltages 35 per

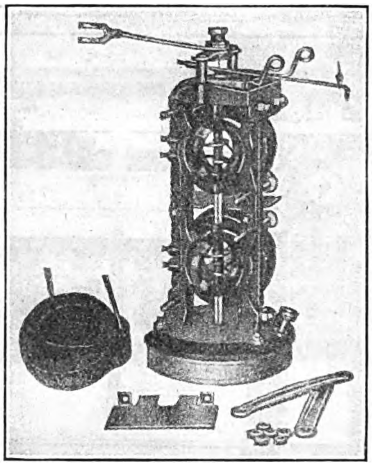


FIG. 60—METERING ELEMENT OF THREE-PHASE, FOUR-WIRE GRAPHIC WATTMETER MADE BY THE ESTERLINE-ANGUS COMPANY.

cent in excess of normal. The instrument is claimed to be equally accurate at all commercial frequencies.

Chart driving mechanism is furnished in three types, namely, marine type clock, electrical clocks suitable for use with impulse timing systems, and synchronous motor drive. Chart speeds of ¾, 1½, 3, 6 or 12 in. per hour are available. The instrument can also be furnished with a relay which can change the chart speed instantaneously from in. per hour to in. per second.

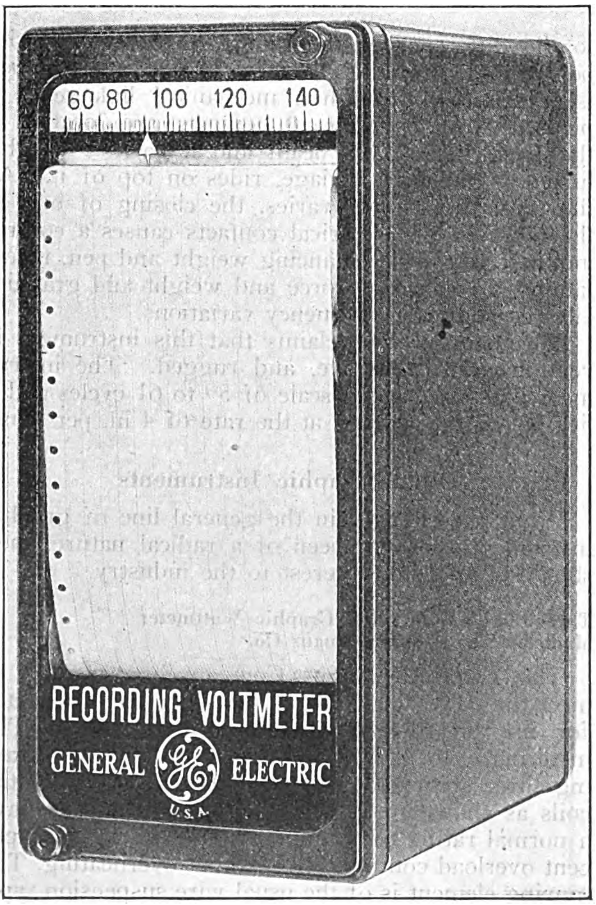


FIG. 61—TYPE CD STRIP CHART RECORDING VOLTMETER MADE BY THE GENERAL ELECTRIC COMPANY—SWITCHBOARD TYPE.

Three-phase, four-wire wattmeters are furnished in single portable, wall, and switchboard type cases. The twin type case is available for wall and switchboard mounting, for combining with any other graphic type instrument, except the volt-ampere meter.

Types CD and CDP Strip-Chart Recording Instruments Made by The General Electric Co.

The General Electric Company has placed on the market a complete line of general-purpose recording instruments for alternating-current and direct-current service, known as the Types CD and CDP. The metering element in the alternating-current instrument is of the electrodynamic type, while the direct-current element is of the permanent magnet type. The moving element of each is mounted in jewel bearings and damped magnetically.

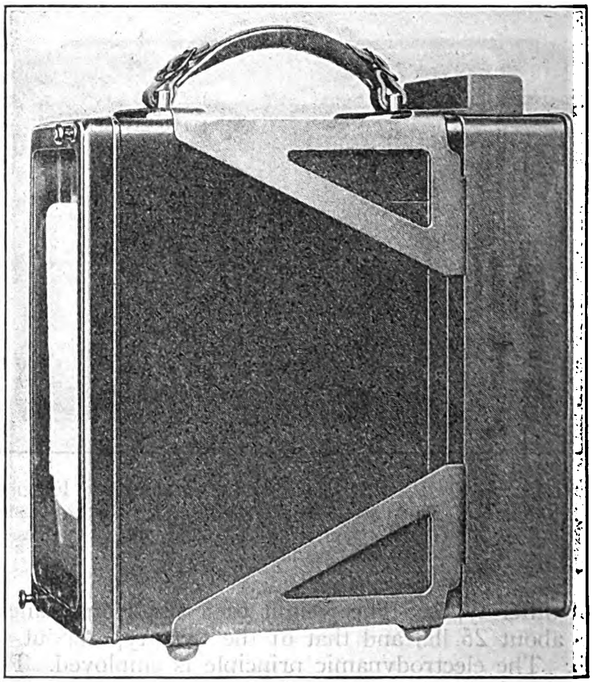


FIG. 62—TYPE CD STRIP CHART RECORDING INSTRUMENT MADE BY THE GENERAL ELECTRIC COMPANY—PORTABLE TYPE.

The record roll is 4⅜ in. wide and has a 4 in. scale. The standard chart speed is 3 in. per hour, but speeds of 1 in. or 2 in. per hour may be supplied with a spring wound clock mechanism. When a Warren synchronous motor clock is used, chart speeds of 1, 2, 6 and 12 in. per hour are available. These instruments are furnished for switchboard mounting as shown in Fig. 61, or for portable use as shown in Fig. 62. Fig. 63 shows

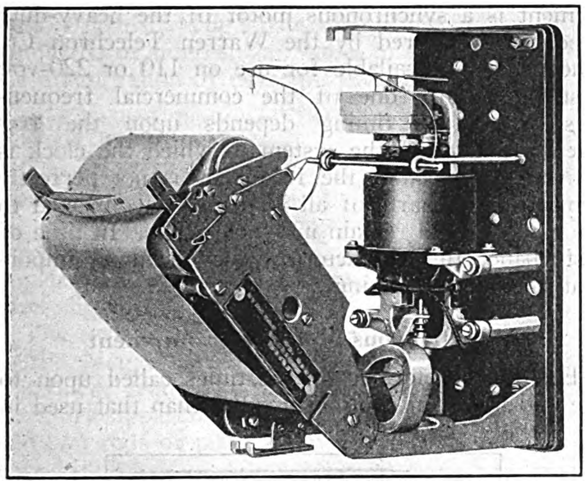


FIG. 63—INTERIOR VIEW OF A TYPE CD A-C. INSTRUMENT.

an internal view of the alternating-current instruments.

Type A Circular Chart Graphic Ammeters and Voltmeters Made by the Westinghouse Electric & Manufacturing Co.

The Westinghouse Electric & Manufacturing Co. has on the market a circular chart, Type A, graphic instrument available either as a voltmeter or an ammeter, Fig. 64. It operates on the electromagnetic principle, and the record is obtained with a pencil, rather than with ink in the usual manner. The manufacturer states that it is ruggedly constructed and has exceptionally strong torque.

Type R Power Factor Recorder Made by the Westinghouse Electric & Manufacturing Co.

There has been considerable discussion during recent years concerning the measuring and recording of three-phase power factor. The Westinghouse Electric & Manufacturing Co. announces a new Type R graphic power factor recorder (Fig. 65), which employs the principle of measuring the vectorial power factor of a three-phase system as recommended by the American Institute of Electrical Engineers.

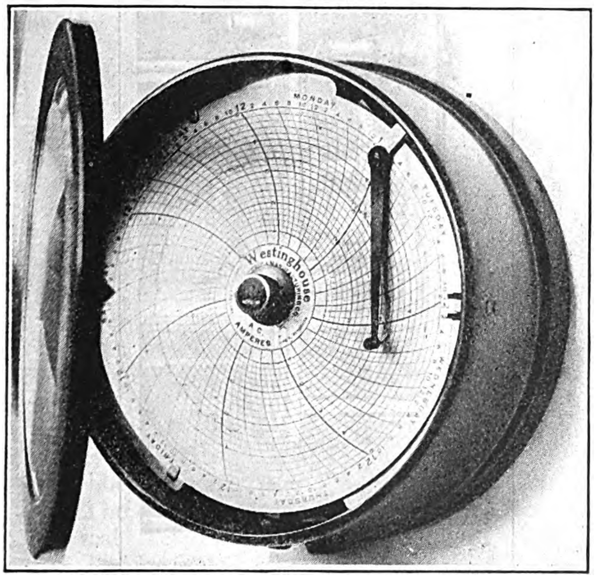


FIG. 64—TYPE A CIRCULAR CHART GRAPHIC INSTRUMENT MADE BY THE WESTINGHOUSE ELECTRIC & MFG. CO.

The manufacturer claims that this instrument will measure accurately the power factor when the current through the 5-ampere coils is as low as one ampere, within the frequency limits of 58 to 62 cycles. This instrument is also built for other frequencies, such as 25 and 50 cycles.

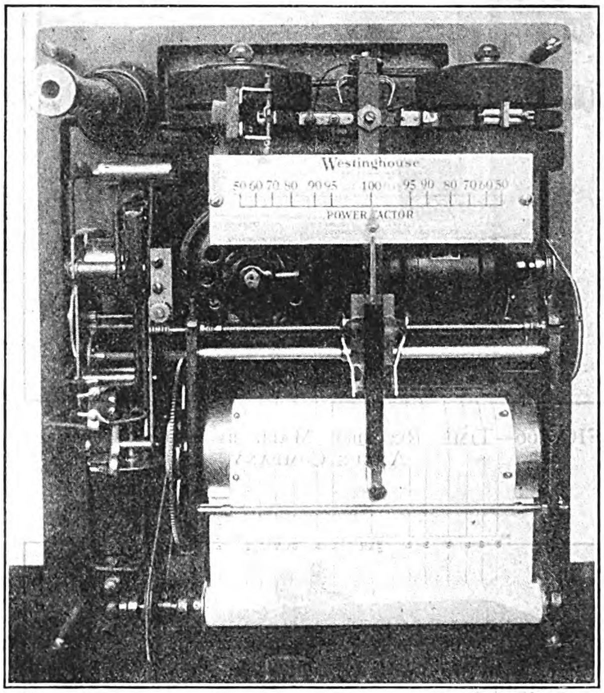


FIG. 65—TYPE R GRAPHIC POWER FACTOR METER MADE BY THE WESTINGHOUSE ELECTRIC & MFG. CO.

Time Recorder Made by the Esterline-Angus Co.

The Esterline-Angus Co. has developed a device for recording time. It consists of a graphic meter built along the general lines of their product. The timing elements consist of small relays which actuate separate pens. There may be 5, 10 or 20 of these, depending upon the model of instrument. Each relay may be used to time a separate operation, or may be used to show one operation in a complex cycle. They are excited from a source controlled by the operation being timed. The general design of this instrument is shown in Fig. 66 and 67.

Synchronous Clock Chart Drive Made by the Esterline-Angus Co.

Synchronous motor drive in use for some years on General Electric Co. recording instruments is now also available for Esterline-Angus graphic instruments. This device, Fig. 68, was developed to meet the demand for more accurate timing. The driving

connection with the measurement of customer, or station loads. The instruments discussed below should be of interest and value to those engaged in the investigation of electrical problems.

Megger Ground Resistance Tester Imported by James G. Biddle

The Megger Ground Resistance Tester is a direct-reading electrical instrument designed for measuring the resistance of ground connections such as driven pipes and rods, buried plates, patented grounding devices, water pipes, ground wires, steel structures, lightning arrester, etc.

The instrument is similar in size and appearance to the Megger Insulation Testing Set. It is self-contained, requiring no external current supply or auxiliary apparatus whatever, except flexible leads and two rods or pipes for use as auxiliary or reference grounds.

A number of ranges are available, from 0 to 3 ohms, up to 0 to 3000 ohms full scale, with as many as three ranges in the same instrument. Fig. 69 and 70 show a side and top view of the device. The following are some of the outstanding characteristics of the Megger Ground Resistance Tester as outlined by the manufacturer:

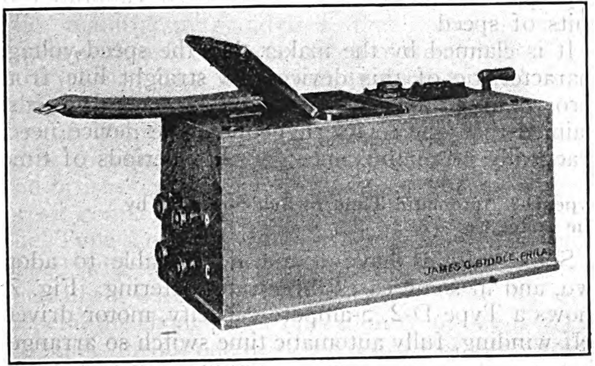


FIG. 69—MEGGER GROUND RESISTANCE TESTER IMPORTED BY JAMES G. BIDDLE.

1. It is direct reading, being of the pointer type, like a voltmeter, and requires no manipulation.
2. It is simple to use, requiring only the making of external connections, turning of the crank and reading.
3. It is portable and weighs only 21 lb.
4. Ground resistance in the vicinity of severe stray earth currents can be measured. Satisfactory results have been obtained with as much as 50 volts difference of potential between grounded points.
5. Variable resistance grounds can be determined because the instrument is direct reading, and the pointer follows instantaneously any change of resistance.
6. It is available in a wide assortment of ranges.
7. The method used permits of high accuracy.
8. The instrument is of the same rugged mechanical construction as the Megger Insulation Testing Sets.

The internal connections of the Megger Ground Resistance Tester are shown in Fig. 71.

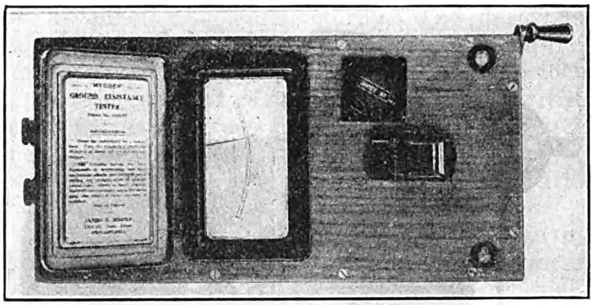


FIG. 70—MEGGER GROUND RESISTANCE TESTER—TOP VIEW.

Power Osiso Made by the Westinghouse Electric & Manufacturing Co.

The Westinghouse Electric & Manufacturing Co. has on the market a four-element power Osiso, Fig. 72 and 73. Although it can be used in the laboratory for general oscillograph work, it has certain special features which make it particularly desirable for investigation of line disturbances. For study of disturbances the Osiso can be made to start in 0.03 second after the disturbance starts. The normal film speed is 3 in. per second, but it can be decreased automatically, if desired, to ½ in. per second after the disturbance has somewhat subsided. The film holder is of the daylight loading type and accommodates a 5 ft. or 10 ft. film. A dark-room film holder that can accommodate a 15 ft. film is also available.

Single-Phase Klydonograph Made by the Westinghouse Electric & Manufacturing Co.

A single-electrode or single-phase Klydonograph has recently been placed on the market by the Westinghouse Electric & Manufacturing Co. This instrument is similar to the three-phase Klydonograph but has only one electrode, and makes use of a film pack instead of roll film. The index pointer

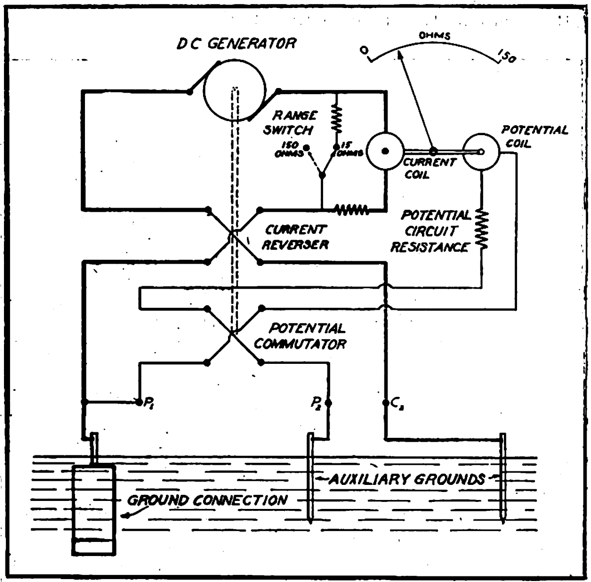


FIG. 71—CONNECTION DIAGRAM OF THE MEGGER GROUND RESISTANCE TESTER.

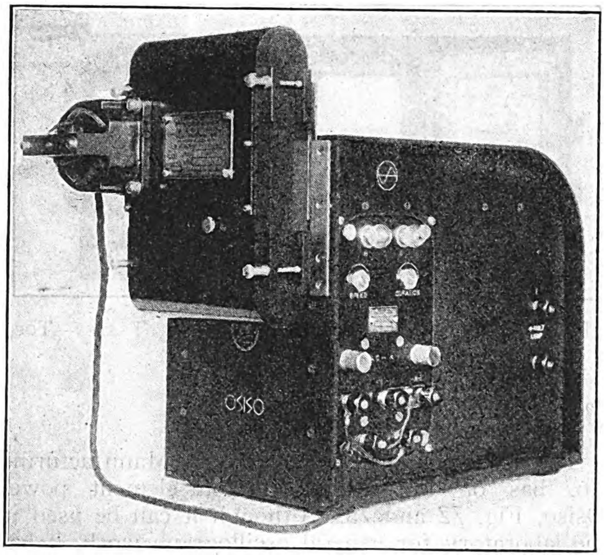


FIG. 72—POWER OSISO MADE BY THE WESTINGHOUSE ELECTRIC & MFG. CO.—MOTOR AND SHUTTER CONTROL PANEL.

on the bottom of the instrument can be advanced one position each day, which moves the electrode to a different position on the film. Therefore, one film may serve to obtain records for one week. The Lichtenberg figures produced on the film have the same characteristics as those produced on the roll film of the larger size, four-electrode, Klydonograph.

The instrument may be connected to the circuit in a manner similar to an electrostatic potentiometer, *i.e.*, taking the potential drop along a string of suspension insulators, to obtain approximately 1800 volts.

The instrument is mounted in a horizontal position and can be installed on the cross arm of a pole or a specially constructed framework. Fig. 74 shows the top view of the single-phase Klydonograph with cover on, while Fig. 75 shows a bottom view. Both figures show the mounting studs.

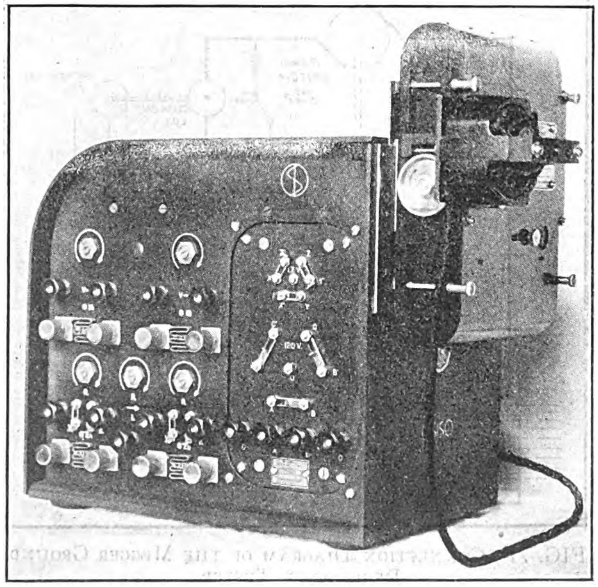


FIG. 73—POWER OSISO—ELEMENT CONTROL PANEL.

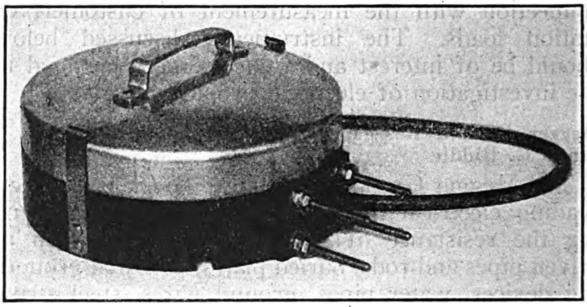


FIG. 74—SINGLE-PHASE KLYDONOGRAPH MADE BY THE WESTINGHOUSE ELECTRIC & MFG. CO.

Tachometer Generator Made by The Esterline-Angus Co.

Fig. 76 and 77 are two views of a new Tachometer Generator manufactured by the Esterline-Angus Company. This generator can be directly connected to shafts revolving at speeds up to 4000 r.p.m. The voltage generated is directly proportional to the speed of the shaft. This voltage value may be recorded on a graphic voltmeter which has been calibrated in units of speed.

It is claimed by the maker that the speed-voltage characteristic of this device is a straight line from zero r.p.m. to approximately 4000 r.p.m. It is also claimed that due to its ruggedness the device needs practically no maintenance for long periods of time.

Type D-2 Automatic Time Switch Supplied by The States Co.

Some utilities have found it desirable to adopt two, and in some cases three-rate metering. Fig. 78 shows a Type D-2, 5-ampere capacity, motor driven, self-winding, fully automatic time switch so arranged that it will change over the circuit from meter "A" to meter "B" at a specified time during a 24-hour

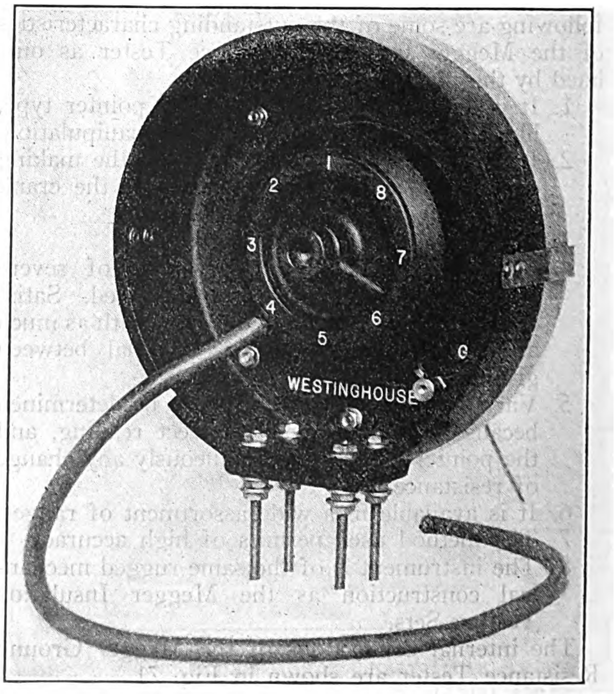


FIG. 75—SINGLE-PHASE KLYDONOGRAPH—BOTTOM VIEW.

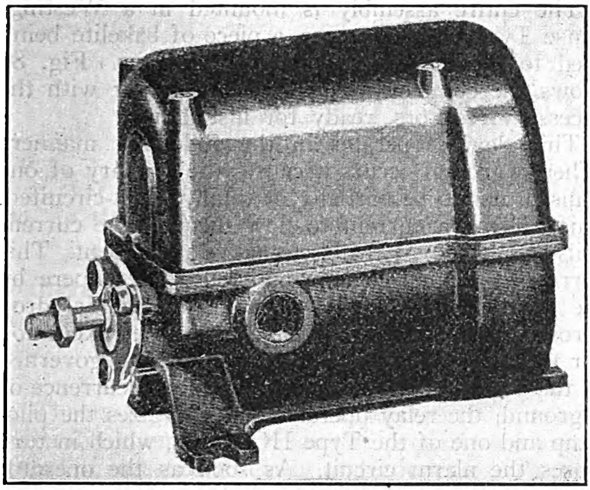


FIG. 76—TACHOMETER GENERATOR MADE BY THE ESTERLINE-ANGUS COMPANY.

period, and at a later selected time, restore the circuit to meter "A."

The manufacturer advises that switches are equipped with a high-grade watch movement having fifteen jewels. The movement is compensated for temperature changes, and has a reserve running capacity of about three days. The movement itself requires no oiling. The motor used in these switches has no brushes, no revolving armature, and no make or break contacts.

The Type D-2 two-rate meter switches may be equipped with a so-called "Sunday Cutout." This is normally a seven-day dial, but may be so set as to suspend the change over operation from one meter to the other during one or two days of the week, for example, from Saturday noon to Monday morning.

Relay Ground Detector Made by the Buffalo General Electric Co.

The Buffalo General Electric Company of Buffalo, N. Y., is using a ground detector that was developed and constructed by its Meter Department, and which, according to the report of this company, is functioning satisfactorily. The device is capable of giving an audible signal to announce the occurrence of a ground, of indicating the phase that is grounded, and of showing the extent of that ground. It is constructed chiefly of standard parts manufactured for other purposes by the General Electric Company and the Westinghouse Electric & Manufacturing Company.

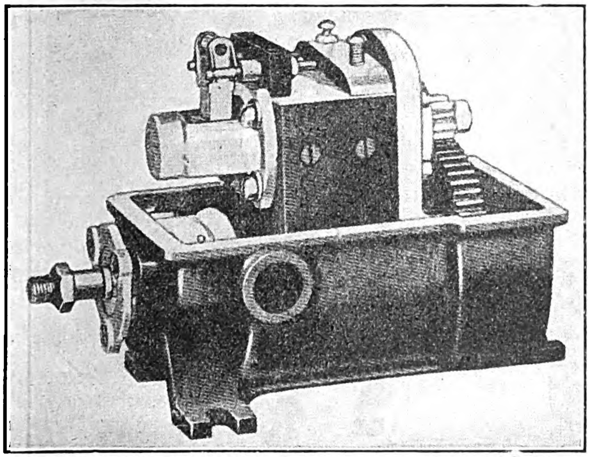


FIG. 77—ESTERLINE-ANGUS TACHOMETER GENERATOR—COVER REMOVED.

A schematic diagram of this device is shown in Fig. 79. Three instrument potential transformers of suitable rating are connected in "Y" to the high voltage system. A current limiting resistor is connected in series with each transformer, and the neutral point is grounded. The secondary, or low voltage windings, are delta connected through a 175-ohm resistor and the current coil of the ground detector relay connected in series. An indicating lamp is connected across each transformer secondary winding and located in any convenient place on the switchboard. The relay proper is constructed of the following parts:

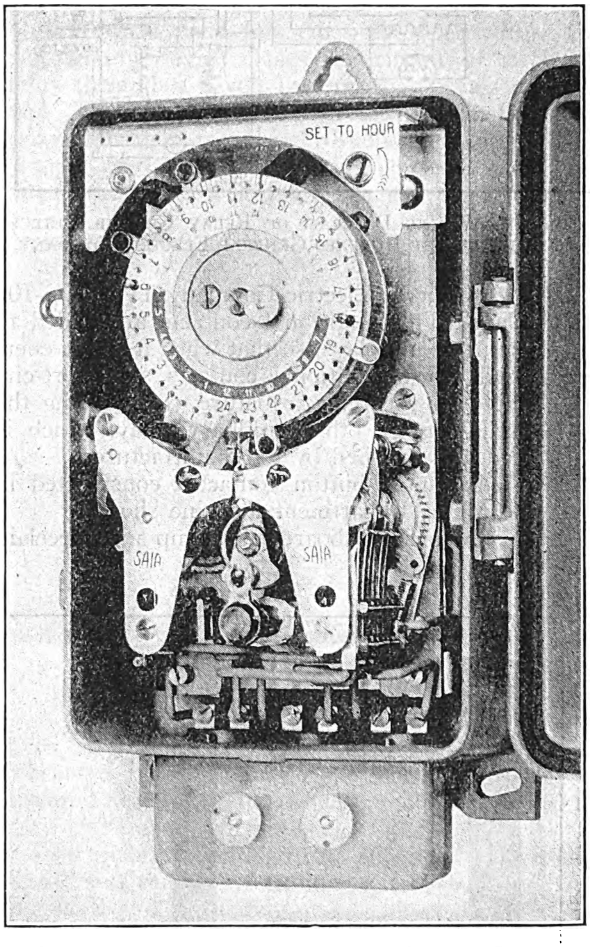


FIG. 78—TYPE D-2 AUTOMATIC TIME SWITCH SUPPLIED BY THE STATES COMPANY.

1. The directional element of a Westinghouse Electric & Manufacturing Company Type CR relay. The current coils are rewound with 180 turns of No. 24 enameled wire. The rest of the element is used unaltered.

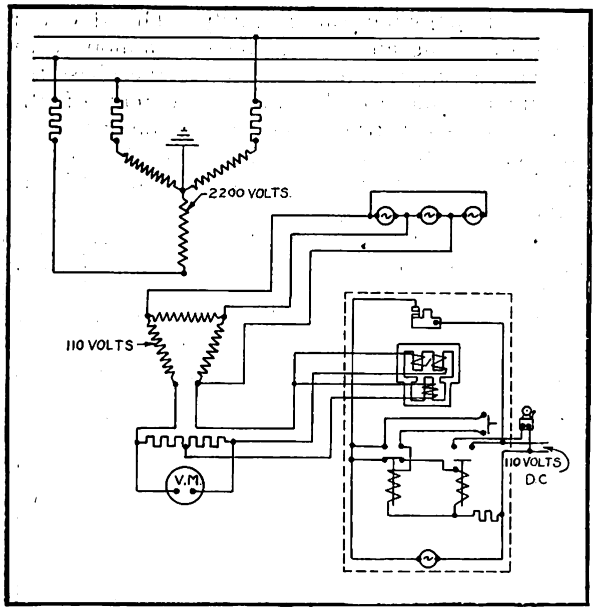


FIG. 79—Wiring Diagram of Relay Ground Detector Built by the Buffalo General Electric Company.

2. Two General Electric Company Type HG-101 relays. Two additional contacts are added to one of these relays, so that when it is not energized, these additional contacts are short-circuited by the relay armature, thus closing the circuit of the other auxiliary relay, which is used as furnished by the manufacturer.
3. A small push-button contactor constructed in the Meter Department machine shop.
4. A regular switchboard pilot lamp and porcelain receptacle.

The entire assembly is mounted in a Westinghouse Type CR relay case, a piece of bakelite being used to mount the Type HG-101 relays. Fig. 80 shows the complete relay device, together with the necessary resistors, ready for installation.

This device operates in the following manner: When a ground occurs it causes the primary of one transformer to be partially or totally short-circuited, thus causing a current to flow through the current coils of the Type CR directional relay element. This current is limited to approximately one ampere by the series resistor in the delta. The potential drop across a portion of this resistor furnishes excitation for the relay potential coil, its value being governed by the degree of the ground. Upon the occurrence of a ground, the relay operates and energizes the pilot lamp and one of the Type HG relays, which in turn closes the alarm circuit. As soon as the operator hears an alarm he closes the push-button switch and thus stops the alarm.

The pilot lamp in the relay case remains on until the ground is cleared, when the relays reset themselves automatically and the device becomes ready to announce another ground.

During a ground, one of the three indicating lamps mentioned above becomes dim or goes out entirely, while the other two become bright. By properly marking these three lamps, the grounded phase can be readily identified.

This device is claimed to be very sensitive, the degree of sensitivity being determined by the adjustment of the counter torque spring of the Type CR relay directional element. If desirable, a time lag can be introduced so that grounds of very short duration will not be announced.

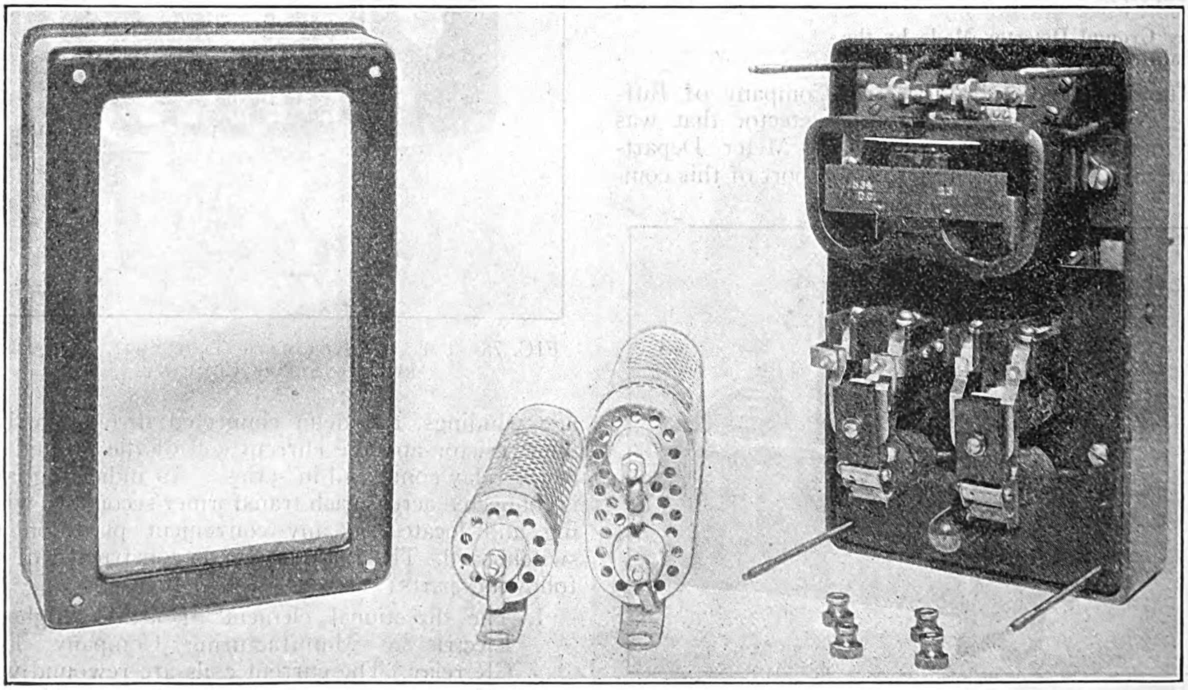


FIG. 80—Relay Ground Detector Built by the Buffalo General Electric Company.

NEW DEVELOPMENTS IN AUXILIARY TESTING EQUIPMENT

The purpose of this serial report on New Developments in Auxiliary Testing Equipment is to bring to the attention of those interested the results of a recent survey made by the Meter Committee.

No attempt has been made to verify the claims made for the devices described. Therefore, the Committee does not officially approve the various devices, but submits this material as worthy of consideration and investigation.

General

The modern electric meter department requires considerable equipment to maintain properly the various types of measuring devices under its care. Accurate standards must be available. Suitable test benches must be provided in the laboratory. Portable loading devices of various types and capacities are needed for use on customer's premises and in the generating stations and substations. There are many other useful pieces of auxiliary equipment which are essential to any well-equipped meter department, whether it be large or small. All of these are necessary if measuring devices are to be safely, accurately and economically maintained.

Realizing that many utilities have developed and built for their own use many pieces of apparatus which may be of interest and benefit to others, a special effort has been made to collect such material for this report. Available new material from various manufacturers is also submitted.

The committee has endeavored to show many forms of such equipment in the several editions of the Handbook for Electrical Metermen; and in subsequent reports has described other new and useful devices. To keep this work up to date further new developments are presented in this serial report.

The Meter Committee of the Engineering National Section, N. E. L. A., hopes to publish future serial reports on this subject from time to time, and will be pleased to receive information on new and useful pieces of auxiliary apparatus suitable for the maintenance of electrical measuring equipment, whether made for the utility company's own use, or by manufacturers engaged in merchandising such equipment.

Timing Devices

In previous publications, the Meter Committee, N. E. L. A., has referred to various timing devices for use in the testing of rotating standards and service meters. The measurement of accurate time intervals is such an important factor in the testing of metering devices, that it is thought worthy of further consideration.

Rotating Standard Timing Device Developed by The Commonwealth Edison Company

The device illustrated in Fig. 1 may be described as a relay-operated time switch for use in testing rotating standards. It operates in the following manner:

A Howard pendulum clock equipped with a control-making device closes the circuit of a 50-ohm relay through a 6-volt battery at intervals of 1 second. This relay closes the circuit of a small solenoid relay operated from a 110-volt d-c. supply. The plunger of this solenoid relay operates a pawl which in turn advances a 96-tooth ratchet wheel 1 tooth or 1/96 of a revolution each second. This device is prevented from coasting by a second pawl, operating on a second ratchet wheel attached firmly to the same shaft as the first wheel.

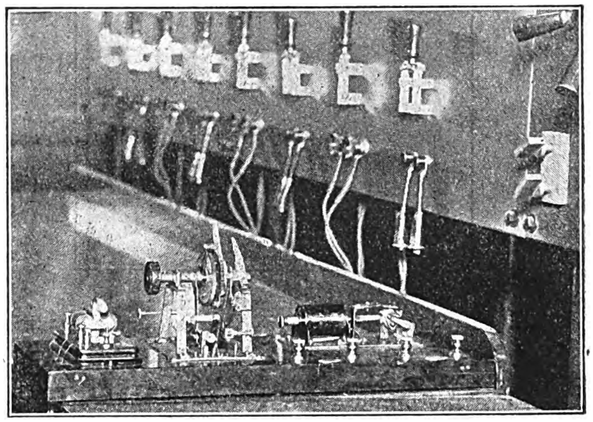


FIG. 1—Rotating Standard Timing Device Developed by the Commonwealth Edison Company.

Two insulated and adjustable arms with contact surfaces at their ends extend radially outward from this shaft and alternately make contact between fixed contacts every 60 and 36 seconds.

An electrically operated switch is operated by these contacts attached to the shaft. This switch in turn closes or opens the potential circuits of the standard meters under test. The 60-second interval is generally used for the period of test, while the 36-second interval is used as the period for observing and recording data about the instruments under test.

Personal error and certain stop-watch errors can be eliminated by the use of this device.

Timing Device Made by the Standard Electric Time Co. for Testing Rotating Standard Watthour Meters

This apparatus is also designed and built to meet the requirements of laboratories where rotating standard watthour meters are tested. It consists of

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Publication No. 289-57, Serial Report, Meter Committee.

a high-grade, 60-beat, self-winding, electric master clock, as shown in Fig. 2, and a special make-and-break relay. The relay is actuated once every minute by impulses from the master clock so that the contacts of the relay are alternately closed for one minute and open for one minute.

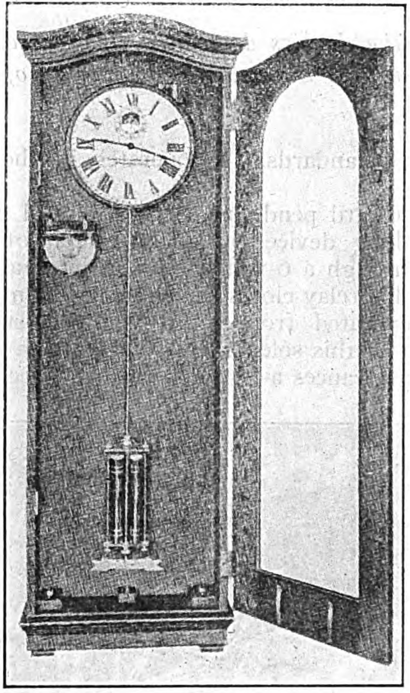

FIG. 2—TIMING DEVICE MADE BY THE STANDARD ELECTRIC TIME COMPANY FOR TESTING ROTATING STANDARD WATTHOUR METERS.

One of the impulse contacts of the master clock is mounted on the escapement wheel staff and revolves once every 60 seconds. The other contact is mounted on the verge staff and oscillates simultaneously with the pendulum. Wiping action at the contacts is thus obtained, which occurs once every revolution of the escapement wheel. The make-and-break relay, shown in Fig. 3, is of rugged construction, having contacts made of ¼ in. diameter tungsten. It is capable of breaking the potential circuit of watthour meters at 115, 230 or 460 volts, therefore no additional auxiliary relays are necessary. When voltages over 115 volts are used, it is advisable to mount the relay in a separate steel cabinet furnished for that purpose.

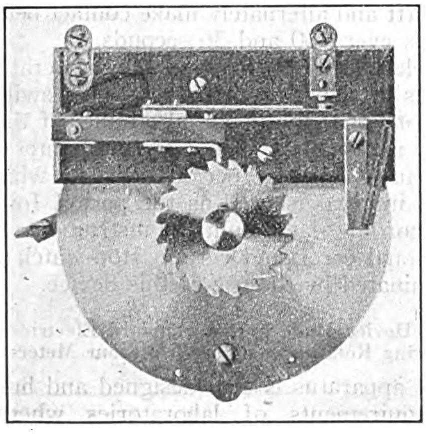

FIG. 3—CAM WHEEL FOR CLOCK SHOWN IN FIG. 2.

As shown in Fig. 3, a cam wheel is arranged in such a manner that a contact arm is alternately raised and lowered by successive impulses from the master clock. This action alternately closes and opens the meter potential circuit.

A set-up key and switch are placed within the reach of the tester so that the potential supply to the rotating standard can be controlled manually if desired.

Contact-Making Devices for Automatic Timing Equipment

Automatic timing devices are frequently operated by means of some form of contact-making device actuated by the pendulum of a second beating high-grade laboratory clock. Care must be exercised in order to prevent added friction in the clock itself and to assure uniform timing. In some contact-making devices the interval between successive contacts is not constant. In others the contact-making device requires considerable maintenance, and may interfere with the operation of an otherwise excellent clock.

To eliminate such difficulties arising from mechanical contact between the pendulum and the auxiliary devices, schemes have been developed where a beam of light fulfills this function.

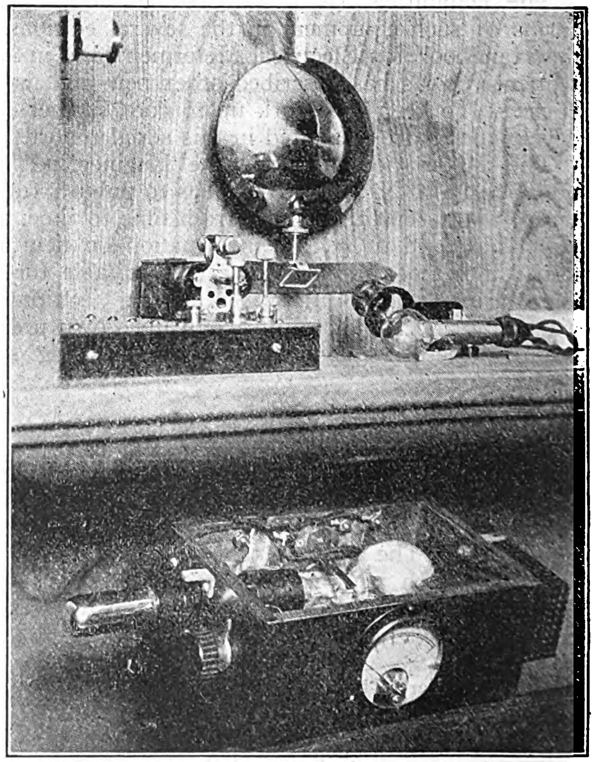

FIG. 4—PHOTO-ELECTRIC CELL ATTACHMENT DEVELOPED BY THE BUFFALO GENERAL ELECTRIC COMPANY.

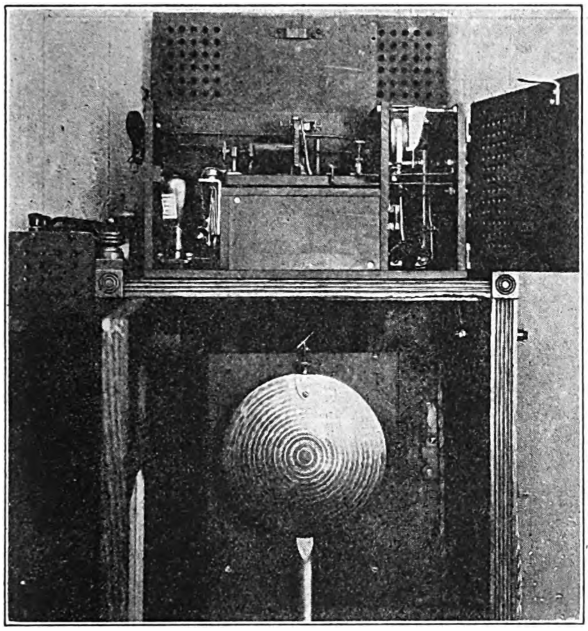

FIG. 5—PHOTO-ELECTRIC CELL ATTACHMENT ASSEMBLED BY THE NEW YORK EDISON COMPANY.

Photo-Electric Cell Attachment Developed by The Buffalo General Electric Company

In this device, electrical impulses are controlled through the medium of a photo-electric cell as shown in Fig. 4. The cell is located in a suitable container fastened to the bottom of the case of a master seconds pendulum clock. A hole has been drilled in the case of the clock just above the photo-electric cell and in line with the seconds pendulum. A small mirror fastened to the pendulum reflects the light of an ordinary automobile lamp down through this hole and on to the photo-electric cell. This momentarily energizes the photo-electric cell, causing the plate current of a radio amplifying tube to increase in value and operate a sensitive relay. This relay in turn operates a second relay, the contacts of which are capable of carrying sufficient current to operate the automatic timing equipment. This latter equipment is described in detail in Publication 25-28, Report of the Meter Committee, N. E. L. A., for 1924-1925, and also in Publication 267-92, a serial report on Auxiliary Testing Apparatus, published in July, 1927.

Photo-Electric Cell Attachment Assembled by The New York Edison Company

A device similar to the one just described has been assembled in the Meter Department of The New York Edison Company and has been in service for about a year. Fig. 5 shows a general view of this device, while Fig. 6 shows the diagram of connection used.

All the component parts of this equipment are standard stock products. The use of the 171-A type of tube eliminates the necessity of using extra sensitive relays.

Test Table Facilities

Both manufacturers and a number of utilities have built various types of special equipment to facilitate the rapid testing of meters in the laboratory. In addition to such equipment, a number of utilities have built test tables of special design to satisfy their particular need. A number of utilities find the fixed or non-portable test table most desirable, while others find that the portable table lends itself well for use inside the laboratory, as well as for work in the field.

Current Transformer Testing Bench Developed by The Union Gas and Electric Company

Fig. 7 shows a special bench, built and used by the Meter Department of the Union Gas & Electric Company, for testing current transformers. The two large V-shaped clamping devices on the bench are designed to receive the primary terminals of various sizes of current transformers. The transformer to be tested is shown on the left in Fig. 7, while the standard transformer is on the right. The secondary terminals of the current transformers are connected, by flexible leads, to the proper terminals on the panel, which in turn are permanently connected to a Silsbee Current Transformer Testing Set made by the Leeds & Northrup Company and located on another bench. Attached to the front legs of the bench are two small panels upon which fuses for the loading transformers are mounted. Additional binding posts are provided to connect transformers which cannot be accommodated by the clamping devices on the bench.

Three transformers and two induction regulators, located under the bench, can furnish any desired current value up to 6000 amperes. The panel at the rear is equipped with terminals for connecting the desired burden to the current transformer under test. Plugs and switches are provided to select any combination of loading transformer and voltage regulator coils, and thus cover the entire range of the equipment. The full secondary no-load voltage of the 6000-ampere loading transformer is about 2.3 volts.

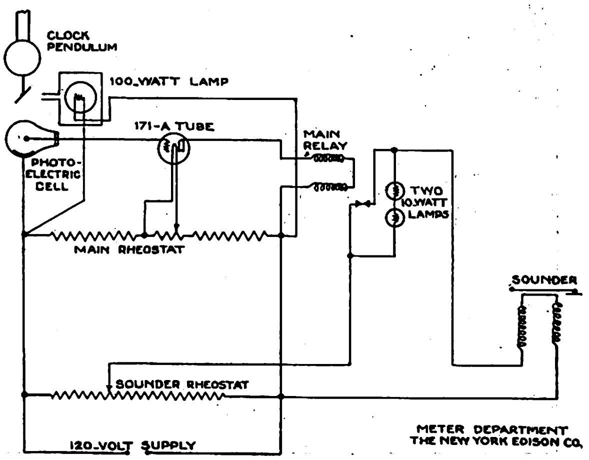

FIG. 6—DIAGRAM OF CONNECTIONS FOR DEVICE SHOWN IN FIG. 5.

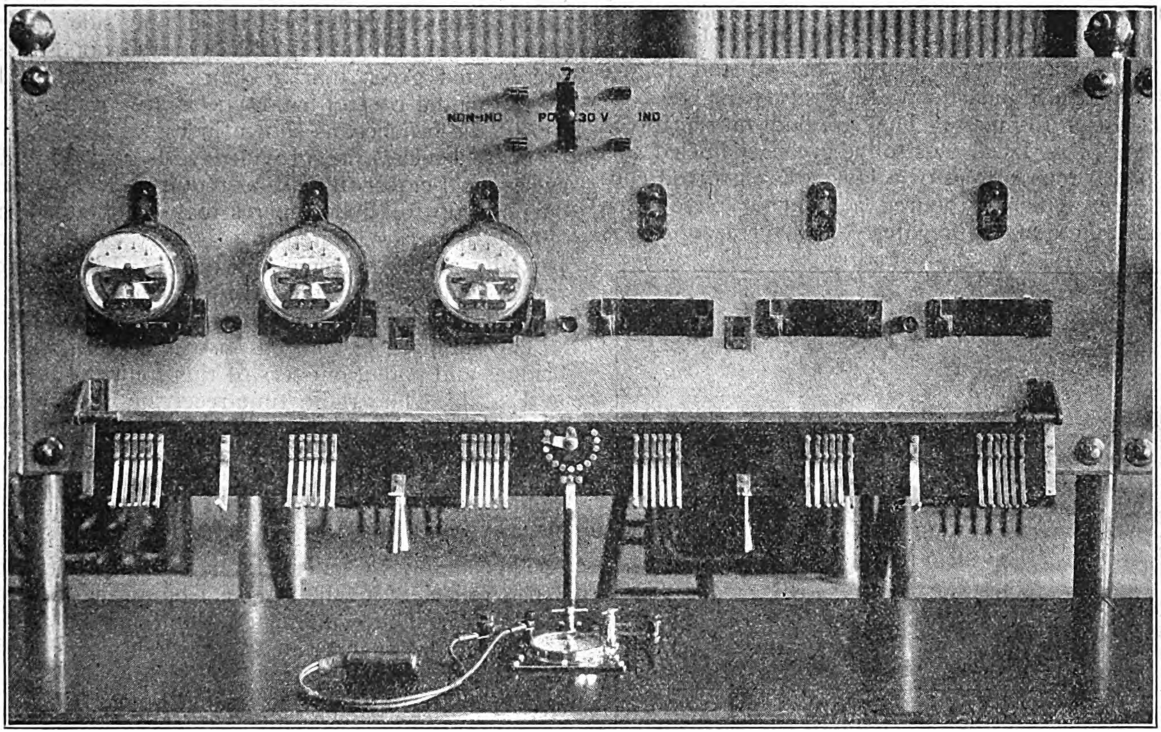

FIG. 9—CLOSE VIEW OF ONE OF THE PANELS SHOWN IN FIG. 8.

Speed Board Developed by The New York Edison Company

Fig. 8 shows a meter testing board developed by The New York Edison Company for testing various types of watthour meters. This type of board eliminates the necessity of making wire connections between the meters and the test supply. Six meters are mounted on each test panel and the hinged terminal board is swung into the working position, making electrical connections through flexible finger type contactors. Fig. 9 shows the details of the hinged terminal board and the flexible contactors which fit over the meter terminal screws when the terminal chamber cover is removed.

Potential is supplied to the six meters simultaneously as soon as the terminal board is swung up. The current circuits are controlled individually through the selector switch mounted at the center of the hinged terminal board.

A rotating test standard is placed into an opening shown in the foreground of Fig. 9 and is used for testing the six meters that can be installed on the test panel.

Tesco Quick Connector Block Made by The Eastern Specialty Company

A convenient appliance for the meter testing laboratory is shown in Fig. 10. It is designed to make possible the speedy connection of watthour meters for test. It is adjustable, and it is claimed that it will fit all types of bottom connected meters. Braided copper ribbon is used to make connections between the four (4) meter terminals of the test device and terminals located on the test panel, not shown in photograph. It is furnished complete with adjustable parts, bakelite plate for leveling, and connection block.

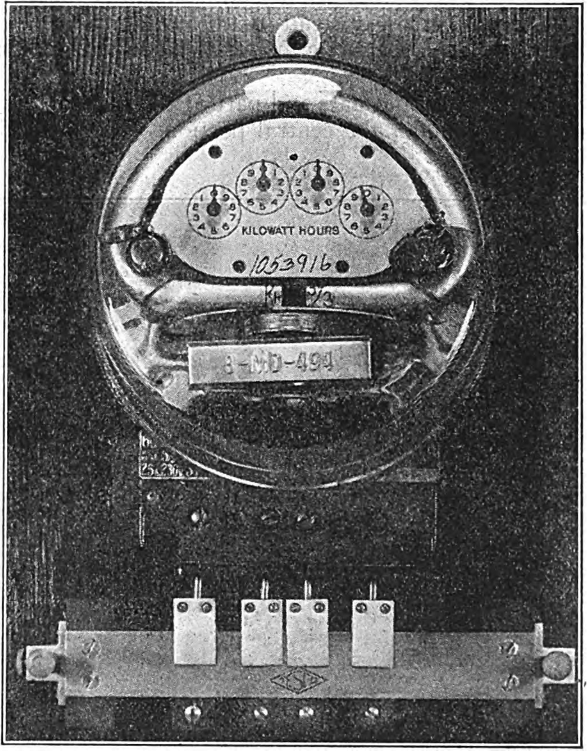

FIG. 10—TESCO QUICK CONNECTOR BLOCK MADE BY THE EASTERN SPECIALTY COMPANY.

Test Benches Designed by The New York Edison Company for Testing A-C. and D-C. Portable Test Instruments and for Maintaining Primary and Secondary Standards

The benches shown in Fig. 11, 12 and 13 are located in the Standardizing Laboratory of The New York Edison Company. They are built on reinforced concrete piers faced with olive-green enameled tile. The bench tops consist of a layer of reinforced concrete over which is poured a layer of olive-green terrazzo-alundum aggregates. The terrazzo top is polished to give a pleasant-looking and rugged working surface. The bench tops are edged with a band of angle brass, lacquered on the outer surface to match the green tile. Tobin Bronze is used throughout for reinforcing instead of the usual iron rods in order to keep magnetic materials away from the instruments.

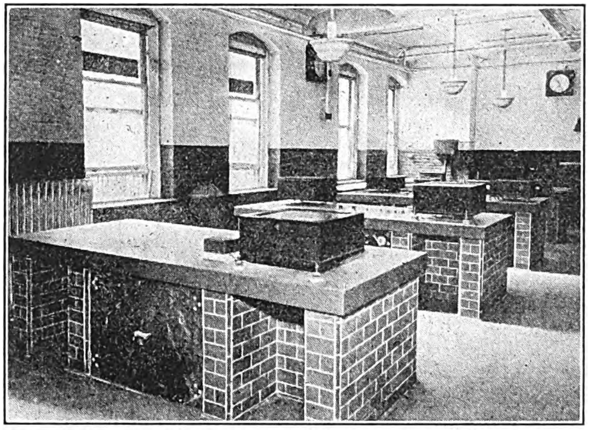
FIG. 11—GENERAL VIEW OF INSTRUMENT TEST BENCHES IN THE STANDARDIZING LABORATORY OF THE NEW YORK EDISON COMPANY.

The loading rheostats and part of the control gears are located under the central portion of each bench. Switches and control handles are mounted on green marble switchboards located on one side of each bench, as shown in Fig. 12. On the opposite side are located green marble doors, as shown in Fig. 11. Potential control hand-wheels are located on the top of the benches, as shown in Fig. 12.

These benches are provided with a-c., 25 and 60 cycles, or d-c. test supplies as required. Heavy direct-currents up to 1500 amperes may be obtained from storage batteries located in a battery cabinet shown partially at the extreme left of Fig. 12. This current is controlled by the multiple hand-wheels at the upper left corner of the switchboard in Fig. 12.

The standard test bench on which are located the bridges and potentiometers of this company is shown in Fig. 13. The radio time-receiving set is located on this bench immediately below the pendulum master clock.

Multi-Range Current Transformer Testing Table Made by Otto A. Knopp

This equipment supersedes and supplements earlier types reported in the Meter Committee report of 1924-1925. The equipment is built in two units:

1. For testing current transformers of 5 to 500-ampere capacity.
2. For testing current transformers of 600 to 3000-ampere capacity.

1. *The 5 to 500-Ampere Unit*

This unit has the following primary current ratings: 5, 10, 12½, 15, 20, 25, 30, 40, 50, 60, 75, 80, 100, 125, 150, 160, 200, 250, 300, 400 and 500 amperes. It is complete in every respect for testing the ratio and phase angle of current transformers within the above limits. It embodies a current supply transformer, multi-range standard current transformer, rheostats, instruments, switches and a panel. The entire equipment is mounted on a bench, as

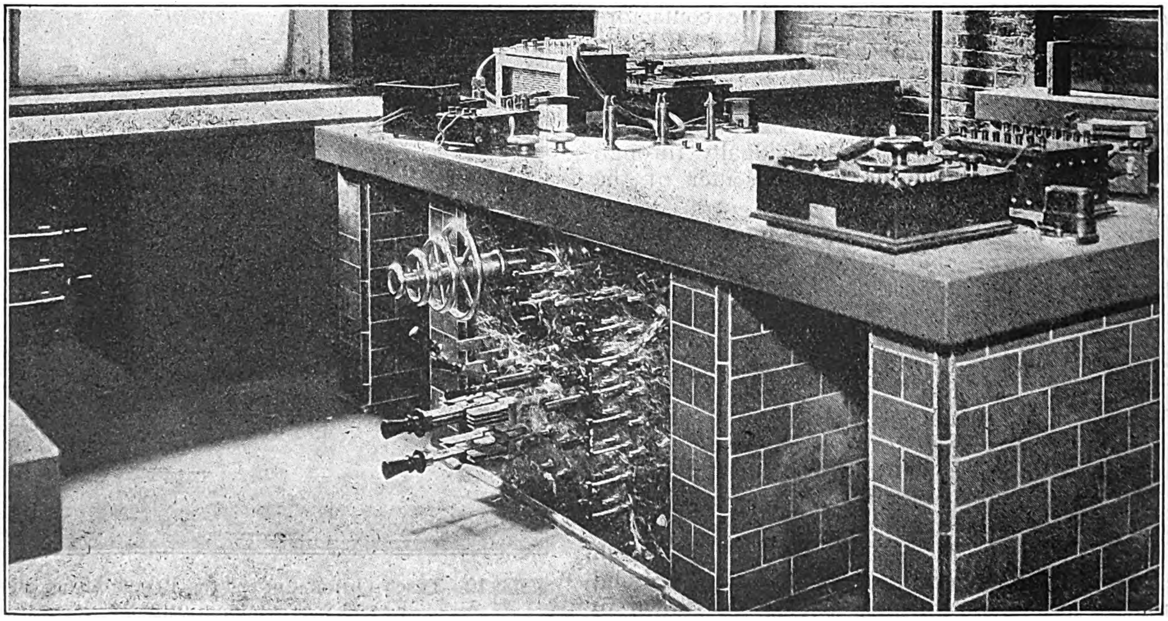
FIG. 12—CLOSE VIEW OF INSTRUMENT BENCH SHOWING CONTROL SWITCHBOARD.

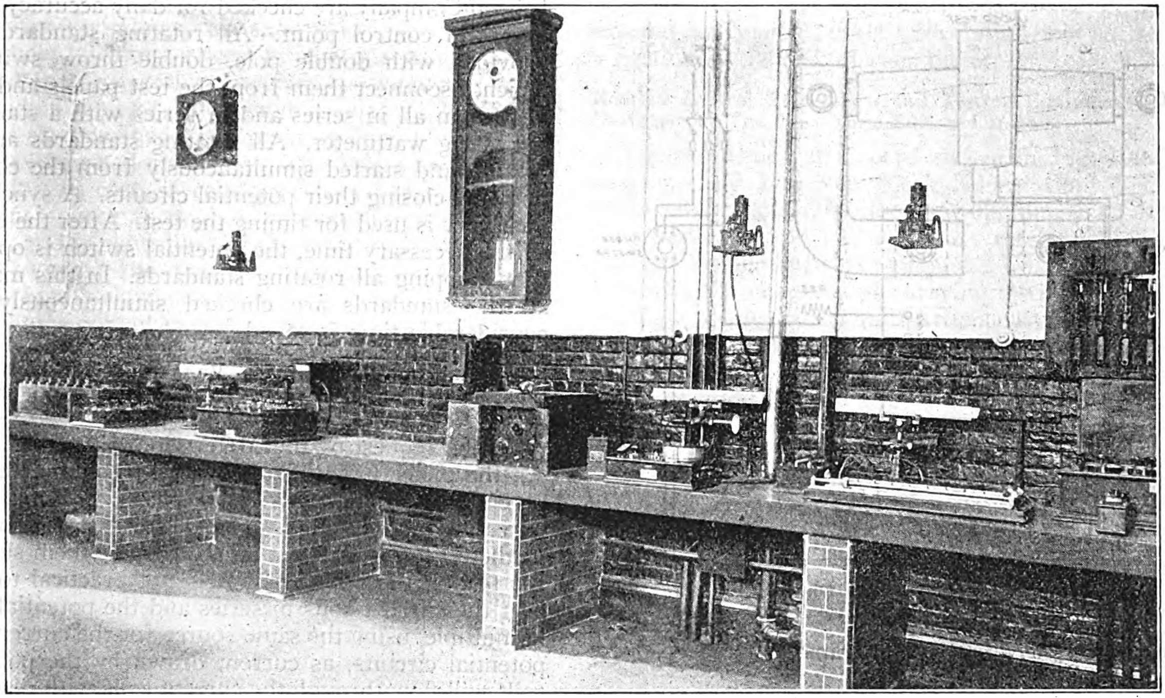

FIG. 13—STANDARD TEST BENCH IN THE STANDARDIZING LABORATORY OF THE NEW YORK EDISON COMPANY.

shown in Fig. 14, and is ready for connection to a three-phase, 220-volt, supply.

The designer claims that the standard multi-range current transformer is of such design that the ratio and phase angle corrections are the same for all ranges. It is also claimed that with this unit it is possible to determine these corrections without any reference standard, by calibrating it against itself.

A Silsbee current transformer testing set manufactured by the Leeds & Northrup Company can be used, but is not necessary, as the Silsbee deflection method can be used. This latter method was discussed in a previous serial report of the Meter Committee entitled "Auxiliary Testing Apparatus" and known as Publication No. 267-92 of the N. E. L. A.

2. *The* 600 *to* 3000-*Ampere Unit*

This unit has the following primary current ratings: 600, 750, 800, 1000, 1200, 1500, 2000, 2500 and 3000 amperes. It is built into a compact unit about 10 in. x 10 in. x 11 in., and includes a loading transformer, as shown in Fig. 15. While it is a complete unit in itself, it could very well be mounted upon a test table with the smaller equipment described above.

A maximum current of 5 amperes is drawn from a 220-volt, 3-phase supply. This is transformed to the proper current value by means of a step-up transformer, which is a part of the equipment. This unit is wired to permit the use of the Silsbee deflection

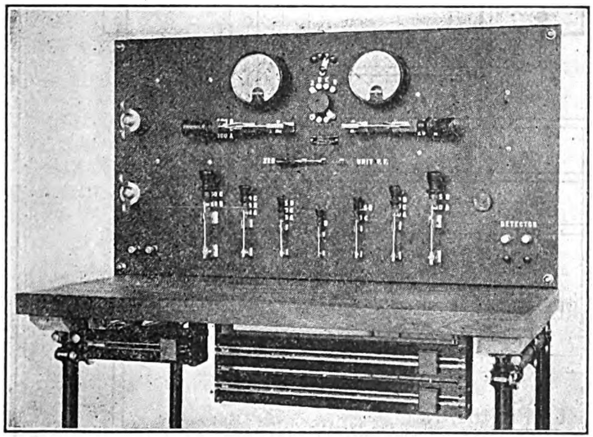

FIG. 14—MULTI-RANGE CURRENT TRANSFORMER TESTING TABLE MADE BY OTTO A. KNOPP, SAN FRANCISCO, CAL. —5 TO 500-AMPERE UNIT.

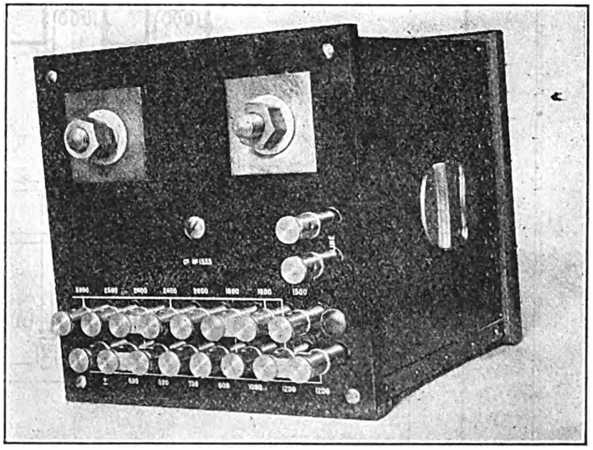

FIG. 15—MULTI-RANGE CURRENT TRANSFORMER TESTING SET MADE BY OTTO A. KNOPP—600 TO 3000-AMPERE UNIT.

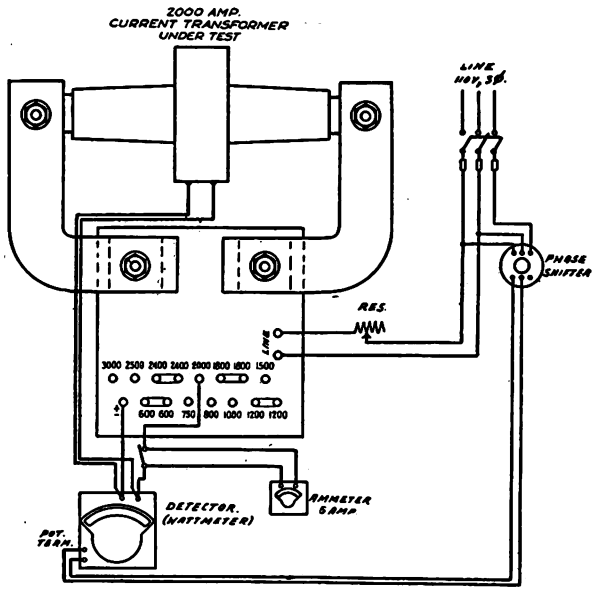
2000 AMP.
CURRENT TRANSFORMER
UNDER TEST
LINE
110V, 3Ø.
PHASE
SHIFTER
RES.
LINE
3000 2500 2400 2400 2000 1800 1800 1500
±
600 600 750 800 1080 1200 1200
DETECTOR.
(WATTMETER)
AMMETER
5AMP.
POT.
TERM.

FIG. 16—TEST CONNECTIONS FOR USING THE SETS SHOWN IN FIG. 15.

method of checking current transformers already referred to above.

Fig. 16 shows a wiring diagram used with the unit just described for determining the ratio and phase angle of a current transformer.

Standard Checking System Developed by The New York Edison Company

The rotating test standards located on the meter testing panels in the laboratories of The New York Edison Company are checked for daily accuracy from a central control point. All rotating standards are provided with double pole, double throw switches, which disconnect them from the test panels and connect them all in series and in series with a standard indicating wattmeter. All rotating standards are set to zero and started simultaneously from the control point by closing their potential circuits. A synchronous timer is used for timing the test. After the elapse of the necessary time, the potential switch is opened, thus stopping all rotating standards. In this manner all the standards are checked simultaneously and considerable time is saved.

Equipment Developed by The Buffalo General Electric Company for Series Testing of Single-Phase, Watthour Meters Without the Use of the Potential Test Links

At the request of the Meter Committee, N. E. L. A., the meter manufacturers recently eliminated the potential test link from single-phase, 115-volt, two-wire, watthour meters. This requires an alteration of the present series test tables to make them suitable for testing these meters. It is not practical to connect the current coils in series and the potential coils in multiple, using the same source for the current and potential circuits, as current drawn by the potential coils will flow through the current coils with resulting inaccuracy in testing. It is, therefore, necessary to have a separate potential source for each meter.

The Buffalo General Electric Company uses a modification of the start and stop method described in Chapter VI of the Handbook for Electrical Metermen. The main feature of the modified method is the use of a special potential transformer having

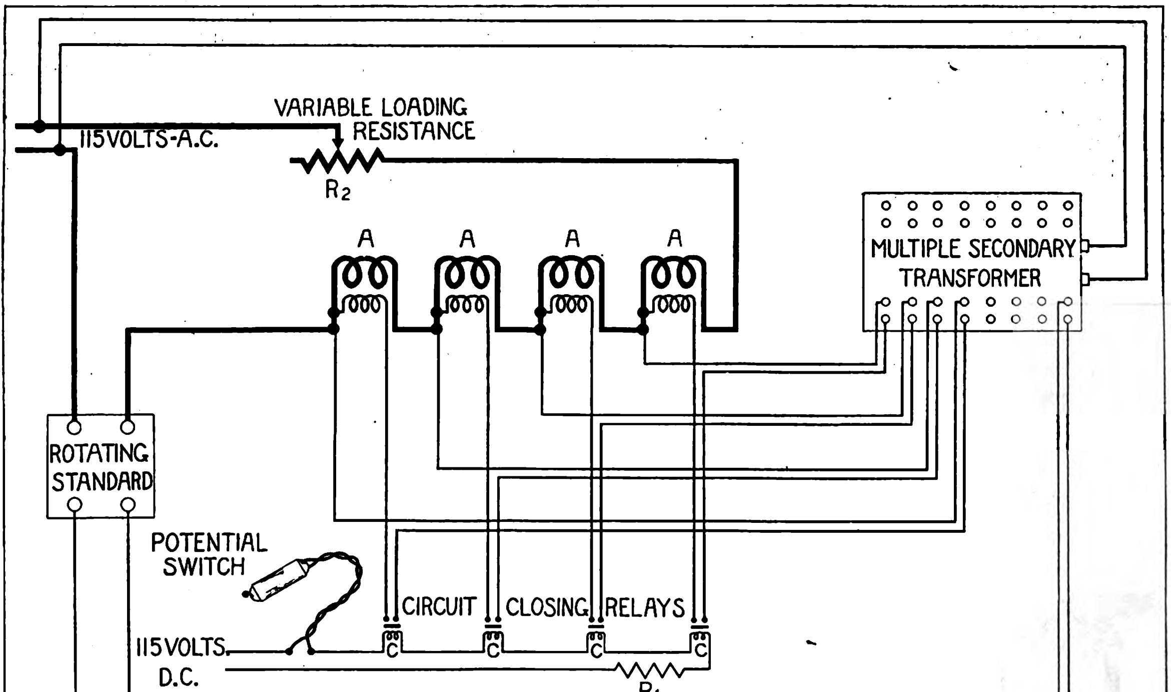
VARIABLE LOADING
RESISTANCE
115VOLTS-A.C.
R2
A
A
A
A
MULTIPLE SECONDARY
TRANSFORMER
ROTATING
STANDARD
POTENTIAL
SWITCH
CIRCUIT
CLOSING
RELAYS
C
C
C
C
115VOLTS
D.C.
R1
FIXED RESISTANCE

FIG. 17—EQUIPMENT DEVELOPED BY THE BUFFALO GENERAL ELECTRIC COMPANY FOR SERIES TESTING OF SINGLE-PHASE WATTHOUR METERS WITHOUT THE USE OF POTENTIAL TEST LINKS.

one primary winding and sixteen carefully balanced secondary windings, as shown in Fig. 17. Each secondary winding, excepting the one which is connected to the rotating standard, is connected to an individual meter (A) through a relay (C). Fifteen relays are provided, the operating coils of the group being connected in series. The operating coil circuit, in this case, is connected to a 115-volt, direct-current source through a current limiting resistor, (R_1), and is controlled by the usual type of potential snap switch. The closing or opening of this switch operates all relays simultaneously, and automatically starts or stops all meters under test.

A modified standard Model T Ford generator relay is used. It is very positive in its action. Fig. 18 shows this relay with cover removed.

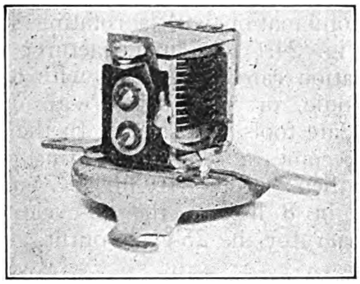

FIG. 18—CLOSE VIEW OF RELAYS "C" SHOWN IN FIG. 17.

When the snap switch is closed, the relays (C) close the individual potential circuits of the meters under test. The switch is allowed to remain closed during the proper number of revolutions of the standard to give correct registration for two, ten or twenty revolutions of the meters under test. The snap switch is then opened, and the relays in turn open the potential circuits of their respective meters. The accuracy of each meter is then read on a stationary card marked in 0.01 revolution, and encircling a portion of the disk of each meter.

Remote Control Test Board and Testing Equipment Designed by The New York Edison Company

The test bench and board shown in Fig. 19 were developed by The New York Edison Company for testing relays and instruments in the new East River Generating Station. The primary reason that led to the development of this equipment was the desire to eliminate the necessity of carrying testing equipment throughout the station and particularly the spreading of the test equipment on the Control Room floor, where it would be in the way of the station operators. In addition, the use of this centrally located equipment saves considerable time in connecting and disconnecting the test equipment.

The test instruments and control devices are permanently located in the Test Room shown in Fig. 19. Connections can be made to any part of the station through the terminal board shown at the right of Fig. 19. Taking, for instance, the case of testing relays, one tester sits in the Test Room at the instruments and another tester goes to the oil circuit breaker gallery, shown in Fig. 20, where the current transformers are located. Using the proper test circuits, this tester makes test connections to the current transformer as shown in Fig. 20; he then proceeds to the Control Room where the relays are located. In Fig. 21 the tester is shown testing a three element over-current relay. He is in constant communication with the tester in the Test Room by means of the Callaphone system. The tester in the Test Room speaks into the wall set shown at the left of Fig. 19, while the tester in the Control Room carries a head set similar to that used by telephone switchboard operators.

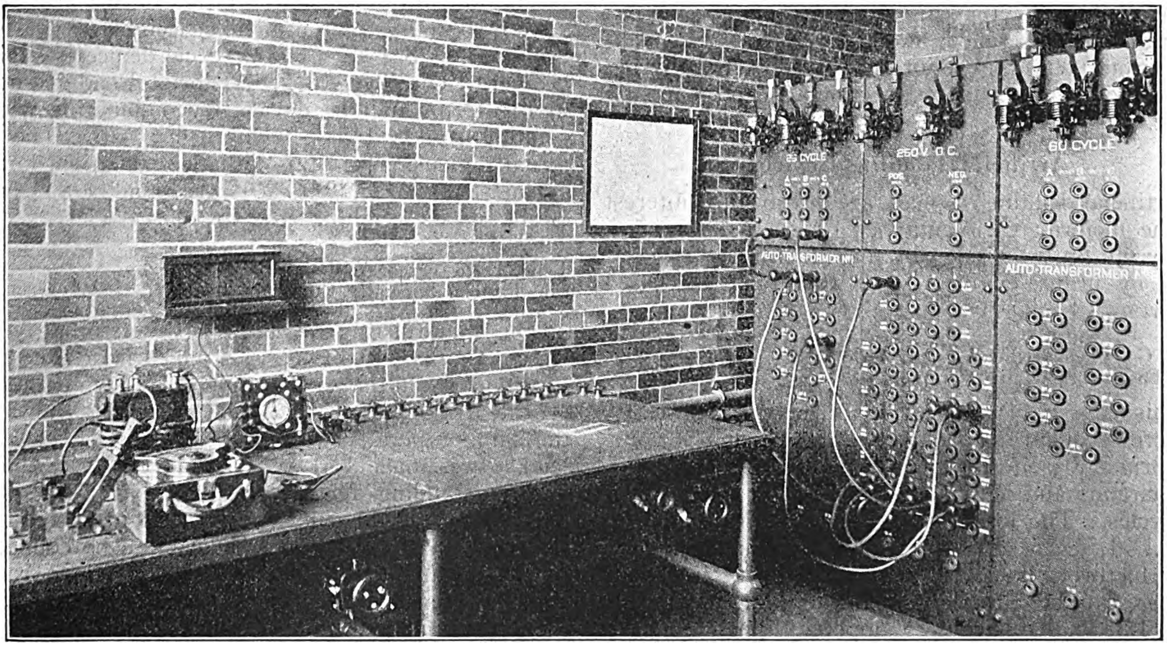

FIG. 19—REMOTE CONTROL RELAY TEST BENCH AND CONNECTION BOARD DESIGNED BY THE NEW YORK EDISON COMPANY.

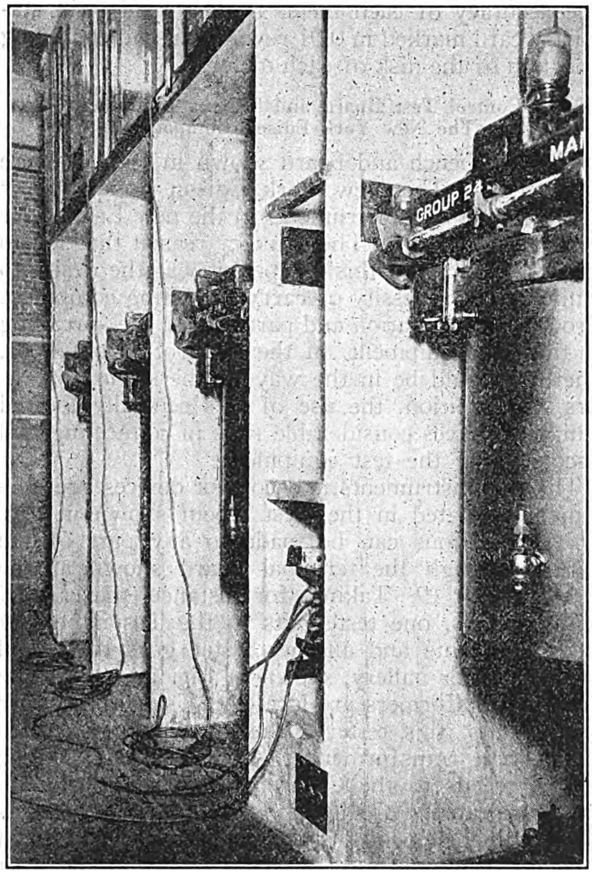

FIG. 20—HIGH TENSION GALLERY TEST CONNECTIONS MADE BETWEEN THE CURRENT TRANSFORMERS AND THE TEST STATION WHICH IS PERMANENTLY CONNECTED WITH THE CONNECTION BOARD SHOWN IN FIG. 19.

This company claims that excellent results have been obtained by the use of this equipment. Considerable time is saved, and the possibility of making wrong test connections is greatly reduced because most of the test connections are permanently made.

Artificial Loading Devices

Artificial loading devices are always of interest to the meterman. A number of such devices recently put on the market by manufacturers or developed by utility engineers are, therefore, discussed below.

Type G Tesco Artificial Load Made by The Eastern Specialty Company

This is a low voltage transformer having a 25-ampere secondary capacity at approximately 4 volts. Its primary is designed for use on 110 and 220-volt circuits and is available for use on either 25 or 60 cycles. The load ratings usually furnished are: 0.5, 1, 1.5, 2.5, 5, 10, 15 and 25 amperes. The manufacturer, however, advises that the following ratings can be furnished upon request: 0.25, 0.5, 0.75, 1.25, 5, 10, 15 and 25 amperes. The secondary load is governed by series resistors, which may be easily replaced when necessary. The manufacturer claims that this device will carry full load current continuously without damage. The device can be readily inspected and repaired when necessary.

The manufacturer also claims that the power factor of this device is 95 per cent at light load and approximately 99 per cent at full load, and that the wave form of the secondary current is practically the same as that of the impressed primary voltage.

The outside dimensions of this device are: 7 in. x 3¾ in. x 6 in. excluding the cover, and 7½ in. x 3¾ in. x 6 in. including the cover. The cover can be furnished with a carrying strap. The 60-cycle device weighs 6 lb., while the 25-cycle device is slightly heavier. Fig. 22 shows an external view of the Type G Tesco Artificial Load, while Fig. 23 shows the device removed from its case.

The Type G Artificial Load can also be furnished for use in combination with a rotating standard, as shown in Fig. 24. The manufacturer states that this combination can be supplied with a cover and carrying handle, or, if desired, with outside case to accommodate tools, leads, etc. In the latter case, this device becomes a "one-man testing outfit." Its dimensions then become 10 in. x 7 in. x 6 in., and its weight 8 lb. for the 60-cycle outfit, and slightly heavier for the 25-cycle outfit.

Type A-25 Tesco Artificial Load Made by The Eastern Specialty Company

According to the manufacturer, the Type A-25 Artificial Load has practically the same characteristics as the Type G, described above. However, the Type A-25 is of somewhat larger dimensions and weight, and has a secondary voltage of 6 volts. The primary voltage is 110/220 volts.

Load adjustment is accomplished by means of double pole switches arranged to give current values of 0.25, 0.5, 1, 2, 5, 10 and *10* amperes.

The outside dimensions of this device are: 6 in. x 6-3/16 in. x 6½ in. The weight of the 60-cycle unit is 8¾ lb. The 25-cycle device is slightly heavier. The Type A-25 Artificial Load is shown in Fig. 25, while the device, in combination with a rotating standard, is shown in Fig. 26. The external dimensions of this latter combination, known as the Type A-25, Cat. 801, are 6 in. x 8½ in. x 12 in. and its weight is 10¾ lb.

Type AS-25 Tesco Artificial Load Made by The Eastern Specialty Company

The manufacturer states that the Type AS-25 Tesco Artificial Load, Fig. 27, which is designed for a secondary output of 25 amperes at 6 volts, and to operate from a 110 or 220-volt primary supply, has the same general characteristics as the Type A-25 load. It is made for both 25 and 60-cycle service. The outstanding feature of this device is its load switching arrangement. It is so constructed that two coils of the rotating standard can be connected to the loading device simultaneously. Two rotary switches are provided, one of which is used to select the proper field of the rotating standard for a full or light load test. The other selects the proper value of test current. The manufacturer claims that, by

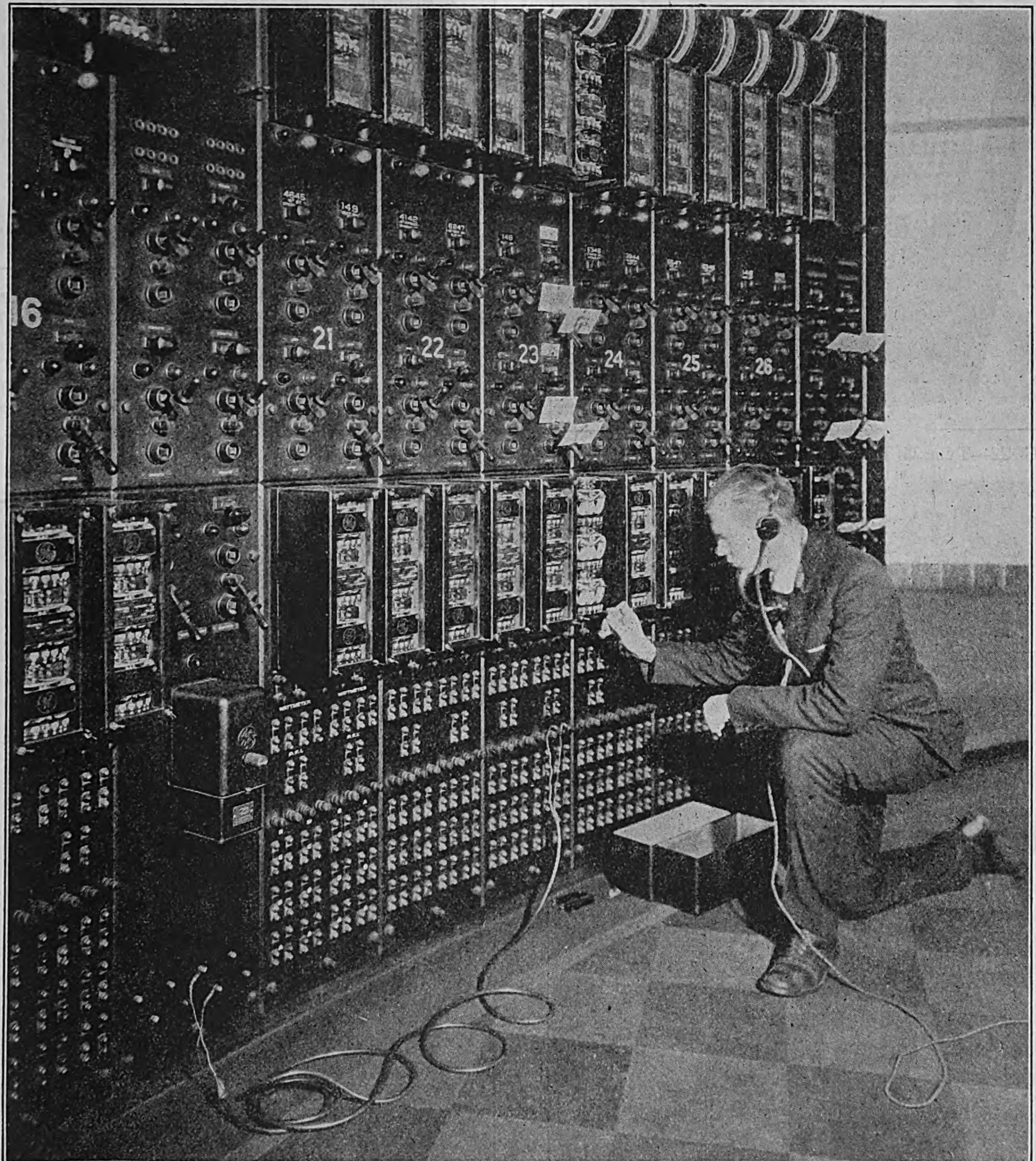
16
21
22
23
24
25
26

FIG. 21—RELAY TESTER IN COMMUNICATION WITH TEST BENCH SHOWN IN FIG. 19.

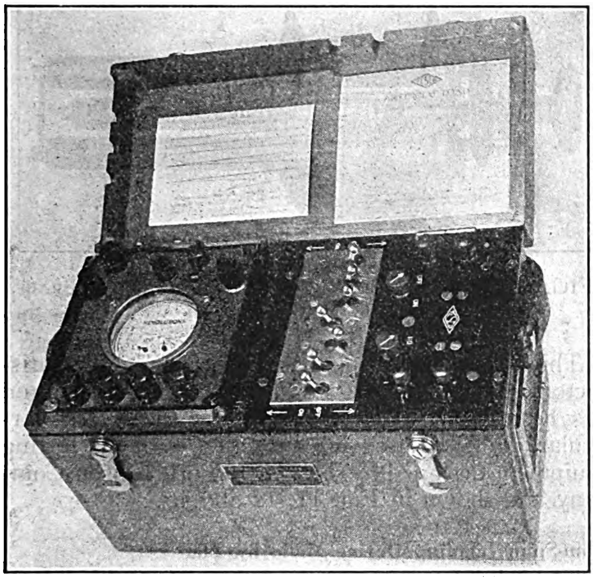

FIG. 26—COMBINATION TYPE A-25 ARTIFICIAL LOAD AND ROTATING STANDARD MADE BY THE EASTERN SPECIALTY COMPANY.

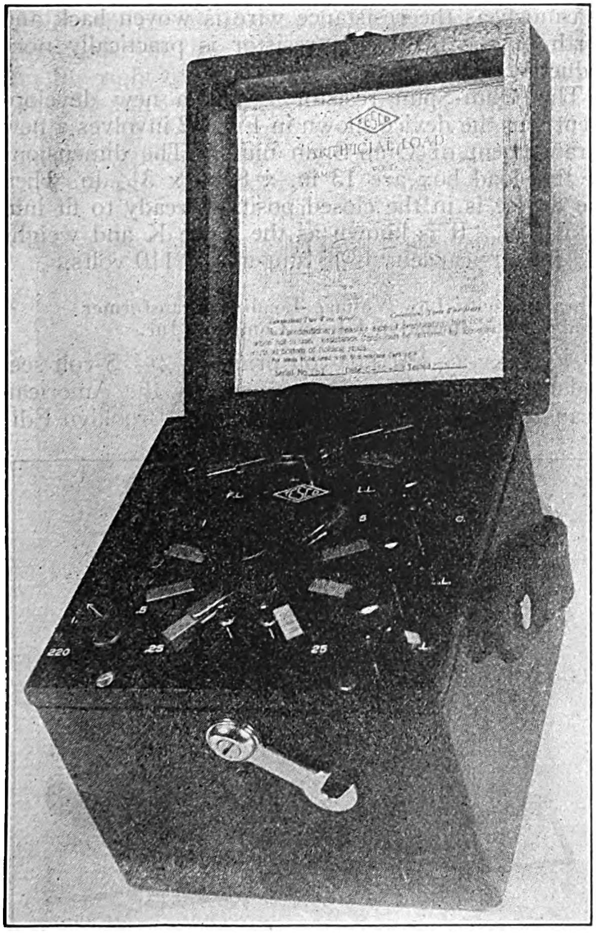

FIG. 27—TYPE AS-25 TESCO ARTIFICIAL LOAD MADE BY THE EASTERN SPECIALTY COMPANY.

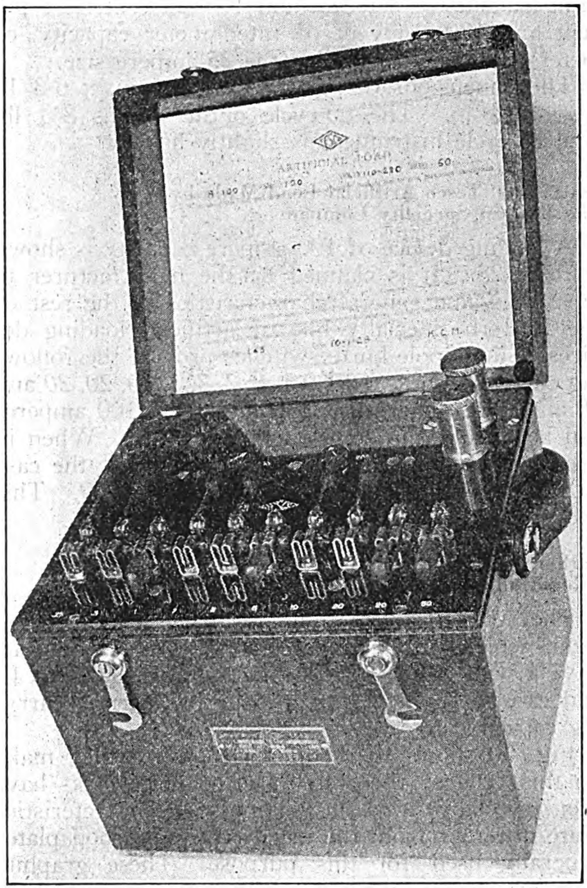

FIG. 28—TYPE A-100 TESCO ARTIFICIAL LOAD MADE BY THE EASTERN SPECIALTY COMPANY.

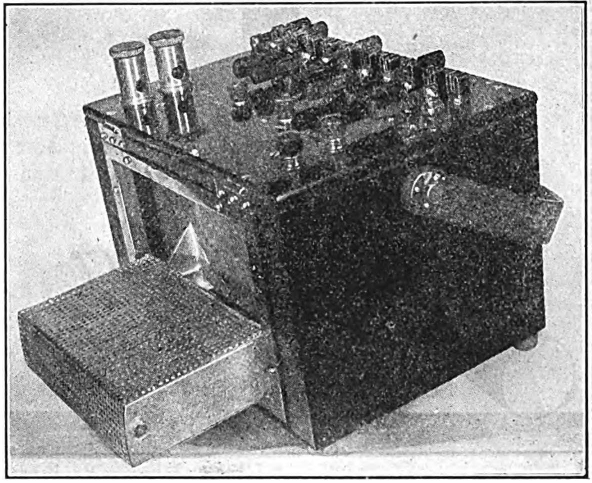

FIG. 29—SECOND VIEW OF DEVICE SHOWN IN FIG. 28.

means of this arrangement, time is saved in switching from one load to another during test, and overloading of the 1-ampere coil of the standard is prevented. Current values are provided for full and light loads at 10 per cent and 100 per cent, or 5 per cent and 100 per cent of rated meter capacity, of meters up to and including the 25-ampere size.

The dimensions of this device are 6 in. x 6-3/16 in. x 6½ in. The 60-cycle outfit weighs 8¾ lb. The 25-cycle instrument is slightly heavier.

Type A-100 Tesco Artificial Load Made by The Eastern Specialty Company

A loading device of 100-ampere capacity is shown in Fig. 28. It is claimed by the manufacturer to have the same general characteristics as the rest of the Eastern Specialty line of artificial loading devices. Single-pole knife switches provide the following current values: 0.25, 0.5, 1, 2, *2*, 5, 10, 20, *20* and 50 amperes. Therefore, currents up to 100 amperes can be obtained in steps of 0.25 ampere. When in use, the resistor unit can be swung out of the case to provide ventilation, as shown in Fig. 29. This prevents undue heating of the instrument.

Carbon Rheostats Made by The Allen-Bradley Company

The Allen-Bradley Company makes carbon rheostats, which, it claims are very flexible, durable, have a wide range of resistance (ratio of 75 to 1) and can be supplied for any desired current-carrying capacity.

Fig. 30 shows the component parts which make up this type of rheostat. The graphite disks have been specially treated and possess characteristics quite different from the usual type of carbon plates generally used for this purpose. These graphite disks are inserted into an insulated steel tube, making a very compact unit.

Fig. 31 shows a 3-tube Type E-2210 rheostat. The manufacturer states that any desired combination of these units can be furnished for any type of mounting desired.

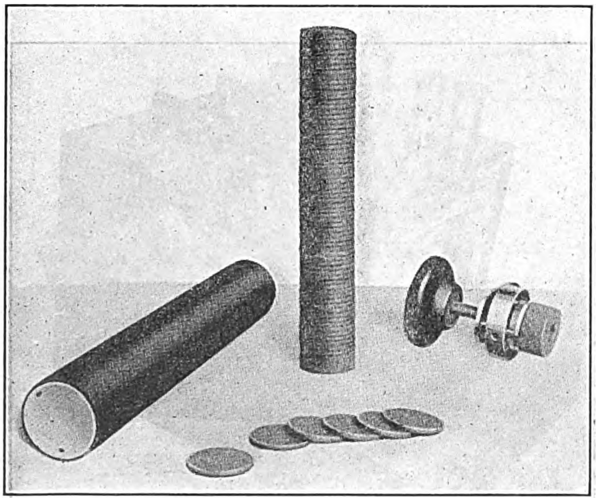

FIG. 30—CARBON RHEOSTAT UNIT MADE BY THE ALLEN-BRADLEY MANUFACTURING COMPANY.

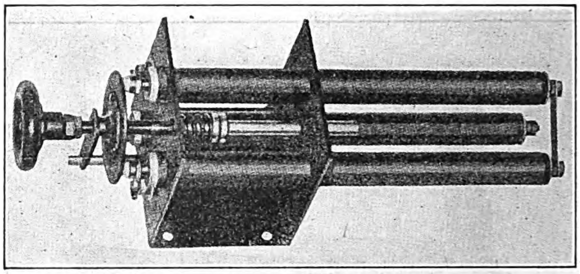

FIG. 31—A THREE-TUBE, TYPE E-2210, ALLEN-BRADLEY RHEOSTAT.

This type of rheostat has been found very satisfactory by The New York Edison Company and has been used very extensively by them. In particular, they are used in connection with the testing equipment designed by The New York Edison Company and shown in Fig. 11, 12 and 19.

Ohm-Spun Loading Device Made by The States Company

This device was designed to meet the demand for a non-inductive rheostat of compact dimensions, light in weight and rugged in construction. These resistors are built by weaving resistance wire into supporting strands of long fiber asbestos thread. Inasmuch as the resistance wire is woven back and forth in one plane, the resistor is practically non-inductive.

The Ohm-Spun resistor is not a new development, but the device shown in Fig. 32 involves a new arrangement of Ohm-Spun units. The dimensions of this load box are 13 in. x 8 in. x 3½ in. when the device is in the closed position, ready to fit into a kit box. It is known as the Type K and weighs 3⅜ lb. Its capacity is 15 amperes at 110 volts.

Large Capacity Low Voltage Loading Transformer Used by The Brooklyn Edison Company, Inc.

A 100 kv-a., 220/110-volt primary, 2½/5-volt secondary loading transformer made by the American Transformer Company is used by The Brooklyn Edi-

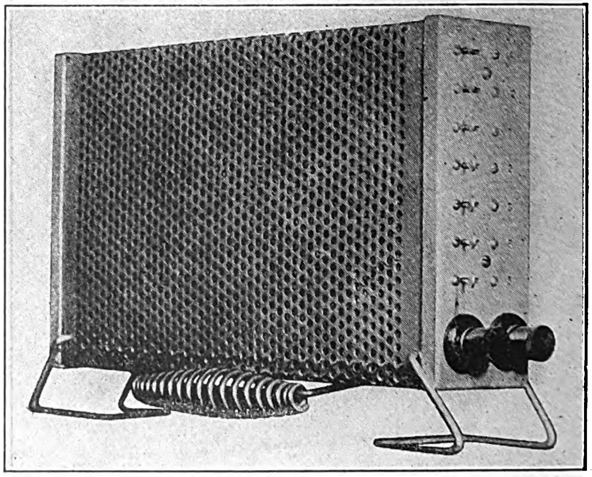

FIG. 32—OHM-SPUN LOADING DEVICE MADE BY THE STATES COMPANY.

son Company to load automatic network protectors for test. It has a maximum capacity of 20,000 amperes. Fig. 33 shows the loading transformer with its load regulating rheostat and switch panel, all mounted on a truck.

Laboratory Storage Battery Control Panel Developed by The Union Gas and Electric Co.

Fig. 34 shows a front view of a specially designed panel built to furnish a variety of series and series-parallel connections for a laboratory storage battery, and to provide charging connections. Fig. 35 is a rear view of the lower portion of the panel, with the cover of the drum switch removed.

The battery is composed of 80 six-volt, 50-ampere-hour lead storage battery units. When not in use, the battery is divided into four groups of twenty units each, to charge at a trickle charge rate from a 240-volt direct-current supply.

At the top of the panel, Fig. 34, are a 200-ampere ammeter, a multi-range voltmeter and a 10-ampere ammeter. A circuit breaker for the battery circuit is located just below the top panel. At the left of the circuit breaker is a five-position voltmeter switch. This makes possible reading separately the voltage of each of the four groups into which the battery is divided when on charge, and the voltage of the direct-current line used for charging. Just below the circuit breaker is a strap for changing the multiplier on the voltmeter. The ammeter switch at the right of the circuit breaker is used to connect the 10-ampere ammeter for reading the charging current of each group separately. The 8-P.D.T. switch is thrown "up" for charging and "down" for discharging the battery. The largest hand wheel turns the large drum switch shown in Fig. 35. It has six positions, which give the values of voltage and current ratings shown in Table I.

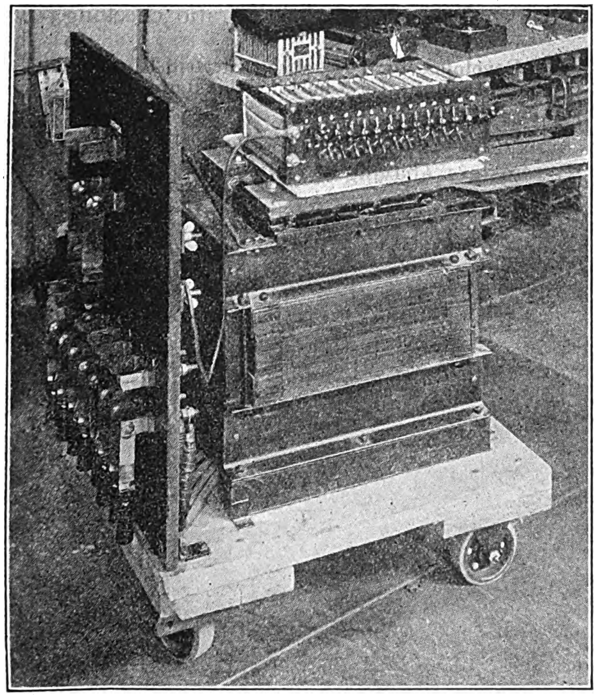

FIG. 33—LARGE CAPACITY LOW VOLTAGE LOADING TRANSFORMER USED BY THE BROOKLYN EDISON COMPANY, INC.

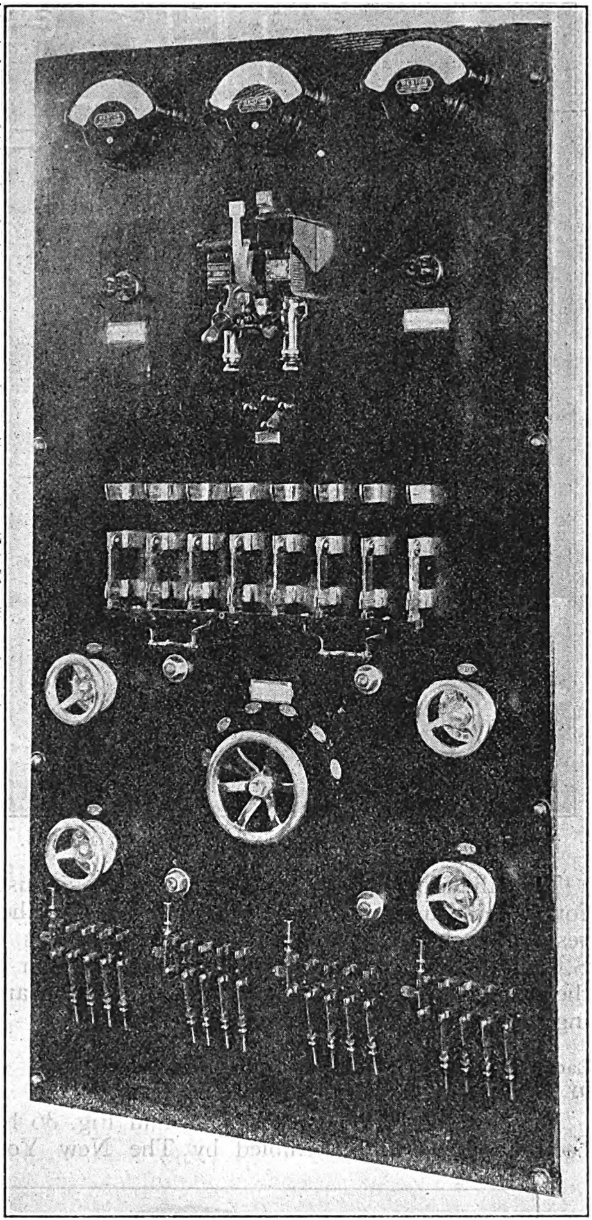

FIG. 34—LABORATORY STORAGE BATTERY CONTROL PANEL DEVELOPED BY THE UNION GAS & ELECTRIC COMPANY.

TABLE I

Position	Voltage Rating (Volts)	Current Rating (Amperes)
A	30	200
B	60	100
C	120	50
D	240	25
E	480	12.5
F	120	Charging position

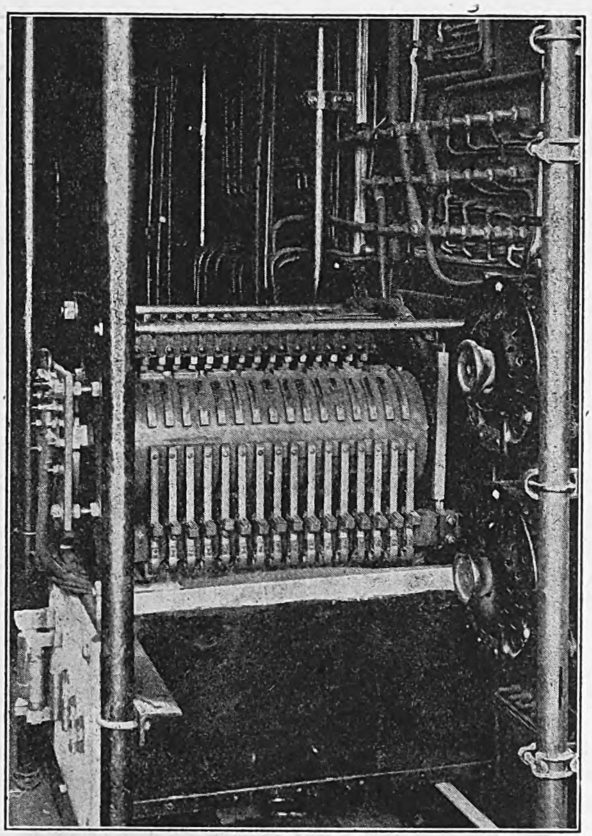

FIG. 35—REAR VIEW OF PANEL SHOWN IN FIG. 34.

The other four hand wheels operate rheostats used for close adjustment of the charging rates of their respective charging circuits. The four groups of S.P.S.T. knife switches, located at the bottom of the panel, are used for rough control of the charging rates of the four sections of the battery.

Large Capacity Portable Testing Battery Assembled by The New York Edison Company

The portable battery truck shown in Fig. 36 has been designed and assembled by The New York Edison Company for supplying test currents up to 1500 amperes. The unit consists of eight Type A-12 Edison cells.

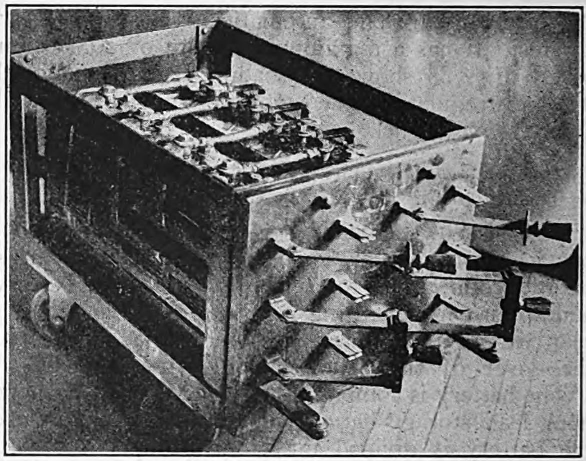

FIG. 36—LARGE CAPACITY PORTABLE TESTING BATTERY ASSEMBLED BY THE NEW YORK EDISON COMPANY.

The switchboard mounted at the end of the truck was specially designed for this purpose and affords a quick and convenient means of connecting the cells in series, parallel, or series-parallel. The copper terminals of the battery are located below the switches.

Register Checking Devices

Most companies feel that it is necessary to check all register ratios in one manner or another. Some may feel that the series testing boards give a sufficiently close check, while others may not. Some count register ratio by hand, while others provide special equipment for register ratio checking.

Device Developed by The Edison Electric Illuminating Company of Boston for Checking the Ratio of Type of Registers

This device is designed to check the ratio of Type OB registers (having a ratio of 3600), and to run

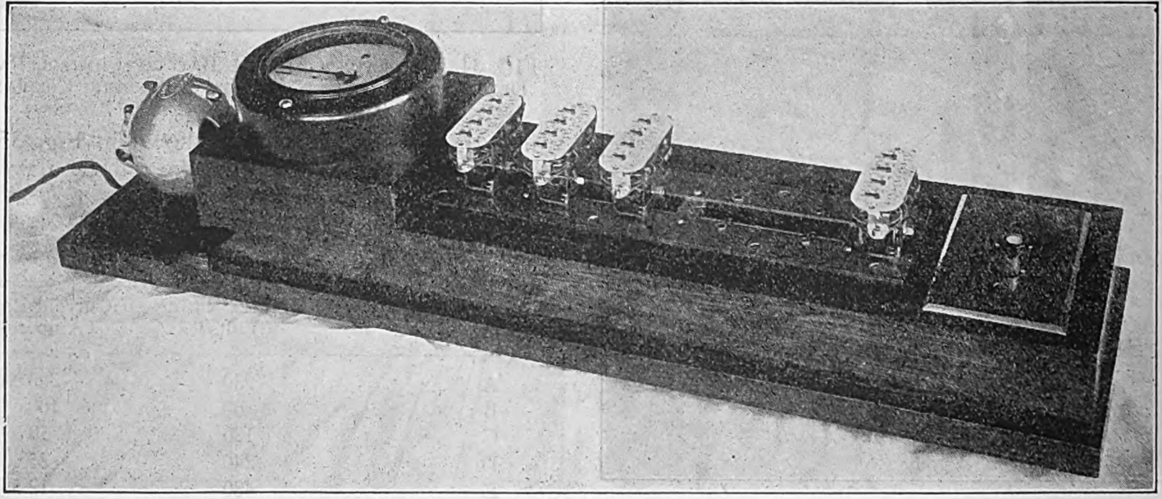

FIG. 37—DEVICE DEVELOPED BY THE EDISON ELECTRIC ILLUMINATING COMPANY OF BOSTON FOR CHECKING THE RATIO OF TYPE OB REGISTERS.

the pointers back to zero after the check. Six registers may be checked simultaneously. In the illustration, Fig. 37, two positions are left vacant to show the shaft pinions and sleeves for the register prongs. The shaft is driven by the small universal motor located at the extreme left of the device. A master register is geared to the shaft. One revolution of the pointer of the master register corresponds to a reading of 1 kw-hr. on the registers under test.

Referring to Fig. 38 the following operations are performed to make a check: the registers, reading 0000, are placed on the device, and the motor is started by throwing switch "B" to position "1," (push button switch on the extreme right of Fig. 37). When the large pointer has made one revolution, the motor is automatically stopped by switch "A," which shifts to position "2." Each register should then read exactly 1 kw-hr. To return the dial pointers to zero, the motor is reversed by throwing switch "B" to position "2." The motor is automatically stopped again by switch "A," which then moves to position "1."

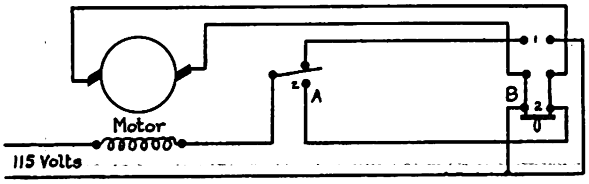

FIG. 38—WIRING DIAGRAM OF DEVICE SHOWN IN FIG. 37.

The speed of the pointer of the master register is approximately one revolution in 18 sec., which means that the time required to check registers is reduced materially by the use of this device.

Device Developed by The New York Edison Company for Checking Register Ratios

This device consists of a shaft having five gear wheels mounted in such positions that four registers may be driven at one time and checked against the fifth or standard register. A small motor supplies the driving force for the shaft, Fig. 39. With this device it is possible to check a number of revolutions of the fastest moving hand, without an excessive loss of time. The motor maintains a speed of approximately 750 r.p.m., and it is found that driving the registers at this speed causes no damage to the gear wheels. The reversing switch on the extreme right of Fig. 39 serves to reverse the motor and to run the registers in either direction.

This device is used for checking General Electric Company Type I-14, I-16 and C-15 registers.

Air-Driven Register Checking Devices Developed by The Union Gas and Electric Company

Fig. 40 shows examples of register checking devices which have proved very satisfactory to the electric meter department of the Union Gas and Electric Company. Where compressed air is available, these devices have been found much more satisfactory than motor-driven devices, and are inexpensive to construct. They are easily controlled over an extremely wide range of speeds in either direction of rotation. This company advises that no register gears have been damaged, whereas with the motor-driven equipment gears were occasionally ruined.

Types I-14 and I-16 registers are checked by using one register, with its worm-wheel removed, as a master. Its worm gear is meshed with that of the register to be checked. The two are then driven by a jet of air blown directly on the first gear of the register. Other types use a turbine wheel, which drives a gear, with which both the master register and the register to be checked are meshed. On each device one register of the type to be checked, having first been checked by inspection, is used permanently as a standard.

Miscellaneous Devices of Interest to Metermen

A number of miscellaneous tools, devices and equipment of interest to metermen are discussed below. They are of such a varied nature that they do not seem to fall under any of the previous classifications.

Micrometer Full Load Adjustment Developed for Rotating Standards by the Pacific Gas and Electric Company

It is thought by the Pacific Gas and Electric Company that the present full load adjusting devices on rotating standards are too coarse to permit close adjustment of the standards without spending an undue amount of time. Accordingly, they have fitted their standards with a simple and effective device for a micrometer adjustment of the full load speed. As a rule, when the magnet clamping screws

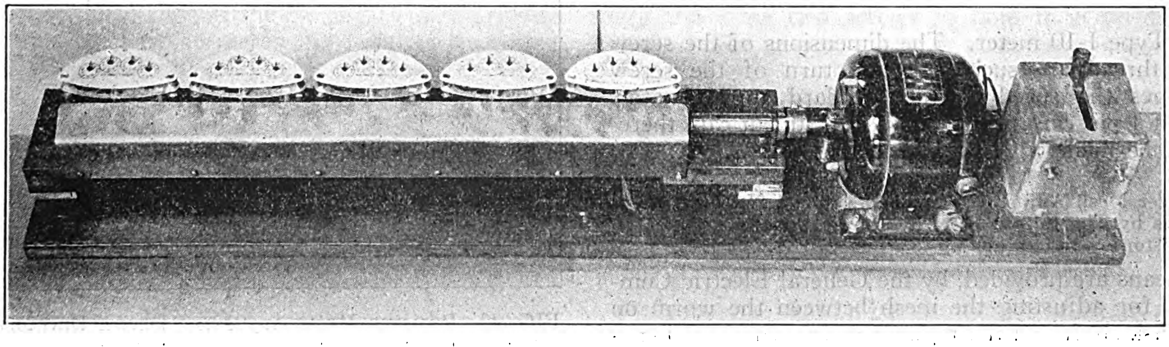

FIG. 39—DEVICE DEVELOPED BY THE NEW YORK EDISON COMPANY FOR CHECKING REGISTER RATIOS.

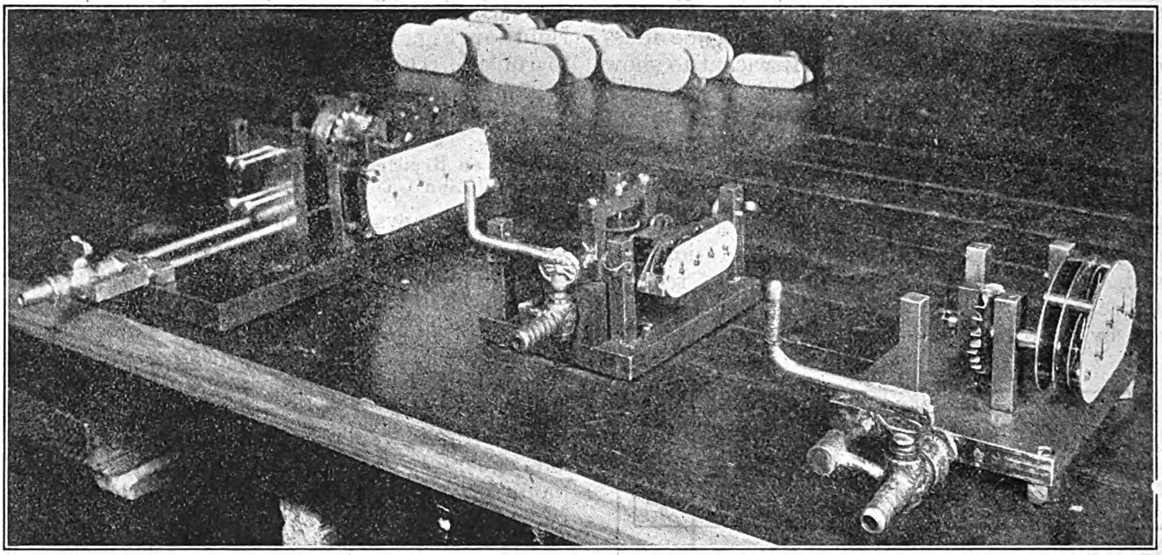

FIG. 40—AIR DRIVEN REGISTER CHECKING DEVICES DEVELOPED BY THE UNION GAS & ELECTRIC COMPANY.

are loosened on a standard, the magnets change their position relative to the disk, before any adjustment is made with the standard magnet adjusting screw. To eliminate this difficulty, a small bronze bracket is placed in front of the magnets, as shown in Fig. 41. A small iron screw is fed into the gap between the magnets in a manner similar to the full load adjustment of the General Electric Type I-10 meter. The dimensions of the screw and thread are such that one turn of the screw changes the speed of the standard approximately 0.1 of 1 per cent. Very close adjustment can, therefore, be made in a very short time.

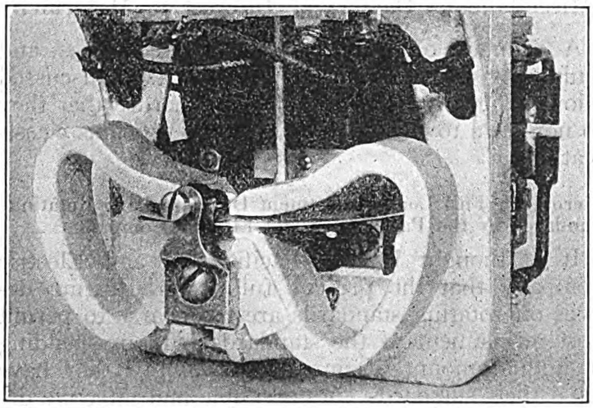

FIG. 41—MICROMETER FULL LOAD ADJUSTMENT DEVELOPED FOR ROTATING STANDARDS BY THE PACIFIC GAS & ELECTRIC COMPANY.

Register Mesh Adjusting Device Developed for Type D-7 Meters by The Edison Electric Illuminating Co. of Boston

Means are provided, by the General Electric Company for adjusting the mesh between the worm on the disk shaft and the register worm wheel of Types D-6, D-7 and I-14 watthour meters. This adjustment is properly made in the factory and should need no further attention as long as the original register is used. It is occasionally necessary to change registers, however, due to installation of contactors for demand meters, or of current transformers of different ratings. While the mesh of the new register may be correctly adjusted on the job, it is convenient to have the adjustment correctly made before the register leaves the meter laboratory.

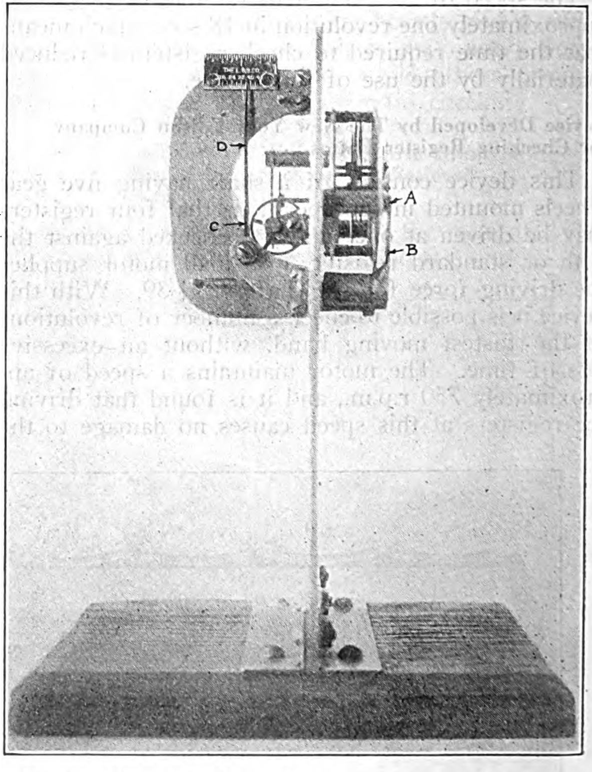

FIG. 42—REGISTER MESH ADJUSTING DEVICE DEVELOPED FOR TYPE D-7 WATTHOUR METERS, BY THE EDISON ELECTRIC ILLUMINATING COMPANY OF BOSTON.

A micrometer device has been designed to make possible the accurate setting of the worm wheels. The register is mounted on the device, as shown in Fig. 42. Two posts "A" fastened to the frame take the place of the usual mounting screws, and the register is held firmly by two clamps, "B." The worm wheel touches plate "C" on the pointer arm "D" and causes this latter to move in front of a scale. The arrangement is such that any movement of plate "C" is magnified several times at the tip of the pointer. The readings of the pointer for registers of meters used with instrument transformers and certain types of demand meters are kept on record. If a new register is required, it is adjusted to correspond with the measurement for the original register. By this means it is possible to allow the installer, who makes the change in the metering transformers, to change the registers at the same time.

Type IM-14 Pointer and Clutch Tension Checker Developed by The Detroit Edison Company

Fig. 43 shows the Type IM-14 Clutch Tension Checker built by the Detroit Edison Company for the use of meter testers in the field. The device is inclosed in a register box, the outside dimensions of which are 3½ in. x 3 in. x 5¼ in., and can be carried in the tester's kit along with his spare registers. The checker is fastened to the removable hinged cover of a register box, Fig. 44, and for convenience, it can be detached from the box when in use.

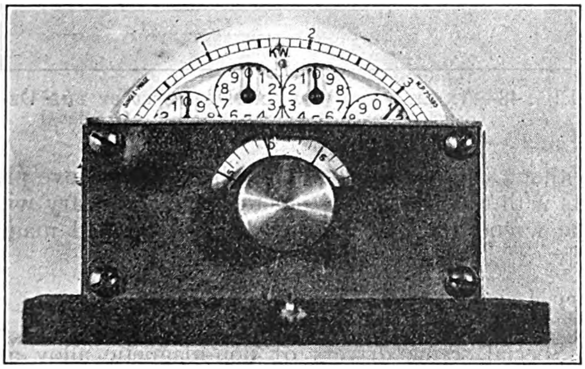

FIG. 43—TYPE IM-14 POINTER AND CLUTCH TENSION CHECKER DEVELOPED BY THE DETROIT EDISON COMPANY.

The checker works on the same general principle as most torque-balancers, with the exception that the jewels which support the moving element are stationary. The hair spring is the same as that used in the laboratory type checker manufactured by the General Electric Company. As it is made of phosphor bronze, it has no tendency to rust, as is the case with a steel spring. The balance wheel and sapphire jewels used in this device are taken from a time clock manufactured by the General Electric Company.

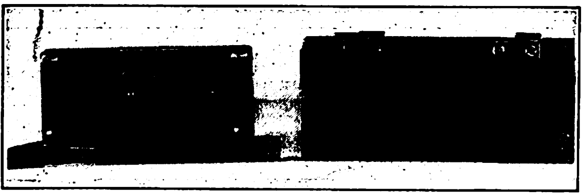

FIG. 44—BOX AND HINGED COVER FOR DEVICE SHOWN IN FIG. 43.

The rotating element is encased in a brass plate frame through which protrude the turning knob and pointer engager. The scale is visible through a semicircular window cut into the plate immediately above the turning knob. The scale has divisions on each side of the zero marking, one side ranging from 0 to 5 gram-millimeters for measuring pointer tension, and the other side from 0 to 25 gram-millimeters for measuring clutch tension. For pointer tension measurement, the pointer is moved to the right, and for clutch tension checking it is moved to the left. For this latter operation, the end of the pointer engages the clutch. By arranging the scale for the pointer and clutch on opposite sides of the zero marking, it is claimed that the chances of error in checking are reduced.

Contact-Making Device Developed for Westinghouse Type OA Registers by The Consolidated Gas, Electric Light and Power Co. of Baltimore

A simple contact-making device for Westinghouse Type OA registers has been devised and used by the Consolidated Gas, Electric Light and Power Company. It consists of a small brass plate, Fig. 45, on which is mounted an auxiliary shaft, gear star wheel, and contact brushes. To attach this device it is only necessary to remove two screws from the back plate of the register train, and to fasten the auxiliary device on the back of the register, using the same two screws to hold it in position, Fig. 46. The auxiliary gear is placed in mesh with the second gear of the register train. It is claimed that the simplicity of mounting makes it possible to install these devices on meters on the customers' premises.

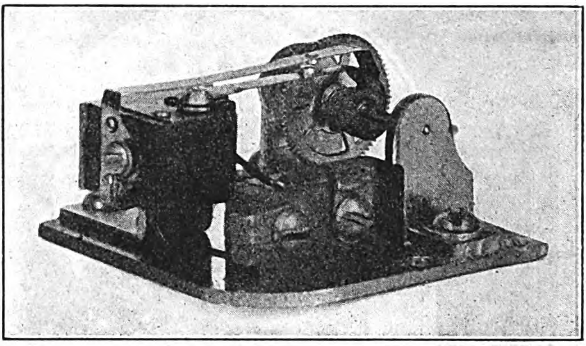

FIG. 45—CONTACT-MAKING DEVICE DEVELOPED FOR WESTINGHOUSE TYPE OA REGISTERS BY THE CONSOLIDATED GAS, ELECTRIC LIGHT & POWER COMPANY OF BALTIMORE.

Armature Testing Device Developed by The New York Edison Company

This device consists primarily of a voltmeter and a resistor, equivalent in value to the resistance of a combination shunt and resistor used in series with watthour meter armatures. The voltmeter is connected directly across two finger contacts which are

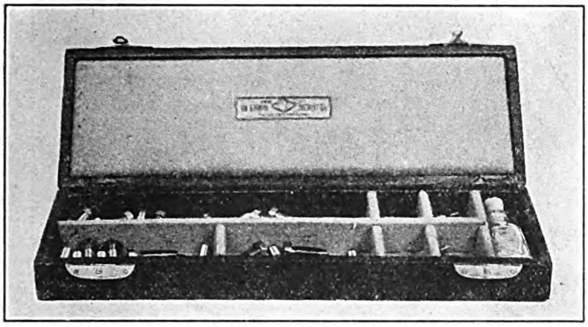

FIG. 50—INTERNAL VIEW OF JEWEL CASE SHOWN IN FIG. 49.

be carried. Special compartments are arranged for pivots, ball bearings, dial hands and oil bottle.

The lid fits securely down on the box and is held closed by two catches.

Meter Tester's Field Kit Used by The Union Gas and Electric Company

Fig. 51 shows a kit designed for the use of meter-men making tests in the field. The case is made of wood and covered with imitation leather. Elastic straps hold the tools in place. The ends of the case are tapered so that the end view of the kit, when closed, resembles a capital letter "A."

Portable Instrument Transformer Testing Sets Made by The Leeds & Northrup Company

The Leeds & Northrup Company makes portable current and potential transformer testing sets, as originally designed by Dr. Silsbee of the Bureau of Standards, Washington, D. C. These sets have been found very satisfactory by a number of public utility companies for testing instrument transformers used with watthour meters.

Fig. 52 shows such a set in use for checking the

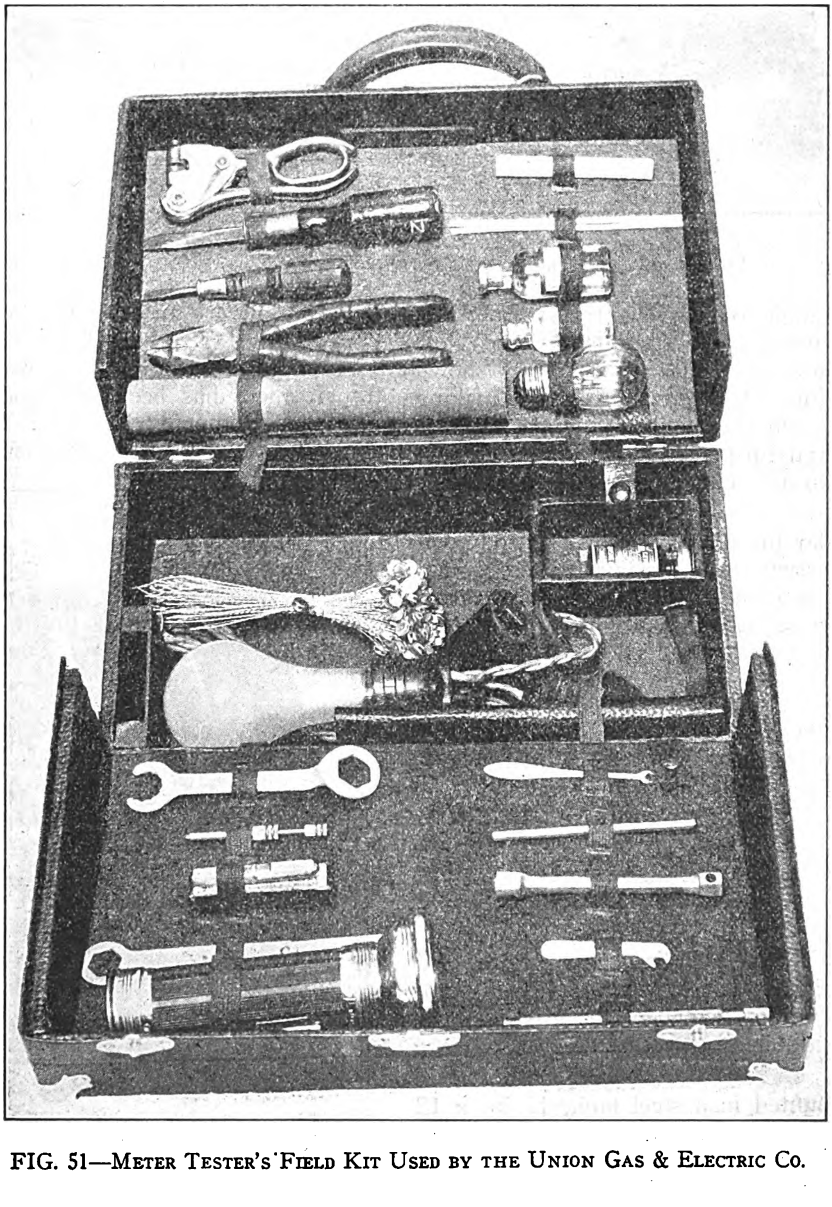

FIG. 51—METER TESTER'S FIELD KIT USED BY THE UNION GAS & ELECTRIC CO.

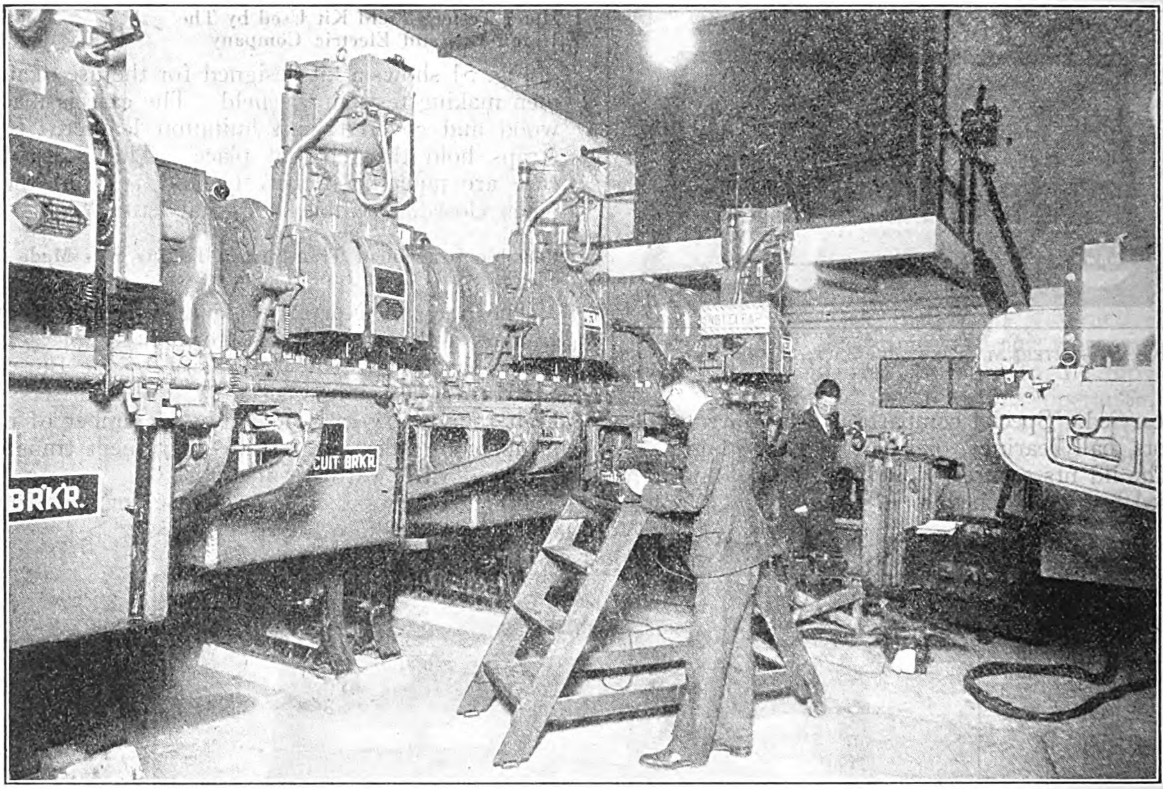

FIG. 52—PORTABLE INSTRUMENT TRANSFORMER TESTING SET MANUFACTURED BY THE LEEDS & NORTHRUP COMPANY IN USE IN AN A-C. DISTRIBUTING STATION OF THE NEW YORK EDISON COMPANY.

ratio and phase-angle of current transformers in one of the a-c. distributing stations of The New York Edison Company. The Silsbee set is shown in the center of Fig. 52, where the tester is making his observations. On the right of the same figure is shown a test transformer supplying large current at low voltage to the current transformer under test.

In this particular installation the use of the portable set became essential, as the current and potential transformers are imbedded in heavy insulating compound, and are permanently mounted in the iron-clad switch gear.

Multi-Range Potential Transformer Standard Manufactured by Otto A. Knopp

The standard potential transformer shown in Fig. 53 supersedes earlier types of a more limited range, reported in the 1924-1925 Report of the Meter Committee, N. E. L. A. The new transformer standard has the following voltage ranges: 110, 220, 440, 1100, 2200, 4400, 6600, 11,000 volts to 110 volts.

It is claimed that the windings are so designed that the same ratio and phase angle corrections apply to all ranges within a few hundredths of 1 per cent for ratio and one to two minutes for phase angle.

The unit is mounted in a steel tank, 12 in. x 12 in. x 10 in., which has a bakelite top. Handles are provided to facilitate transportation.

Adjustable Burden Made by The Leeds & Northrup Company for Testing Current Transformers

An adjustable burden for use in testing current transformers has been developed by the Leeds & Northrup Company, Fig. 54. This adjustable burden has a maximum rating of 50 volt-amperes at 60

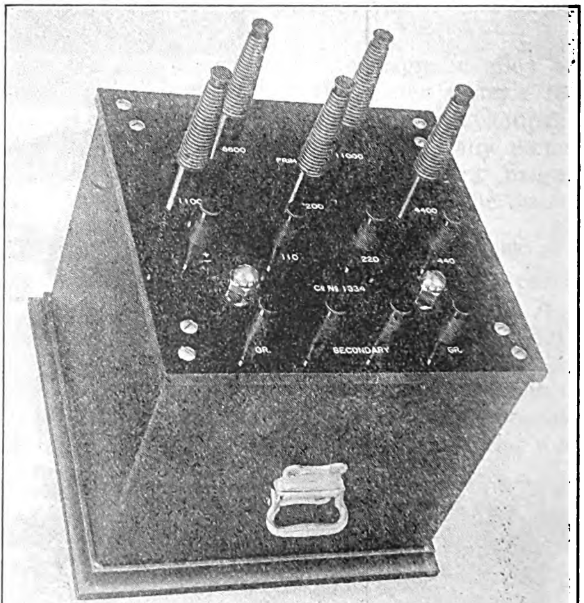

FIG 53—MULTI-RANGE POTENTIAL TRANSFORMER STANDARD MANUFACTURED BY OTTO A. KNOPP.

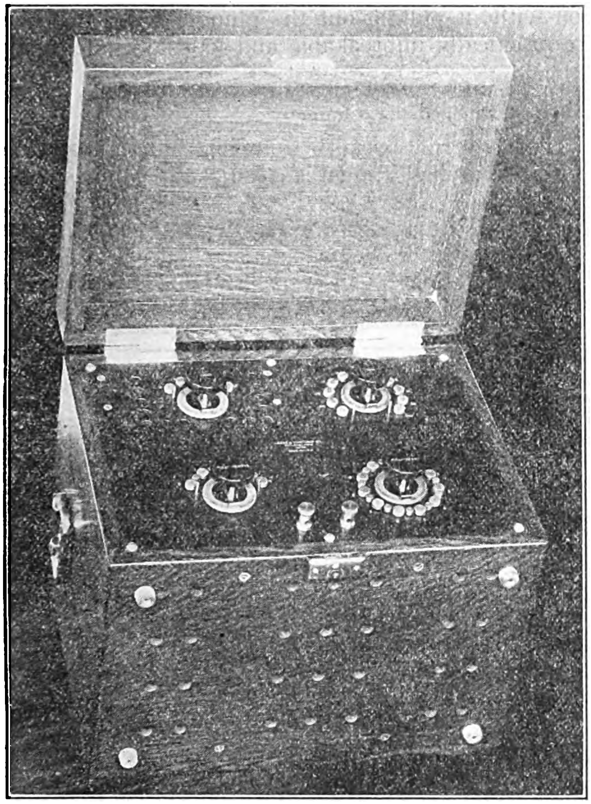

FIG. 54—Adjustable Burden Made by the Leeds & Northrup Company, for Testing Current Transformers.

cycles. The burden power factor can be varied between 100 per cent and 10 per cent. This latter value can be obtained using only the inductance portion of the device. The resistance section can be adjusted in steps of 0.04 ohm, while the inductance section can be adjusted in steps of 0.1 millihenry. The apparatus is designed to carry 5 amperes continuously, or 7.5 amperes for a short time.

This company has in the process of development a similar set of burdens for potential transformer testing, and also a portable device for measuring both current and potential transformer burdens.

Marking Current Transformers

The reading of current transformer nameplate ratios is very often necessary after the transformer has been placed in service. In some cases the transformers are so located that this becomes a rather difficult and dangerous task. To eliminate this difficulty, some companies find it advisable to mark the respective nameplate ratios on the transformers, with large numerals, legible at a considerable distance. Fig. 55 shows the practice of the Consolidated Gas, Electric Light and Power Company of Baltimore.

Other companies, such as The New York Edison Company, find it more advisable to stencil the manufacturer's serial number rather than the nameplate ratio on each transformer. The complete nameplate data are kept on record in the office. Therefore, all the necessary data for any transformer becomes available once its serial number is determined.

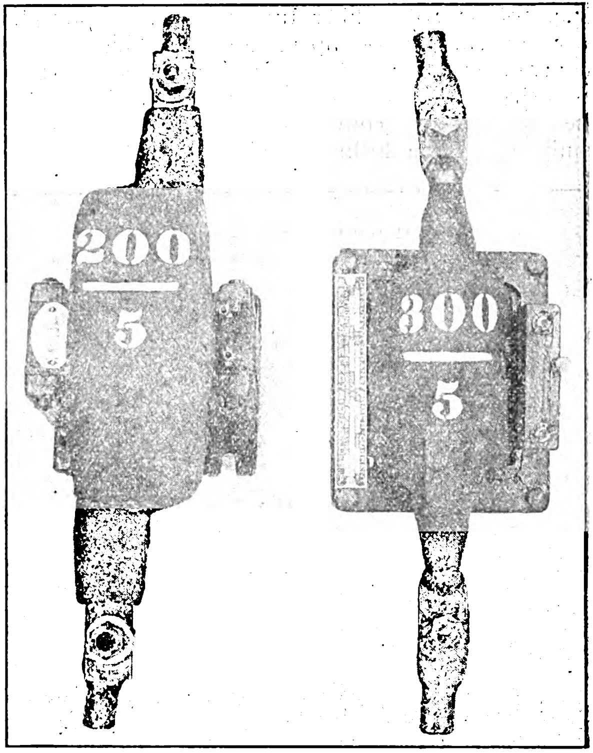

FIG. 55—A Method of Marking Current Transformers with Large Numerals.

Adapter Test Clip Developed for Test Lead Plugs by The Detroit Edison Company

The Detroit Edison Company has developed a device consisting of a test clip, to which is attached a plug receptacle, so that it can be forced over the usual test lead plug. The receptacle holds the plug securely with a friction fit, and a test connection can be easily made with the test clip. This device, Fig. 56, is claimed to be valuable when using a series loop while working on test boxes. With two additional test clips the series loop can be safely held in place.

Saf-T-Klips Made by The Superior Switchboard and Devices Company

Saf-T-Klips as manufactured by the Superior Switchboard and Devices Company constitute an improvement in test clips for meter work. The Saf-T-

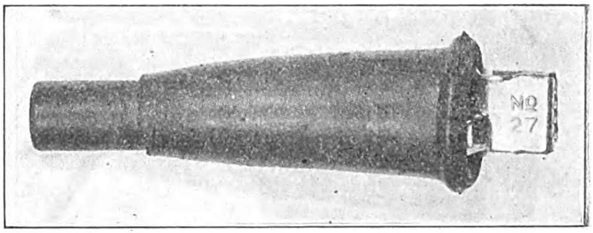

FIG. 56—Adapter Test Clip Developed for Test Lead Plugs, by the Detroit Edison Company.

Klip consists of a fiber tube inclosing a phosphor bronze spring of 60-ampere capacity. This spring is so arranged that, when the plunger or rod is pressed into the tube, the contacts located at the end of the spring are compressed. The contacts are equipped with a locking device especially designed for this company's "1000 Line" Test Switches, described elsewhere in this report. Fig 57 shows the Saf-T-Klip in the open and closed positions. Fig. 58 shows the Saf-T-Klips in use on a Superior test switch.

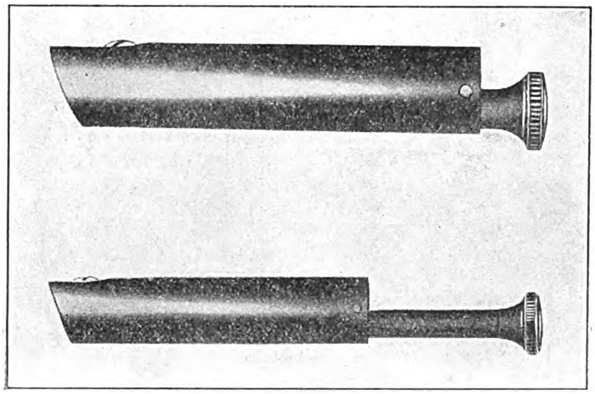

FIG. 57—SAF-T-KLIPS MADE BY THE SUPERIOR SWITCHBOARD COMPANY.

The manufacturer claims that it is impossible to pull off the Saf-T-Klip after it is placed in position without pulling out the plunger; also that they are practically unbreakable and will last indefinitely.

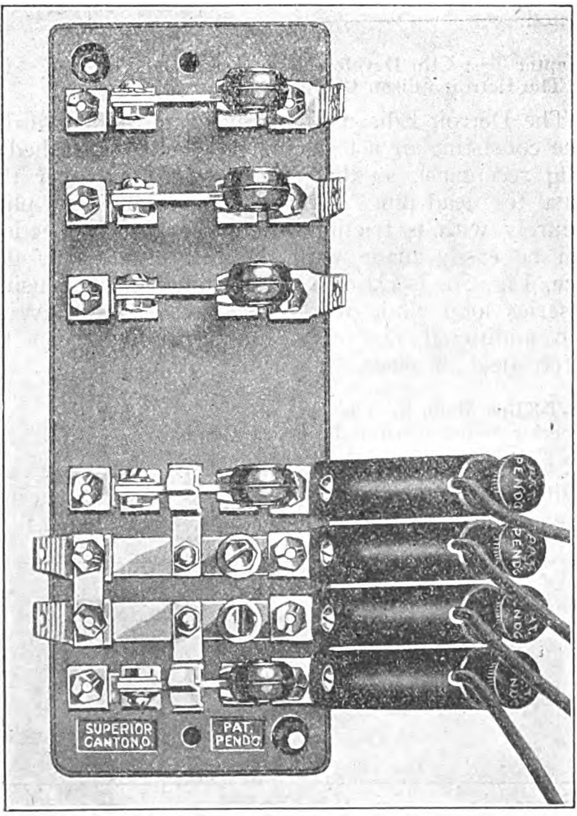

FIG. 58—SAF-T-KLIPS MOUNTED IN POSITION.

Tesco Type ES-7 and ES-10 Test Switches Made by The Eastern Specialty Company

The Eastern Specialty Company announces a line of test switches known as the Tesco Types ES-7 and ES-10. The Type ES-7 test switch, Fig. 59, is designed especially for use with two and three-phase, three-wire, two-element meters. The Type ES-10 test switch, shown with cover removed in Fig. 60, is designed for use with three-phase, four-wire, three-element meters. They are furnished in either front or rear connected types, with and without glass covers. The bases are made of molded material, and the switch blades are of special cold-rolled copper. Auxiliary blades are attached to one blade of these switches to short-circuit the secondary circuits of current transformers before breaking the circuit through the main blades.

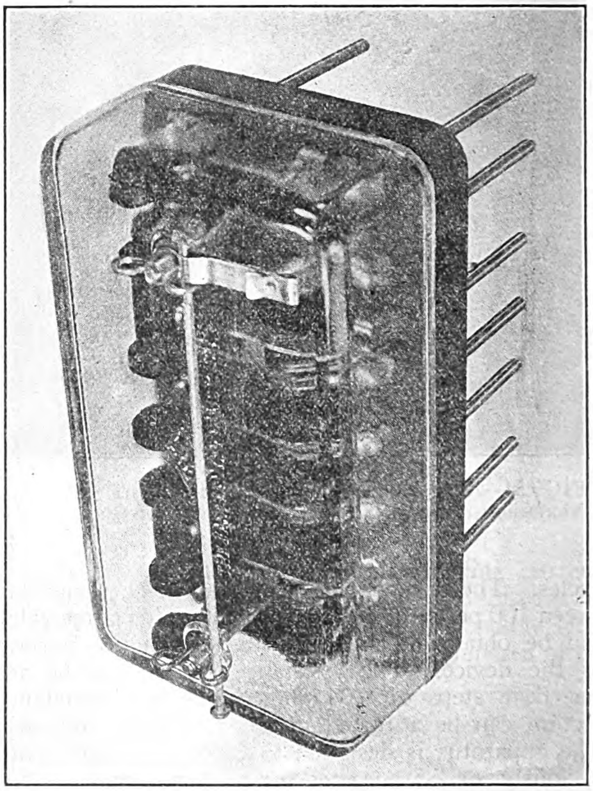

FIG. 59—TESCO TYPE ES-7 TEST SWITCH MADE BY THE EASTERN SPECIALTY COMPANY.

Type SJ Test Block Made by The States Company

One of the features of the new States Company Type SJ Test Block is the shunted jack principle used in the design of the current units. The shunted jack scheme eliminates the possibility of forgetfulness on the part of the tester to tighten screws or other arrangements, sometimes used to clamp jack contacts in switch type test blocks. Further, the jack contacts are not depended upon to

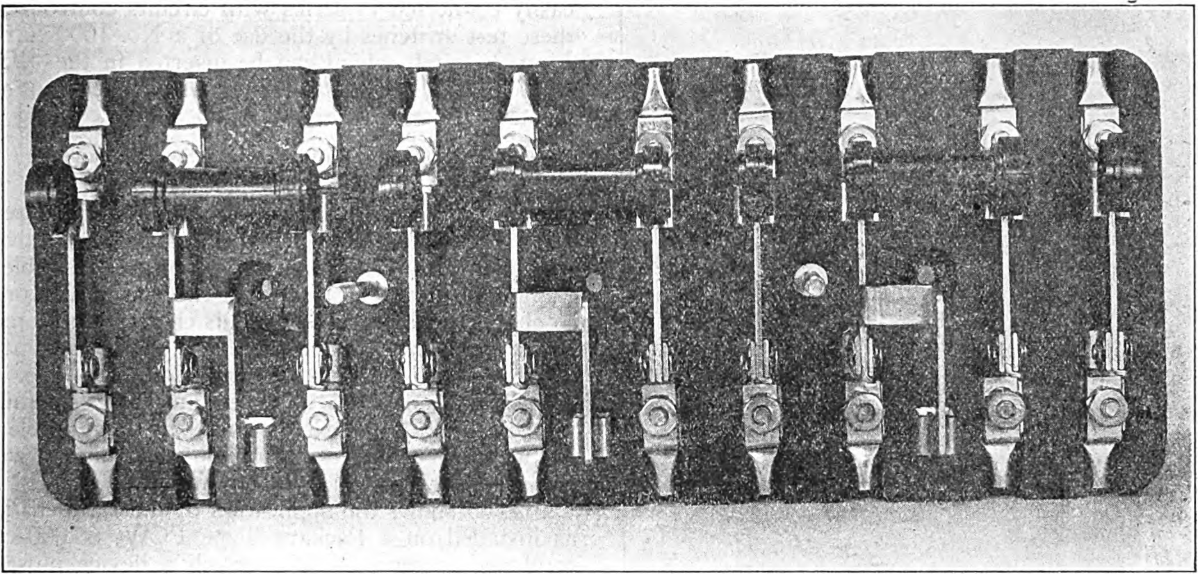

FIG. 60—TESCO TYPE ES-10 TEST SWITCH MADE BY THE EASTERN SPECIALTY COMPANY.

carry current. Reference to Fig. 61 shows that a knife switch shunts the jack contacts. This switch is open only when the jack is in use. The cover of the block may be removed without disturbing connections. It cannot be replaced unless all of the switch blades are in the "closed" position. The current units of the block are so arranged that it is impossible to open-circuit current transformer secondaries.

The test plugs, which may be supplied with the blocks, are easily inserted at right angles to the block. A specially formed test clip strip insures good test clip connection, and eliminates the possibility of a test clip slipping off.

All switch and jack jaws are made of special high

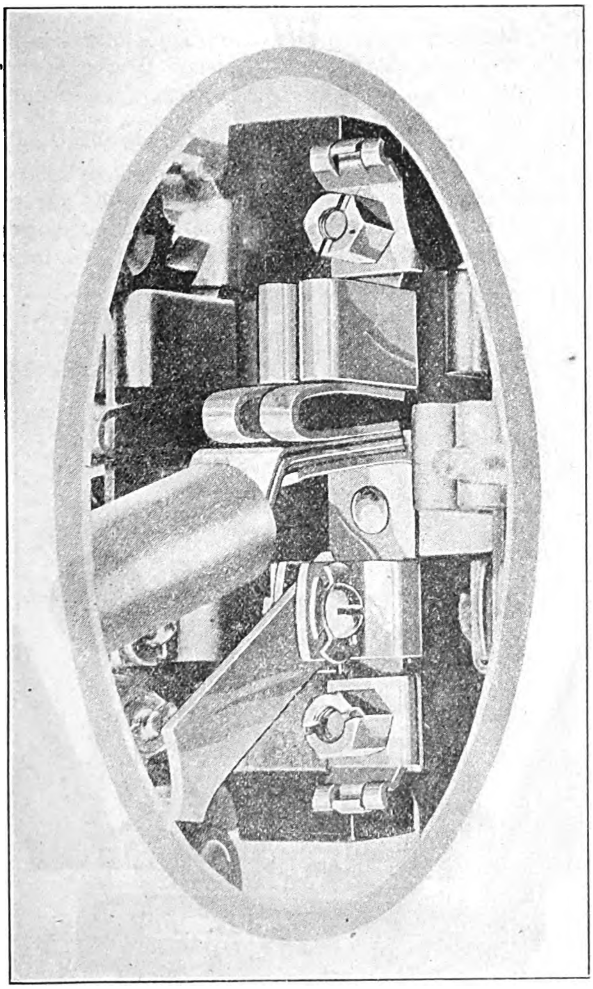

FIG. 61—DETAIL OF CONSTRUCTION OF THE TYPE SJ TEST SWITCHES MADE BY THE STATES COMPANY.

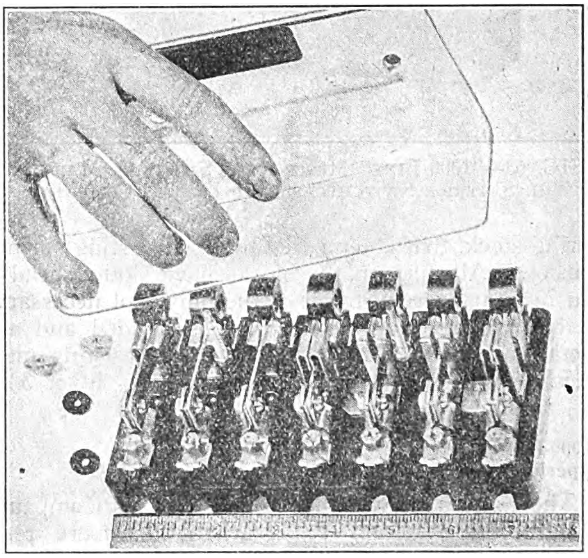

FIG. 62—COMPLETE VIEW OF A TYPE SJ TEST BLOCK, DETAILS OF WHICH ARE SHOWN IN FIG. 61.

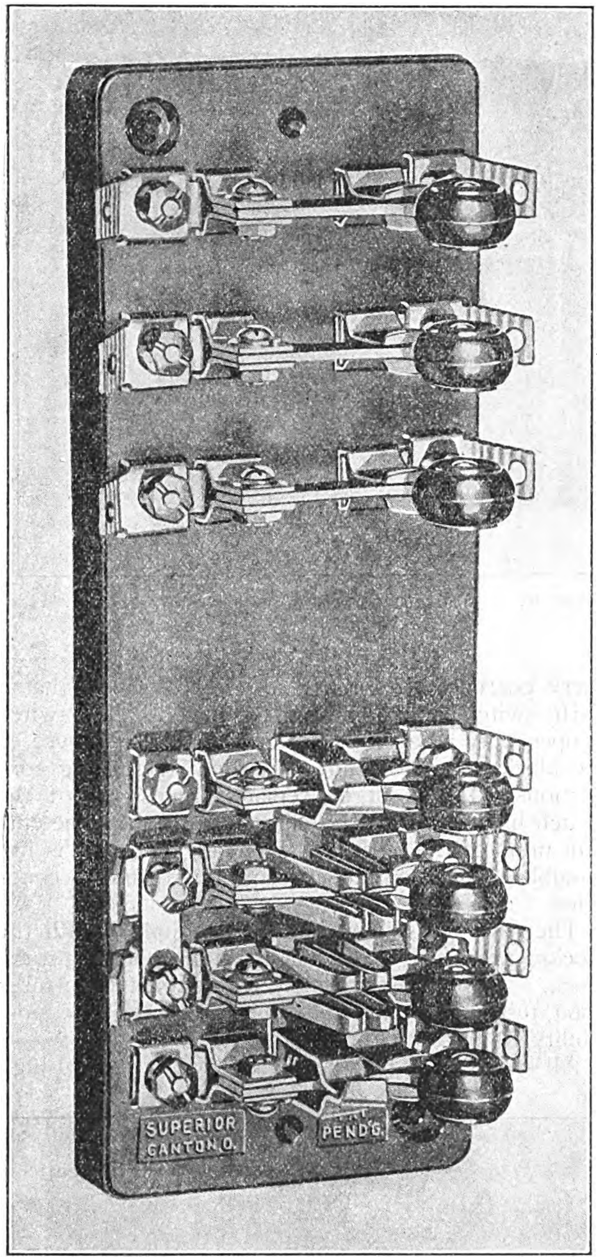

FIG. 63—"1000-LINE" METER TEST SWITCHES MADE BY THE SUPERIOR SWITCHBOARD AND DEVICES COMPANY.

spring stock, that is tempered to give a lasting spring tension. All nuts on the blocks have slotted heads. An ordinary screw driver is the only tool necessary to make connections. The base is molded and all metal parts are treated with corrosion-resisting material. The seven-pole block base is 7½ in. x 3¾ in., as shown in Fig. 62.

"1000-Line" Meter Test Switches Made by The Superior Switchboard and Devices Company

The Superior Switchboard and Devices Company has recently put on the market 60-ampere test switches known as the "1000-Line" Superior Meter Test Switches. The unit known as the Cat. No. 1040 test switch is shown in Fig. 63. Ammeters can be easily connected in series with circuits controlled by these test switches by the use of a No. 1000 Saf-T-Plug, Fig. 64, which can be inserted in the "1000-Line" jack, built into one leg of each current element.

Current Transformer Ratio Changer Switch Made by the Packard Electric Company

Due to the variable load conditions encountered when measuring the exchange of power between interconnected systems, it is sometimes desirable to change the current transformer ratio, at will, in order to obtain higher accuracy. This change can be readily accomplished by the use of a device manufactured by the Packard Electric Company, Fig. 65. This device may also be used in cases of straight industrial load metering, where it is desirable to change the current transformer ratio quickly without undue trouble and power shutdown.

Fig. 66 shows the application of the ratio changer as installed on a Packard Type PCW, 66,000-volt, combined metering outfit. Such a device must be

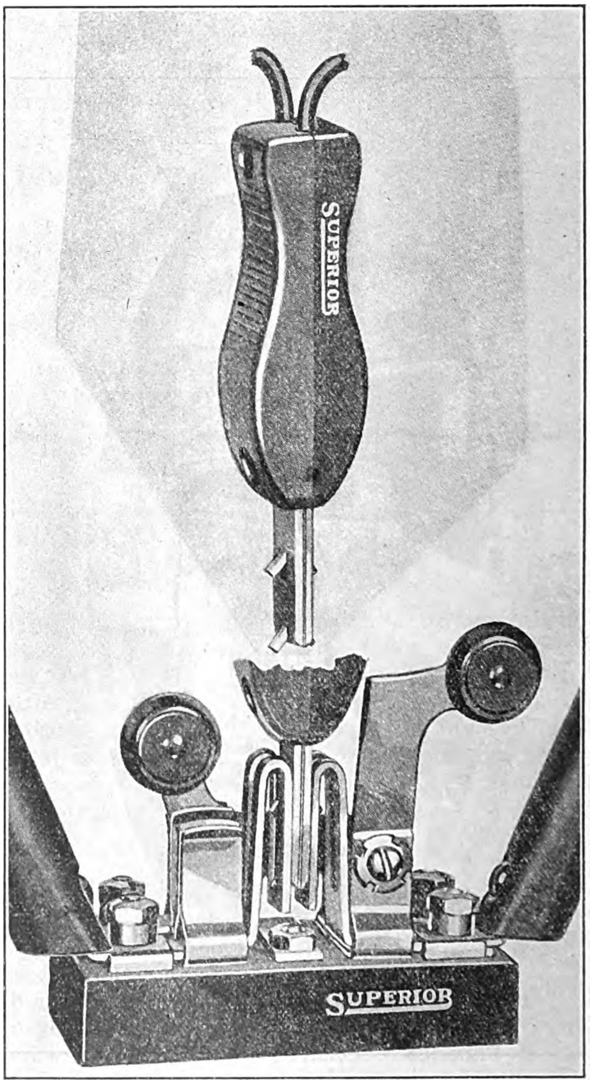

FIG. 64—DETAIL VIEW OF THE TEST SWITCHES SHOWN IN FIG. 63.

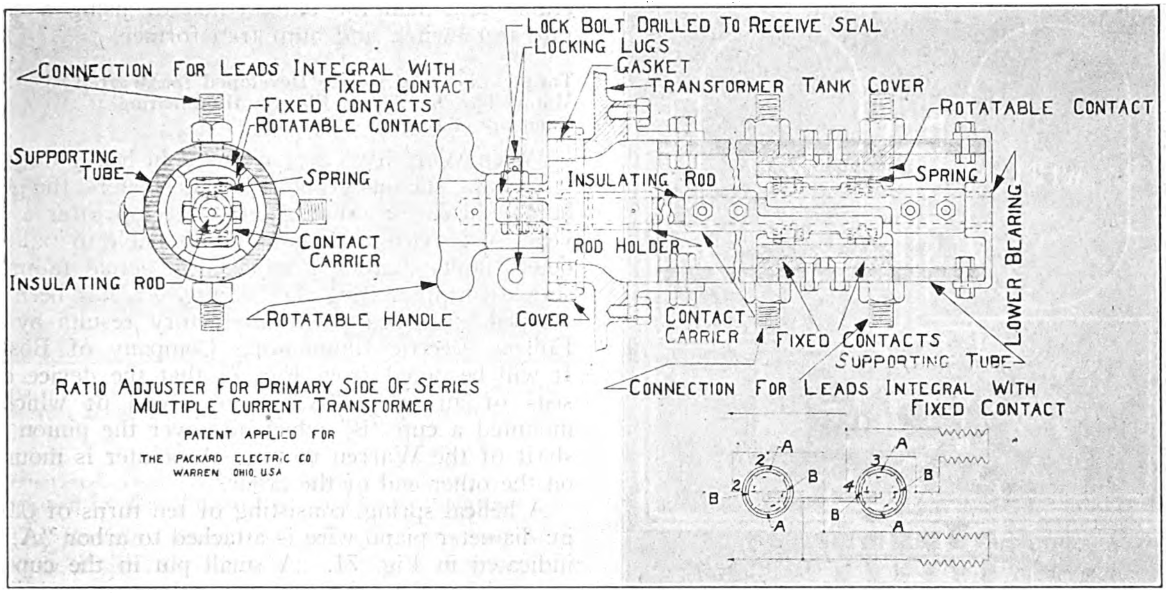
LOCK BOLT DRILLED TO RECEIVE SEAL
LOCKING LUGS
GASKET
TRANSFORMER TANK COVER
CONNECTION FOR LEADS INTEGRAL WITH FIXED CONTACT
FIXED CONTACTS
ROTATABLE CONTACT
ROTATABLE CONTACT
SUPPORTING TUBE
SPRING
INSULATING ROD
SPRING
LOWER BEARING
CONTACT CARRIER
ROD HOLDER
INSULATING ROD
ROTATABLE HANDLE
COVER
CONTACT CARRIER
FIXED CONTACTS
SUPPORTING TUBE
CONNECTION FOR LEADS INTEGRAL WITH FIXED CONTACT
RATIO ADJUSTER FOR PRIMARY SIDE OF SERIES MULTIPLE CURRENT TRANSFORMER
PATENT APPLIED FOR
THE PACKARD ELECTRIC CO
WARREN OHIO USA
A
2
2
B
B
A
A
3
4
B
B
B
A

FIG. 65—CONSTRUCTION DETAIL OF CURRENT TRANSFORMER RATIO CHANGER SWITCH MADE BY THE PACKARD ELECTRIC COMPANY.

installed in a manner that only authorized employees can operate it, inasmuch as the watthour meter readings must be taken each time the ratio is changed.

The Quadraphaser Made by The States Company

For metering reactive volt-ampere-hours, it is necessary to supply to the potential circuit of the meter a voltage displaced 90 deg. from the voltage used for metering watthours. The Quadraphaser is a device which combines the necessary transformers to produce this voltage, along with a four-pole Type DT angle blade switch.

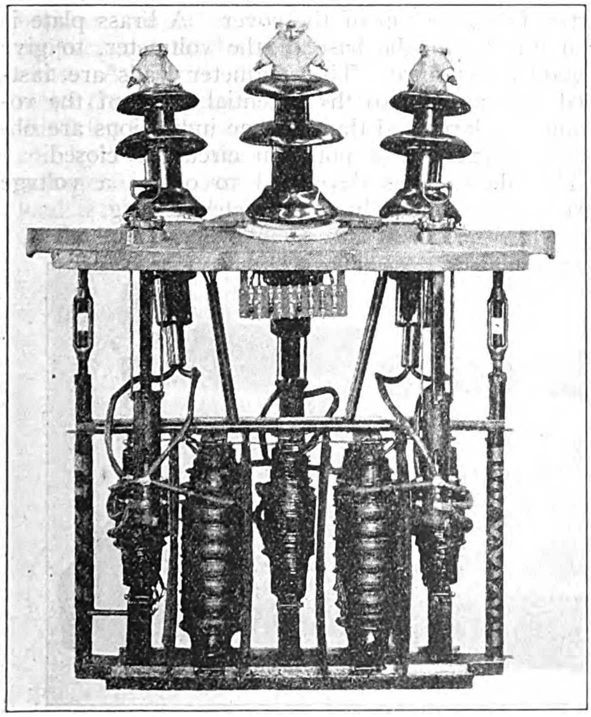

FIG. 66—RATIO CHANGER SWITCH INSTALLED ON A 66,000-VOLT METERING OUTFIT.

The manufacturer states that the transformers are especially designed and have ample capacity for the particular service of measuring the reactive component. The four-pole switch serves to disconnect the transformers and to supply normal voltage to the meter for testing it as a watthour meter. The Quadraphaser is normally supplied with a cover made of bakelite with metal ends. It is impossible to place the cover of the Quadraphaser on the base unless the switch is in the "run" position. This eliminates the possibility of leaving the meter registering kw-hr. rather than reactive kv-a-hr. after the test.

The device, Fig. 67, is 12 in. long, 4 in. wide and 3½ in. high. Fig. 68 shows the wiring diagram of an installation where a Quadraphaser is used.

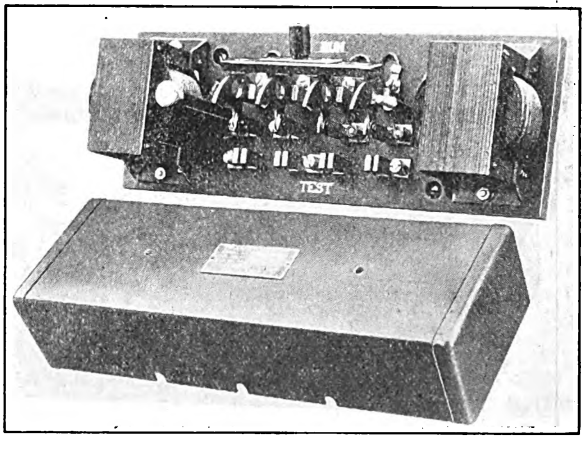

FIG. 67—THE QUADRAPHASER MADE BY THE STATES COMPANY.

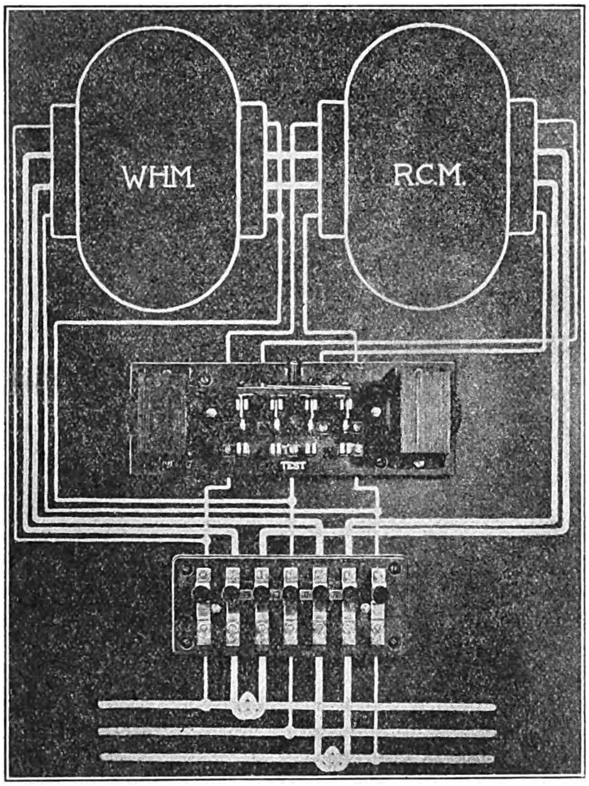

FIG. 68—CONNECTION DIAGRAM FOR USE WITH THE DEVICE SHOWN IN FIG. 67.

Reactiformers Made by The Superior Switchboard and Devices Company

Another device of a similar nature and designed for the purpose of combining phasing transformers with a meter testing device is manufactured by the Superior Switchboard and Devices Company.

The Reactiformer shown in Fig. 69 is designed for three-phase, three-wire service, while the one shown in Fig. 70 is designed for three-phase, four-wire service. The manufacturer states that both the initial cost and the cost of operation are considerably less than the old method of using a separate test switch and auto transformer.

Torque Checking Device Developed for Warren Motors by The Edison Electric Illuminating Company of Boston

When Warren motors are used in heavy duty instruments, such as graphic demand meters, the gears become worn or other defects develop after a few years of service, and the motor is liable to fail. To detect faulty motors in advance of actual failure, a simple torque testing device, Fig. 71, has been developed and used with satisfactory results by the Edison Electric Illuminating Company of Boston. It will be noted from Fig. 71 that the device consists of an arbor "A," on one end of which is mounted a cup "B" which fits over the pinion and shaft of the Warren motor. A pointer is mounted on the other end of the arbor.

A helical spring, consisting of ten turns of 0.017-in. diameter piano wire is attached to arbor "A," as indicated in Fig. 71. A small pin in the cup engages the pinion of the motor under test.

A motor is considered safe to use if, at rated voltage, it has sufficient torque to turn the pointer one complete revolution. All motors with less torque are returned to the manufacturer for repairs.

Combined Rotating Standard and Voltmeter Assembled by The Buffalo General Electric Company

The Buffalo General Electric Company has equipped all its rotating standards with a modified Type TA, Roller Smith voltmeter, Fig. 72. In order to obtain sufficient room to accommodate the depth of the voltmeter, a 2⅝-in. hole is bored in the cover of the standard, and the voltmeter is inserted from the top of the cover. A brass plate is then fitted over the base of the voltmeter, to give a good appearance. The voltmeter leads are fastened permanently to the potential posts of the rotating standard, and thus voltage indications are obtained whenever the potential circuit is closed.

This device was developed to obtain a voltage survey simultaneously with meter testing.

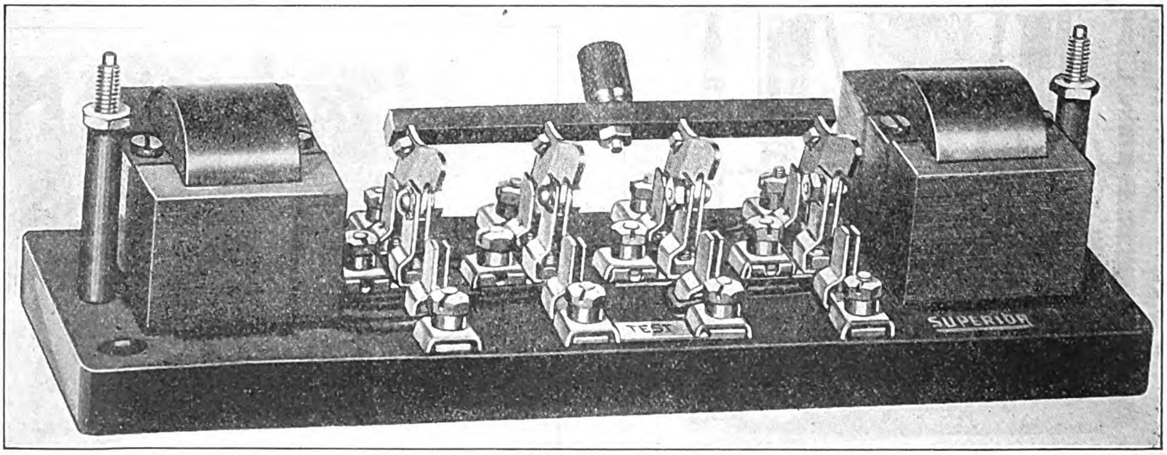

FIG. 69—REACTIFORMER DESIGNED FOR 3-PHASE, 3-WIRE SERVICE MADE BY THE SUPERIOR SWITCHBOARD & DEVICES COMPANY.

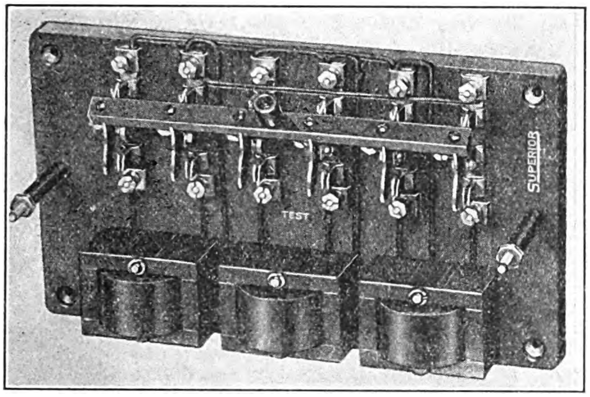

FIG. 70—REACTIFORMER DESIGNED FOR 3-PHASE, 4-WIRE SERVICE MADE BY THE SUPERIOR SWITCHBOARD & DEVICES COMPANY.

Alternating-Current Voltmeter Testing Device Developed by The Buffalo General Electric Company

The Buffalo General Electric Company has developed a device, shown schematically in Fig. 73, for checking alternating-current voltmeters. It consists of a transformer of three windings on a conventional "H" core. The winding on one outside leg serves as the primary, which can be excited from any convenient 115-volt source of a given frequency, such as a potential transformer. The winding on the center leg serves as a secondary or source of potential for the instruments under test. It is provided with several taps to cover the range of voltage desired. The third winding is on the remaining leg of the core, and is connected to a variable resistor.

The device functions in the following manner: With no load on either of the two secondary windings, the flux set up by the primary coil is divided between the other two legs of the core, inversely proportional to the reluctance of the magnetic circuits. As load is placed on the center coil, the flux in its core decreases and accordingly the flux in the third leg increases. As load is placed on the third coil by varying the resistance in series with it, the voltage of the second coil is increased. Hence, as load is increased on the third winding, the voltage on the instrument under test is increased. The rheostat in the third coil, together with the various taps in the center coil, enables the operator to obtain any voltage value quickly and smoothly within the range of the device. The whole device is mounted in a carrying case similar in size and weight to a rotating standard.

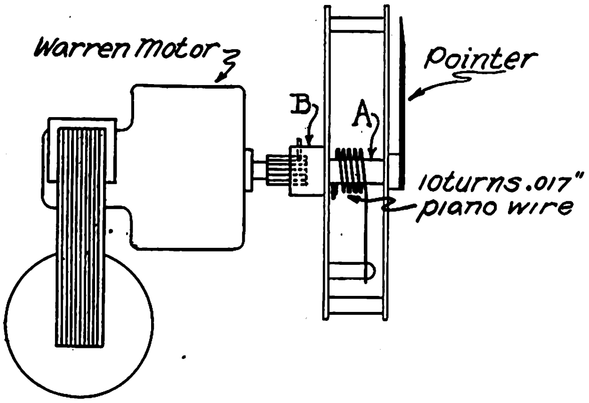

FIG. 71—TORQUE CHECKING DEVICE DEVELOPED FOR WARREN MOTORS BY THE EDISON ELECTRIC ILLUMINATING COMPANY OF BOSTON.

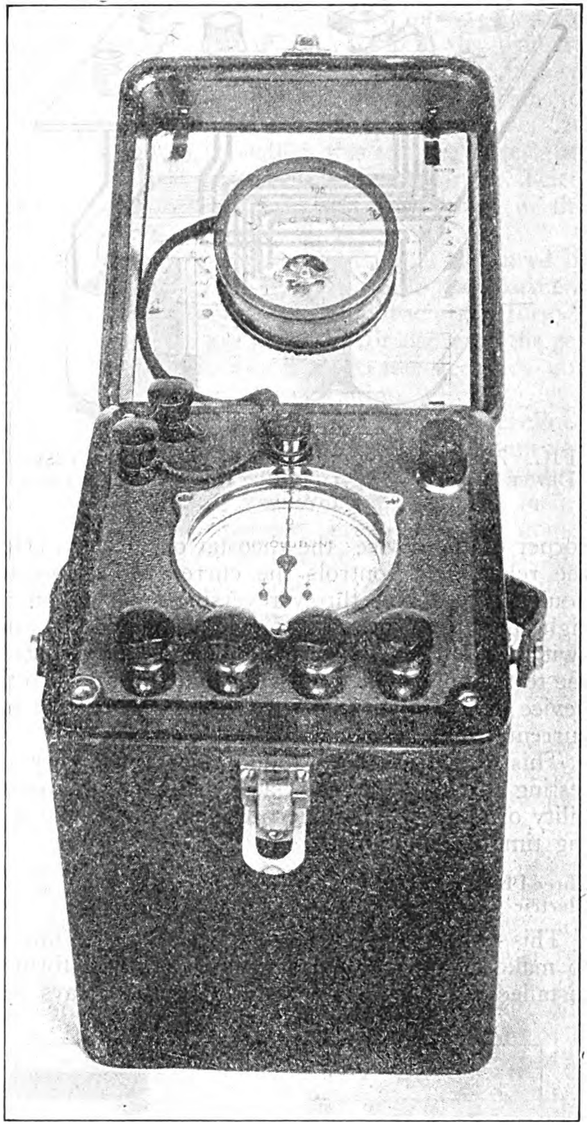

FIG. 72—COMBINED ROTATING STANDARD AND VOLTMETER ASSEMBLED BY THE BUFFALO GENERAL ELECTRIC COMPANY.

Equipment Assembled by The New York Edison Co. for Testing Automatic Sub-Station Line Relays

For testing the sensitivity of "Line Relays" used in automatic sub-stations equipped with the General Electric Company distributor type of supervisory system, the device shown in Fig. 74 has been designed and constructed by The New York Edison Company.

The Line Relay, "R" in Fig. 74, is inserted into the jack located at the upper left hand corner of the device. A test supply of 48 volts is connected to the binding posts shown at the upper right hand

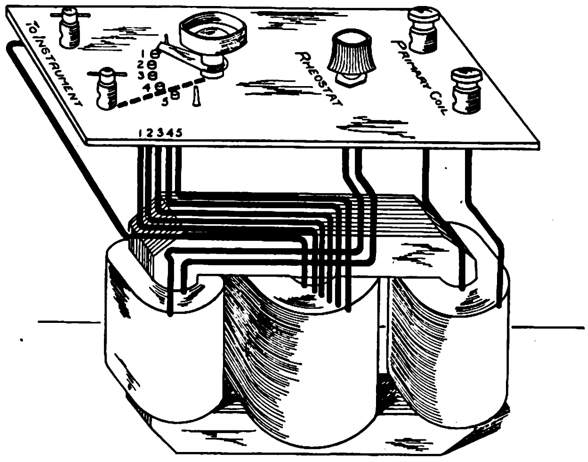

FIG. 73—ALTERNATING-CURRENT VOLTMETER TESTING DEVICE DEVELOPED BY THE BUFFALO GENERAL ELECTRIC COMPANY.

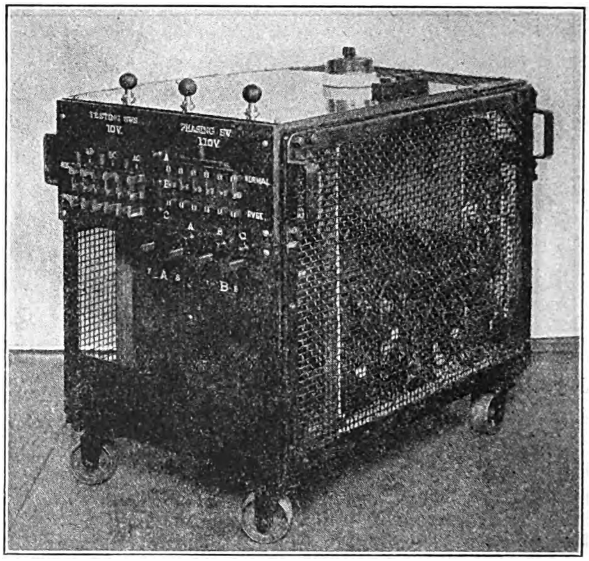

FIG. 75—THREE-PHASE TEST SET USED BY THE UNION GAS & ELECTRIC COMPANY FOR TESTING TRUCK SWITCH RELAYS.

corner of the device; the rheostat on the left, below the relay jack, controls the current; the flush-top double pole double throw reversing switches on the right permit the necessary switching; and the snap switch, below the right hand binding post controls the test supply. The milli-ammeter, connected to the device by a plug and jack, serves to measure the test current, which is 70 to 80 milli-amperes.

This device has been found very satisfactory for testing this type of relay, as it eliminates all possibility of wrong test connection and reduces the testing time to a minimum.

Three-Phase Test Set Used by the Union Gas and Electric Company for Testing Truck Switch Relays

This test set, Fig. 75 and 76, is designed primarily to make an overall test on relays and transformers installed on truck switches where the relays and current transformers are mounted on the movable member of the truck. The test is made by applying three-phase current directly to the main contacts of the truck switch and noting the operation of the relays.

Where truck switches are assembled and wired in the shop before delivery to the field, a final check can be made in a few minutes using this device. If a test in the field is desired, the set can readily be transported to the desired location.

The following tests can be made with this device:

Determination of ratio and polarity of current transformers. .

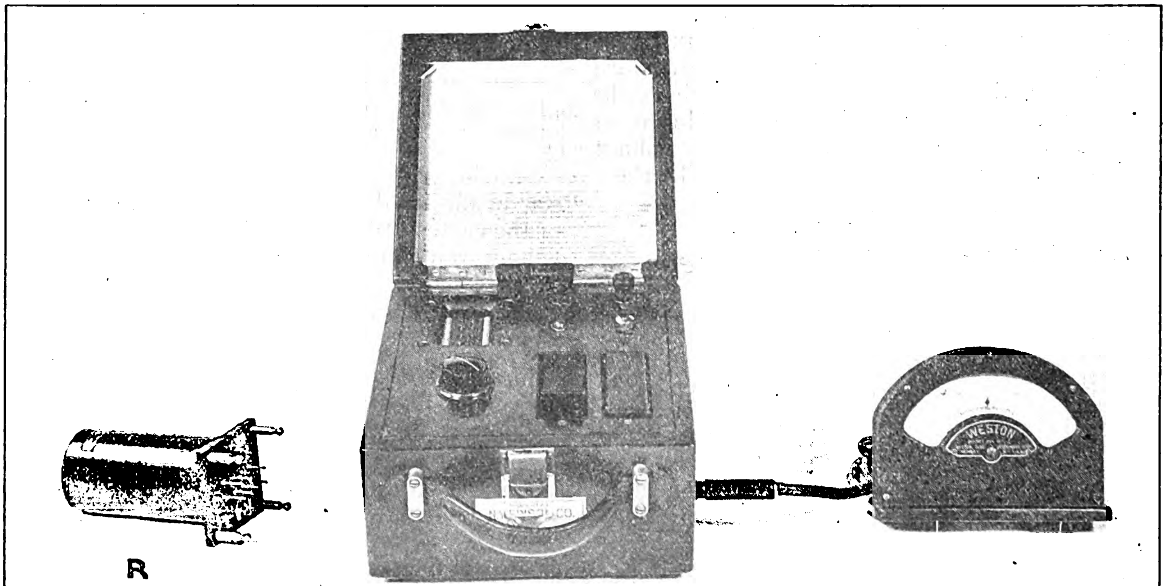

FIG. 74—EQUIPMENT ASSEMBLED BY THE NEW YORK EDISON COMPANY FOR TESTING AUTOMATIC SUBSTATION LINE RELAYS.

- Determination of ratio and polarity of potential transformers (when mounted on movable member).
- Determination of operation of over-current relays.
- Determination of the wiring condition of over-current relays.
- Determination of operation of directional relays.
- Determination of the wiring condition of directional relays.
- Determination of phase relations between feeder and customer's bus.
- Location of loose connections.

The test set consists primarily of three single-phase transformers, each having three secondary windings. The main secondary winding is designed to supply 1200 amperes at 5 volts for 10 minutes. One of the auxiliary secondary windings is designed to supply 10 volts for exciting the potential element of a power-directional relay, while the other auxiliary winding is designed to supply 115 volts for testing directional relays, and for determining phase relation between the customer's bus and the potential transformers mounted on the stationary member of the truck switch, or on another switch. The primary windings can be connected to 230 or 460-volt circuits.

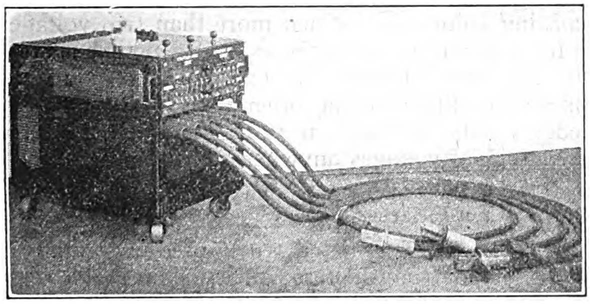

FIG. 76—DEVICE SHOWN IN FIG. 75 WITH SECONDARY CABLES ATTACHED.

Each transformer is excited through a double-pole switch and is wired so that, with all switches closed, the primary windings are connected in delta. Each transformer can also be energized separately to determine if each relay is connected to the proper phase.

The 5-volt winding of each transformer is supplied with 300,000-circular mil flexible leads and contactors which fit into the truck switch contacts. A grid resistor is connected in series with each lead, to reduce the current to approximately 600 amperes, for the purpose of determining the operation of the relays at the lower current values. A short strap is provided to short-circuit this resistor.

The ten-volt auxiliary windings are connected to a six-pole reversing switch to make possible the reversal of phase rotation. These windings are connected in delta by the six-pole reversing switch, and then to three terminals. The terminals are connected to the relays through the auxiliary contactors on the truck switch. The 115-volt auxiliary windings are similarly connected to three terminals through a six-pole reversing switch.

When potential transformers are mounted on the movable member of the truck switch, the primary windings of the potential transformers are connected directly to a 230 or 460-volt supply by means of a three-pole snap switch mounted on the test set. As the truck switches for which this test set is designed are used on 7800 and 13,200-volt feeders, sufficient voltage is applied to the directional relays in this manner.

The current in the main windings is measured by means of small through-type current transformers, which are slipped on one lead from each transformer. When instruments are required for use with the set, the portable type is used for greater accuracy and to prevent damage in transportation.

The method of connection has been determined and marked so that, when the test set is connected to a truck switch and current applied, the action is the same as if a fault had been applied to the feeder in service. In this manner, three-phase and single-phase faults can be simulated. By means of the potential reversing switches, the action of the directional relays can be tested under conditions which represent a fault on either of the two feeders supplying a given loop installation.

The utility that designed this set advises that by its use any errors of operation that are present, especially such errors that occur only when all the circuits of the truck switch are energized, can be detected. Tests with this device are made to supplement a detailed wiring check of relays.

Resistor Assembled by the New York Edison Co. for Testing Power-Directional Relays

A resistor has been developed by The New York Edison Company for testing power-directional relays at low voltage. This unit, shown in Fig. 77, eliminates the necessity of using a low reading voltmeter, as at 8 amperes it gives a voltage drop of 3 volts. Eight amperes and 3 volts are test values at which the relay must operate in 0.25 second to pass the low voltage test.

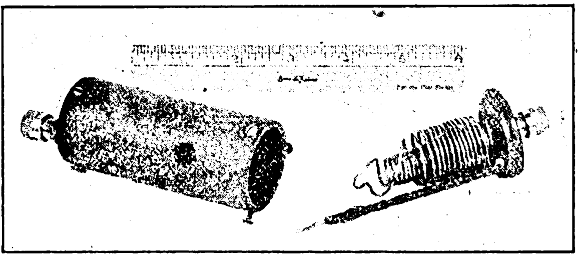

FIG. 77—RESISTOR ASSEMBLED BY THE NEW YORK EDISON COMPANY FOR TESTING POWER-DIRECTIONAL RELAYS.

The resistor is inserted in the current circuit of the relay, and the current is adjusted to 8 amperes. The voltage appearing at the terminals of the resistor is applied to the potential coil of the relay, with the assurance that its value is 3.0 volts and it is in phase with the current.

The resistor is wound non-inductively of manganin wire, which also eliminates resistance changes with temperature.

Three-Wire Test Lamps

Meter testers of the Brooklyn Edison Company are supplied with three-wire test lamps, for use when working on sections of the system which have been changed over from delta services, metered with 120-240 volt, three-wire, single-phase meters, to one of two legs and neutral of a four-wire, three-phase system giving 120-208 volt service. These test lamps consist of two lamps connected in series, and the connection between them is brought out so that voltage to ground can be readily checked. The middle lead is made shorter in order to identify it, and thus prevent placing a single lamp across 208 or 240 volts.

If the two outside leads are placed across a circuit and the lights do not burn at full brilliancy, the middle lead is then grounded. If the lights come up to full brilliancy, the circuit is identified as a 120-208-volt circuit. If the circuit is a 120-240-volt, single-phase circuit, the lights will remain brilliant with or without the neutral wire grounded.

This method of connecting test lamps is used quite generally by other utilities for identifying various types of services.

A Method of Recording Two or More Voltages on One Chart Used by The Edison Electric Illuminating Co. of Boston

It is sometimes desirable to obtain a record of two or more voltages on one chart, as for example, the voltages of the two sides of a three-wire, single-phase circuit or the individual phases of a polyphase circuit. This may be done by means of a switching device that will alternately connect the voltmeter across the different voltages to be measured. Fig. 78 schematically illustrates a transfer or commutating switch of this kind for obtaining the voltages of the two sides of a three-wire, single-phase circuit. Fig 80 shows a chart obtained by the use of this device. It will be noted that the time intervals are not equal, the voltmeter being connected to one side for a longer time interval than to the other side. This is done so that the voltage records may be readily identified.

When the voltmeter connection is transferred from one side to the other, the circuit is broken for a very short interval, and the stylus or pen arm tends to return to the zero point of the chart. The line thus made on the chart further aids in distinguishing between the records of the two voltages. The transfer switch may be a separate clock-driven device, as shown in Fig. 78, or may be a part of the recording voltmeter. When more than two voltages are to be recorded, as in the case of a polyphase circuit, the time interval for one voltage should be longer than that for the others. Knowing the sequence of the voltages, it is then easy to identify the individual voltages anywhere on the chart.

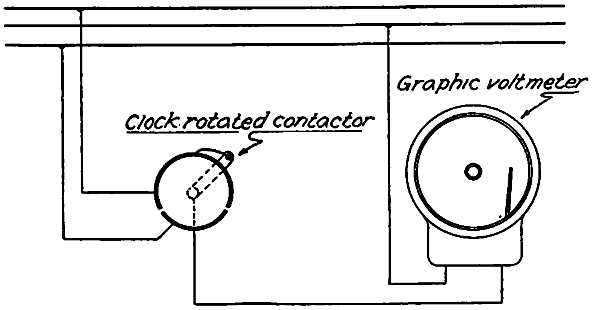

FIG. 78—A METHOD USED BY THE EDISON ELECTRIC ILLUMINATING COMPANY OF BOSTON FOR RECORDING TWO OR MORE VOLTAGES ON ONE CHART.

Meter Truck Used in the Laboratory of The Union Gas and Electric Company

Fig. 79 shows a meter truck used to transport meters to and from the test panels in the Inside Test Department of the Union Gas and Electric Company. These trucks are substantially built of oak and equipped with rubber-tired steel wheels. Each truck has a capacity of eighty meters. A bar across the end facilitates handling.

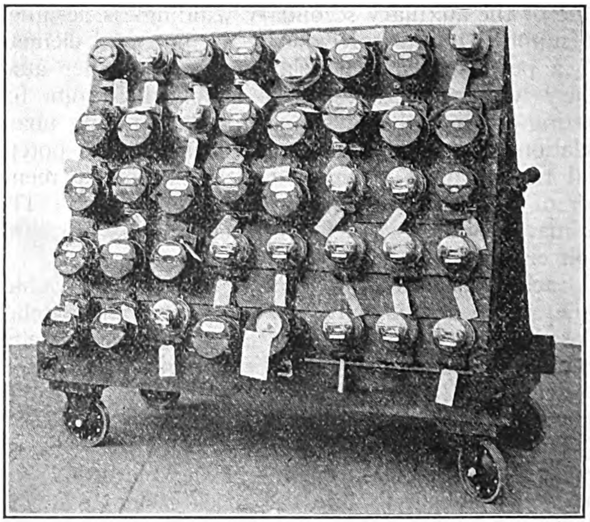

FIG. 79—METER TRUCK USED IN THE LABORATORY OF THE UNION GAS & ELECTRIC COMPANY.

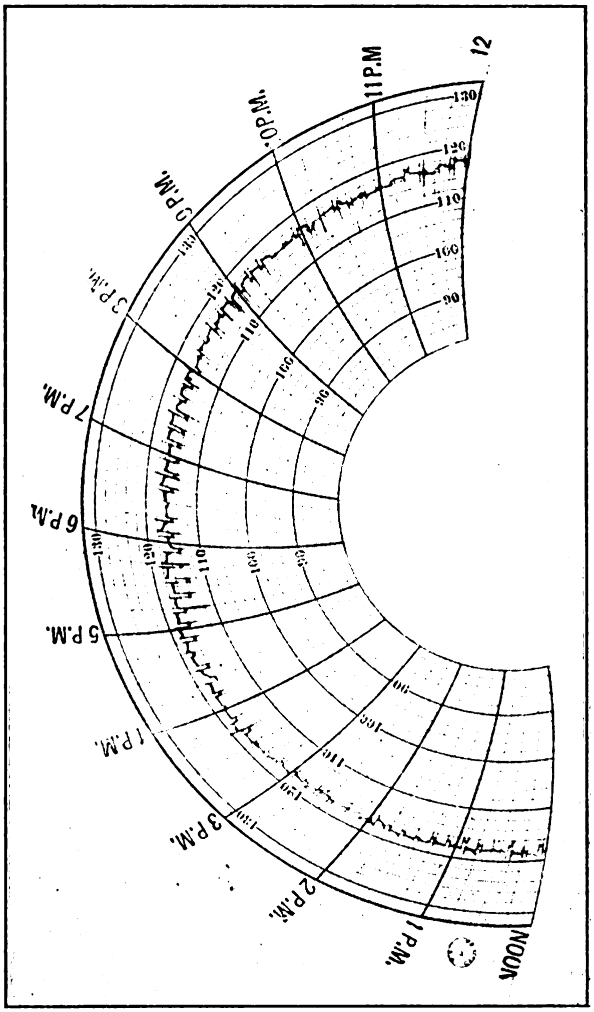

FIG. 80—CHART SHOWING VOLTAGE RECORDS MADE BY THE DEVICE SHOWN IN FIG. 78.

PRACTICAL USES OF STEEL AND CONCRETE POLES

STEEL POLES

A steel pole, as distinguished from a steel tower; is defined as a narrow beam structure, which may be located in approximately the same space as a wood or concrete pole.

The following report presents some of the general considerations relative to the use of steel poles followed by a summary of replies to a questionnaire on their use by companies in this country.

The general advantages of steel poles over wood poles may be summarized as follows: Longer life, greater strength, lower maintenance cost and smaller depreciation charges. The disadvantages are: Higher initial cost, greater hazard for linemen at work, and in the case of fabricated structures, greater ease with which they may be climbed by an unauthorized person.

However, there is no hard and fast rule which dictates the use of steel poles over wood poles or any other structure. Each line must be judged on its own merits, and a careful study made of all the factors involved before a choice can be made.

The conditions under which steel poles are frequently used are as follows:

(a) When the right of way is narrow or otherwise restricted, such as on city streets, along highways, along railroads or on private property.

(b) At angles in the line where conditions will not permit the use of guys, then self-sustaining steel poles may be used.

(c) Where the number of circuits, size of conductors and length of span require strength which it is impracticable to secure by the use of wood poles.

(d) Where a study of the economies of the line show that the larger capital cost and heavier fixed charges of a steel pole line are more than offset by its lower maintenance and depreciation charges.

(e) Where the importance of the line or the available right-of-way is insufficient for a steel tower line, but is suitable for a steel pole line.

(f) Where the matter of appearance is of sufficient importance to warrant the extra cost of steel poles.

Design Specifications

Specifications pertaining to design should cover fully the following points:

Voltage of line.
Maximum length of span and ruling span.
Size of wire. material and characteristics.
Assumed thickness of ice and velocity of wind.
Number of circuits and arrangement.
Number and size of ground wires, if any.
Distance between phases.
Distance between circuits.
Length of insulator string, including hardware
Lateral swing of insulator string.
Minimum clearance to steel of live parts.
Minimum clearance of conductors over ground. over highways, to adjacent structures, etc.
Maximum tension in conductors.
Amount of tension reduction in conductors to allow for swing of insulators into catenary, under condition of broken conductor.
Number of broken conductors.
Maximum angle in line.
Loading combinations.
Allowable unit stress—tension, compression, shear and bearing.
Slenderness ratio of compression members.
Minimum size of shapes and bars allowed.
Minimum thickness of metal allowed.
Size of bolts and bolt holes.

The following matters of detail design should also be considered in the specifications:

Accessibility of all parts for inspection; avoidance of pockets or depressions which would hold water; avoidance of eccentricity in joints and connections, or a proper provision for eccentric stresses where eccentricity is unavoidable; chamfering the back of the inside angle in lap splices; inclination of lattice bars and other latticing details.

Such details as type of ground wire connection, insulator, support, size and location of ladder bolts, if any, and type of foundation or footing, should also be given consideration in the specifications.

Fabrication

The quality of fabrication is of utmost importance, not only that the resulting line may be first class, but also that erection difficulties and costs may be reduced to a minimum.

Specifications should usually include the following requirements:

Workmanship to be in accordance with first-class practice.
All members to be carefully straightened at shop before being shipped.
All members to be properly marked for identification in the field, and such marks shall not later be rendered illegible by galvanizing or careless handling.
Small parts to be securely wired into bundles, and all nuts, bolts, etc., to be boxed and marked.
One of each type of pole to be completely assembled at shop before any shipment is made.
If material is galvanized, it should be done as

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the last process of fabrication.

Careful handling and inspection will be necessary in order to avoid shipment of members warped by galvanizing process.

Minimum diameter of bolts to be specified. If possible, all bolts to be of same diameter throughout structure in order to facilitate erection.

Threads of bolts to be outside of members connected, i.e., bearing to be on full section of bolt.

Preferable that not more than three members be held by one bolt.

Punching to be done accurately, but an occasional slight inaccuracy in the matching of holes that may be corrected with a reamer will be tolerated.

Inaccurate punching, which necessitates drifting during erection, not to be accepted.

Foundations

Steel pole footings can be designed either for earth back-fill or for concrete, depending upon the character of the line and other considerations.

The question of adequate foundation design is very important. The maximum load on the poles and the resulting reaction in the soil, together with the soil condition, should be carefully analyzed.

When set in earth, channels and plates are bolted to the main footing members in order to distribute the load over the soil. If set in concrete, then the concrete block distributes the load.

Summary to Replies to Questionnaire

The information printed below is the result of answers to a questionnaire which was sent to all principal utilities of the country. Forty-six replies to the questionnaire were received. Six of these replies indicated the use of steel tubular poles for trolley and street lighting and were, therefore, excluded, leaving forty replies which have been summarized below.

Question: Describe uses of steel poles, giving span, size and number of conductors and voltages of lines supported.

	Transmission	*Distribution*
Number of users reported	24	16
Spans used	300 ft. to 440 ft. 600 ft. to 800 ft. in two special cases.	90 ft. to 180 ft.
Size of conductors	Up to 4/0 copper	Up to 1,000,000 C.M.
Number of conductors	From 3 to 6	Up to 10
Voltage	Up to 120 kv. 33 to 66 kv. most common.	

From the above table it is obvious that steel poles have a wide variety of uses for practically all types of transmission and distribution service. The most common use is for transmission lines of 300 to 440 ft. spans, the poles carrying three or six conductors up to 4/0 in size and at a voltage of between 33 and 66 kv. Two replies indicated spans of 600 to 800 ft. using six conductors at 110 or 120 kv. Distribution lines on steel poles are generally in city streets and consist of secondary lines in conjunction with trolley lines. Six replies indicated distribution lines up to 4400 volts are placed on steel poles.

Question: What is the width of right-of-way and what clearance to ground, adjacent buildings and other structures do you provide for?

Only eleven replies give data on right-of-way. In these cases the width of the right-of-way varies between 10 and 100 ft., the most common width being 30 ft. The balance of the replies indicate that steel poles were placed on streets or highways or on private property with easements. This indicates that steel poles are suitable where right-of-way is narrow either by reason of circumstances or because of cost. Generally the experience of utilities seems to be that a right-of-way for steel poles is much easier to obtain than for towers, and is usually less expensive.

Clearances in general conform with the National Electrical Safety Code.

Question: What crossarms are used on steel poles? Is provision made on the poles for additional arms in the future?

Companies using steel arms	28
Companies using wood arms	8
Companies using both steel and wood arms	2
Companies making no provision for additional arms	21
Companies providing for additional arms	14

Cases where provision is made for additional arms are mainly those where tubular steel poles are employed, or where the voltage is below 4400. There are three cases of provision for additional arms at voltages up to 60 kv.

Question: What reasons led to the use of steel poles?

The following reasons for the use of steel poles are given in the order of their importance, as shown by the replies to the question:

1. Appearance
2. Strength
3. Narrow, economical right-of-way
4. Durability
5. Economy
6. City ordinance required them
7. Safety
8. Freedom from fire hazard.

Question: Describe steel poles used.

Four types are reported in use and are listed below, showing the number of cases in which they are used.

Square with four angles latticed together	17
Channels or two angles latticed together	12
Steel tubular	9
Triangular, U-shaped channels latticed together	3

Question: Are self-supporting poles used for angular loads or are corner poles guyed?

Replies indicating corner poles are guyed	25
Replies indicating poles are self-supporting	15

Of the latter group two companies limit self-supporting poles to a 5 or 10-degree angle, although the majority use heavier construction to carry heavy angles, which would ordinarily require guying.

Question: To what extent has it been necessary to guy steel poles to take care of longitudinal stresses?

No longitudinal guys used	20
Guys each mile or for heavy strains or in marshy ground	8
Guys used for deadends or railroad crossings only	2

Question: Are poles designed to carry torsion from broken wires and from deadend conditions?

Designed to carry torsion due to broken conductors and deadends	18
Designed to carry torsion due to broken conductors only	4
Not designed to carry torsion	11

Question: What factor of safety and what unit stresses were used in the design?

Very little data is available on safety factor and unit stresses.

Out of 12 replies 7 use factor of safety of from 1.5 to 2; 4 use factor of safety of from 2 to 3; 1 uses factor of safety of 4.

The unit stresses employed range from 18,000 to 30,000 lb. per sq. in, the most general figure used being between 18,000 and 20,000. The tendency seems to be to use a low factor of safety of approximately 1.5, and to specify the strength of the pole, thus assuring it will not be overloaded.

Question: Are poles set in earth or concrete?

Set in concrete	31
Set in earth	4
Set in either earth or concrete	5

Question: Is any special protection against corrosion used at the ground line?

Companies reporting no protection used	15
Companies reporting concrete footings used as protection	11
Companies reporting protection by paint or galvanizing only	10
Companies reporting protection by steel collars	5
Companies reporting protection by asphalt or pitch	3

Concrete footings extending several inches above the ground line is the practice referred to in the second group of replies. Trolley poles are the only poles protected by steel collars. Asphalt or pitch is used either on top of concrete foundations which extend above ground, or around the steel when concrete footings are below the surface.

Question: Describe the method used in transporting and setting steel poles.

Shipped same as wood	16
Shipped knocked down	12
No data given	12

In general steel poles are shipped the same as wood, especially for the smaller sizes. The larger size poles as well as the galvanized poles are generally shipped knocked down, while painted poles are assembled as much as possible before shipping.

Set with gin pole or piece by piece	16
Set the same as wood poles	9
Set with derrick	7
No data given	8

In some cases poles are assembled on the ground and are set by using the foundations as a hinge and raising the top to a vertical position by means of pikes.

Question: What is practice in stepping poles?

Replies indicating no steps used	28
Replies indicating steps are used	9
Replies indicating no data	3

In general steel poles are not stepped. This is due either to the ease with which some lattice poles may be climbed or to the fact that tubular steel poles are accessible with ladders.

Question: What special construction has been provided to minimize the possibility of climbing by unauthorized persons?

Replies indicating no precautions taken	28
Replies indicating inaccessible steps (i.e., 8 ft. above ground)	7
Replies indicating wire netting or steel plates were used	5

The last group uses netting or plates to cover up accessible lattice work. In several cases the companies depend entirely upon danger signs to give the necessary protection.

Question: Are all poles equipped with danger signs?

Replies indicating no danger signs used	22
Replies indicating danger signs are used	18

Of the first group, sixteen employ steel poles to carry fairly low voltage wires.

Question: Are steel poles occupied jointly with communication companies? What is voltage limit of electric lines in such joint occupancy?

Steel poles are rarely occupied jointly with communication companies. Only four cases were found in all the replies, the voltage limits of the distribution lines in these cases being between 2300 and 7500.

Question: Are larger insulators used on steel poles than for the same lines on wood poles?

Companies using no larger insulators than for wood poles	25
Companies using larger insulators	13
Companies giving no data	2

Practically the only cases where larger insulators are used is in suspension type construction at fairly high voltages, in which cases an extra unit is added.

Question: Are poles protected by painting or galvanizing?

Companies protecting poles with paint......	22
Companies protecting poles with galvanizing..	11
Companies protecting poles by either paint or galvanizing, depending on conditions......	5

The general practice seems to be to protect steel poles by means of paint. Galvanizing is gradually becoming more popular, however, on account of its long life under proper conditions.

The maintenance cost of galvanized structures is considerably less than that of painted structures, which must be repainted every two or three years. Under some atmospheric conditions, however, galvanizing is out of the question; as along the sea coast, in railroad yards and terminals, and in heavy industrial districts where the air is charged with sulphur fumes, as for instance in the Pittsburgh district. Under such conditions, the life of galvanizing is very short and a good paint job will outlast it. A pitch paint on a lead base has been found very satisfactory in such cases.

Question: What has been your experience with regard to deterioration of steel poles? Any data relative to the life of the protective covering on galvanized poles will be of special interest.

Galvanizing has been reported which is 30 years old and is still in good condition. Life of paint is reported to be from two to five years. Some cases of deterioration of tubular poles have been reported. Replies indicate the necessity of a protective covering to prevent deterioration in the vicinity of the ground line.

Question: What is practice for grounding poles?

The following tabulation indicates the practice in grounding poles:

Companies grounding poles with plates or rods buried or driven into the earth...........	14
Companies reporting no grounds are used...	11
Companies reporting poles are self-grounding being set in earth or having the lower ends extending through the concrete footing....	10

Question: Describe any special practices or unusual application of steel poles in connection with transmission or distribution lines.

Very few special uses of steel poles are given. The most common seems to be as substation towers; however, there are only three cases of this sort. One reply indicates that the use of steel poles for 120 kv. construction is unusual, this type of line being usually carried on towers. One reply states that a steel pole was used for transportation of a two-circuit 110-kv. line by using a vertical bus and four deadends.

One company reports the use of 5 in. expanded steel poles on curb line construction, using four such poles to form a platform supporting 3-250 kv-a. transformers.

An unusual combination steel and concrete pole has been developed in Australia. The pole consists of two standard steel channels with flanges facing each other, separated by bolts at intervals, the space between the channels being filled with concrete. The pole is much lighter than a reinforced concrete pole of equivalent strength, and is but slightly heavier than wooden poles which it takes the place of. The pole develops great strength due to the supporting action of the concrete between the channels. The pole has only about 50 per cent of its steel exposed, and therefore requires less painting than an ordinary steel pole. Poles of this type have been made which are 99 ft. in height, for flood lighting service, 50 ft. poles having been made for transmission line service.

Question: What is public's reaction toward steel poles as regards appearance?

Of the replies received on this subject, the public opinion of steel poles seems to be favorable, on account of their good appearance.

Replies indicating no opinion given by public.	20
Replies indicating favorable opinion........	13
Replies indicating no serious objection......	4
Replies indicating public does not like them, claiming they look clumsy...............	2
Replies reporting poles were installed because of city ordinance.......................	1

In concluding the report on steel poles the Committee wishes to acknowledge the valuable assistance of Mr. E. A. Van Deusen of the Central Hudson Gas & Electric Corporation, who contributed the discussion of the general considerations relative to the use of steel poles.

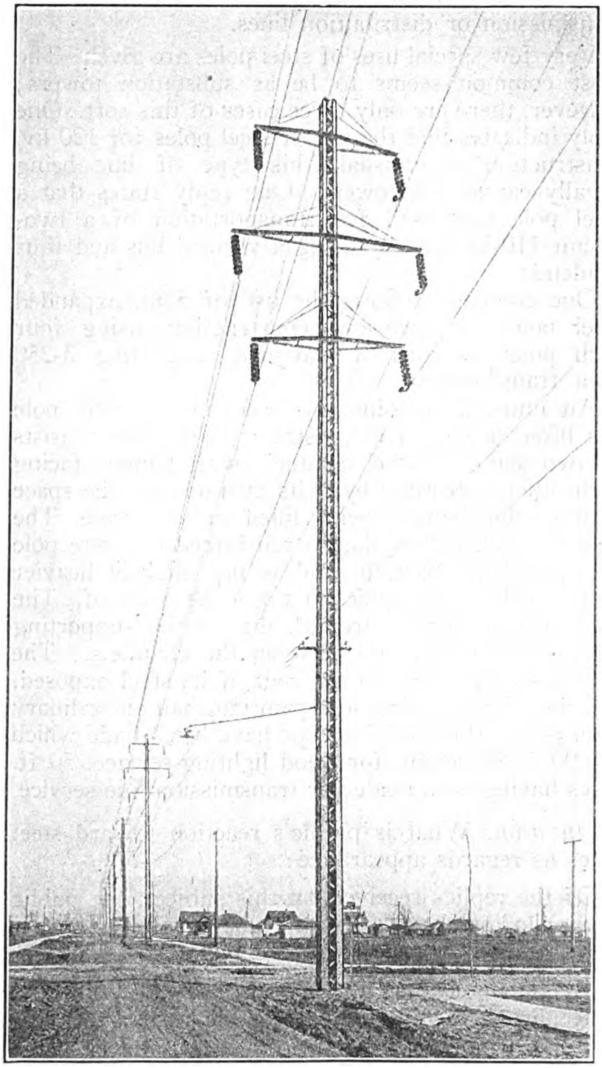

FIG. 1—120 KV. 2 CIRCUIT 3/0 COPPER CONDUCTORS AND GROUND WIRE. POLE HEIGHT, 85 FT.; WEIGHT, 10,000 LB. SPAN LENGTH, 300 FT. DETROIT EDISON CO.

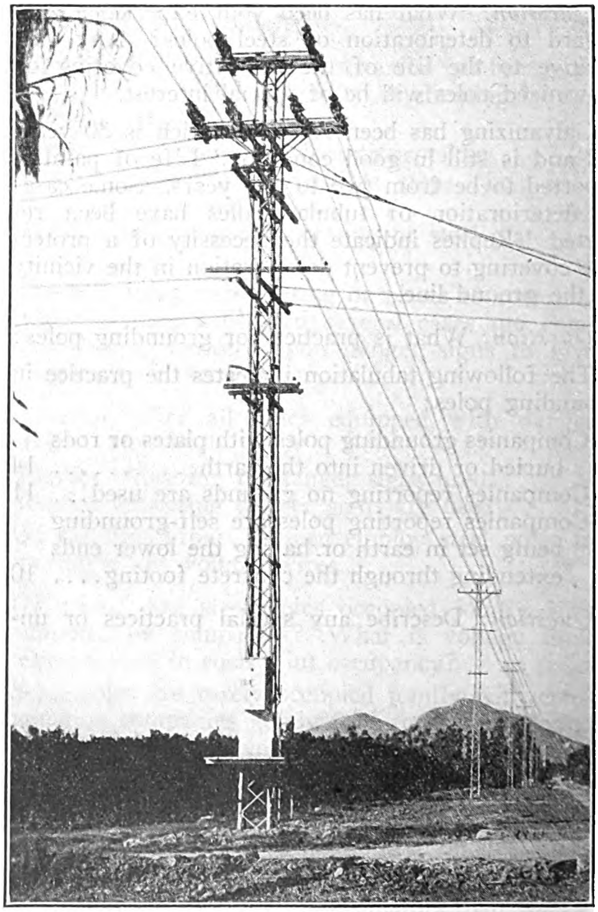

FIG. 2—CORNER POLE WITH 3-POLE AIR BREAK SWITCHES IN THE TWO THREE-PHASE CIRCUITS. 66 FT. HIGH. TOTAL WEIGHT, 1100 LB. THE SOUTHERN SIERRAS POWER CO.

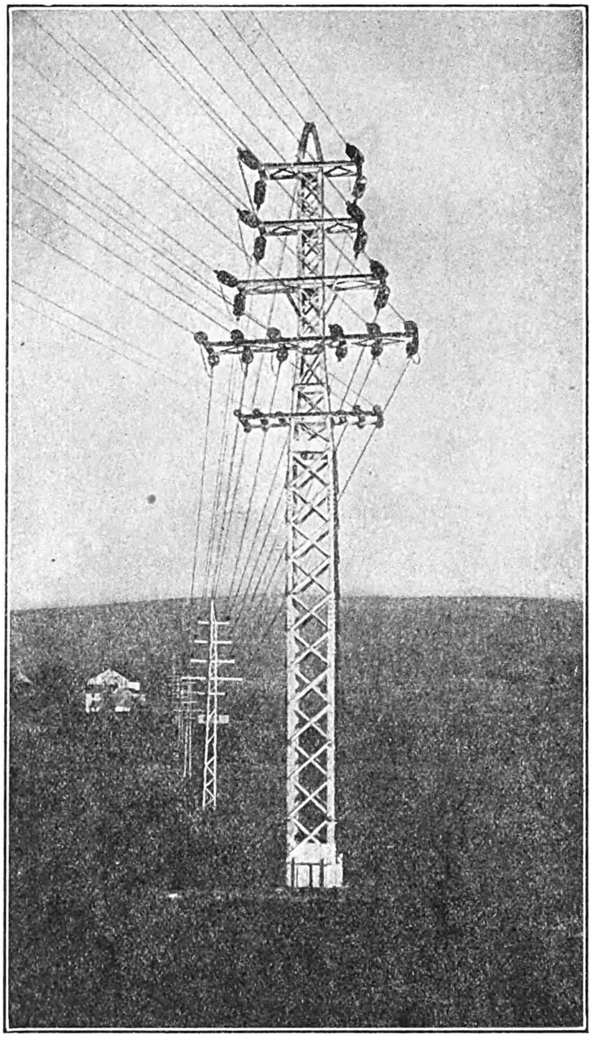

FIG. 4—STANDARD STEEL POLE FOR SMALL ANGLES, NOT TO BE GUYED. PENN CENTRAL LIGHT & POWER CO., ALTOONA, PA.

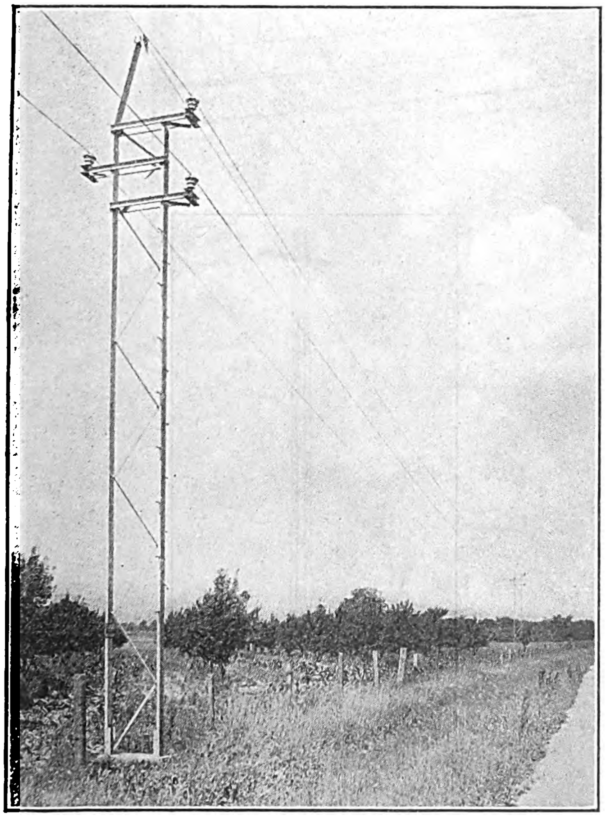

FIG. 3—33 KV. 3-3/0 A.C.S.R. AND A 7/16 IN. STEEL GROUND WIRE 440 FT. SPAN. ROCHESTER GAS & ELECTRIC CORP., ROCHESTER, N. Y.

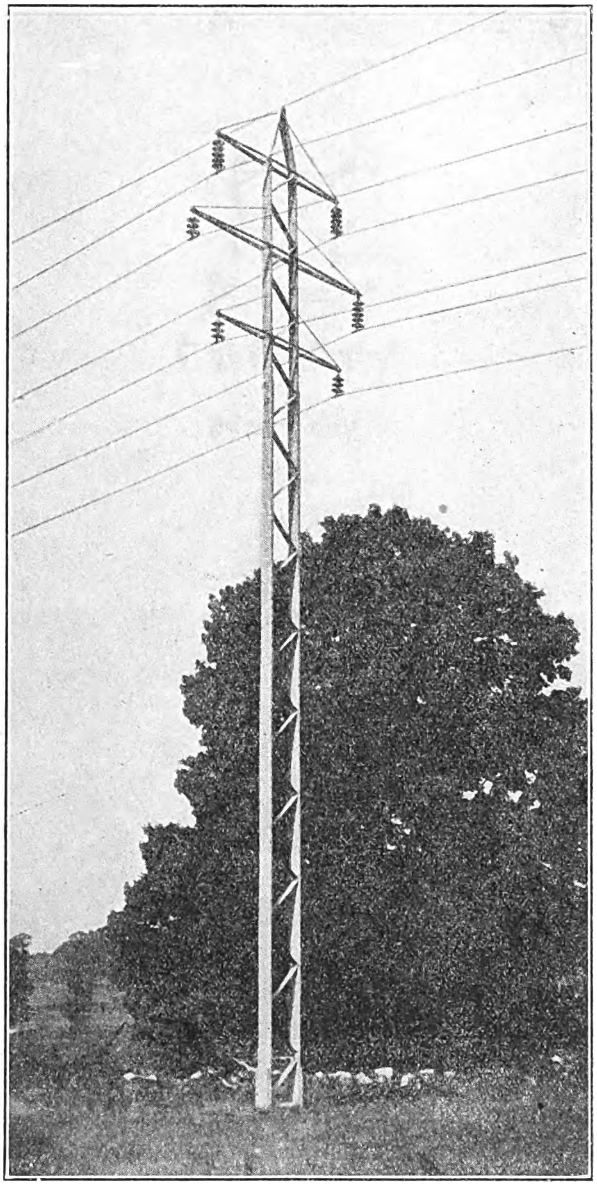

FIG. 5—STEEL POLE MADE UP OF TWO CHANNELS SEPARATED BY A CRIMPED STEEL BAR RIVETED OR WELDED TO THE CHANNELS. ARCHBOLD BRADY CO., SYRACUSE, N. Y.

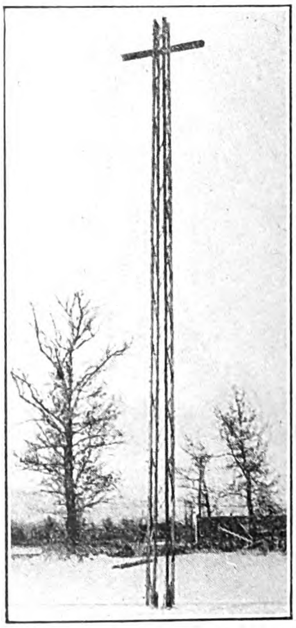

FIG. 6—STEEL POLE MADE UP OF EXPANDED ANGLES WALTER BATES STEEL CORP., GARY, IND.

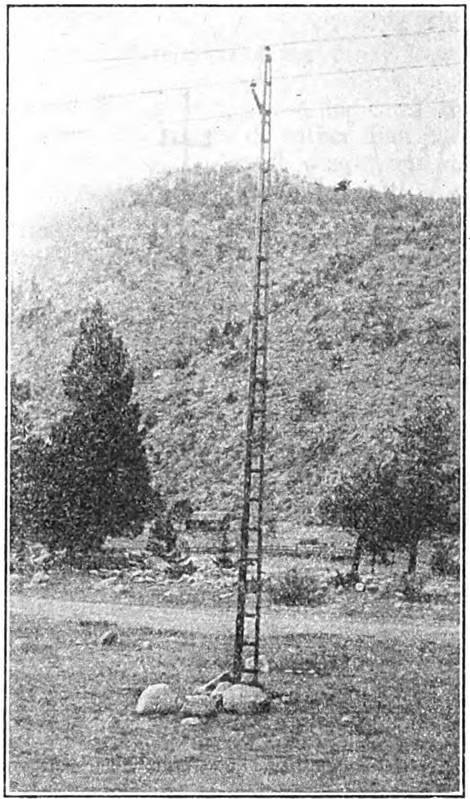

FIG. 8—TRIPARTITE POLE MADE UP OF THREE U-SHAPED MEMBERS HELD TOGETHER BY TRIANGULAR SPACERS. 11 KV. LINE, 3 CONDUCTORS, NO. 1 COPPER, 400 FT. SPAN. PUBLIC SERVICE CO. OF COLORADO, IDAHO SPRINGS, COLO.

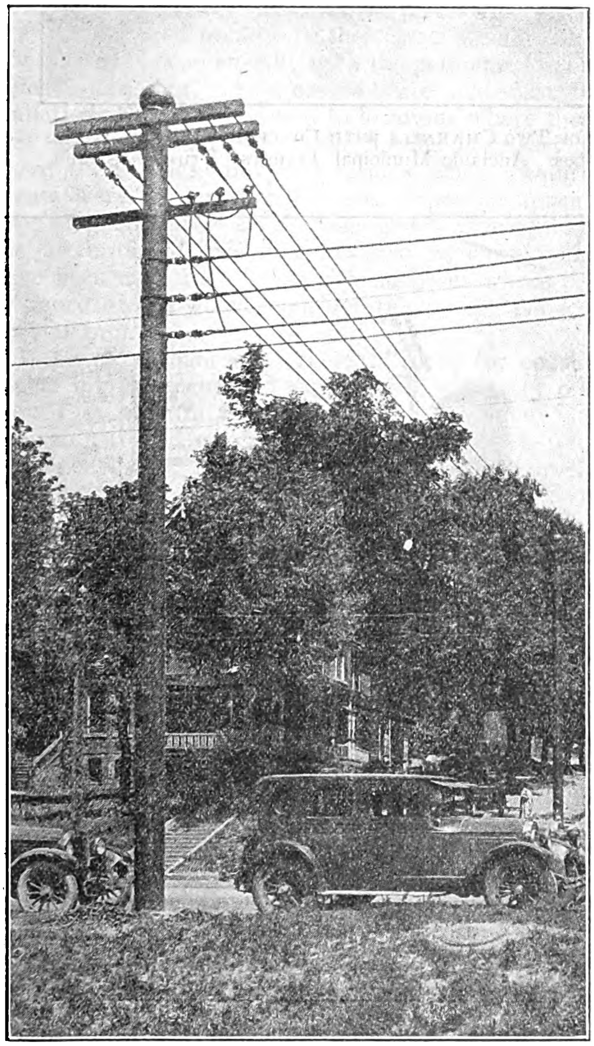

FIG. 7—TUBULAR STEEL POLE USED BY UTAH POWER & LIGHT CO., SALT LAKE CITY, UTAH.

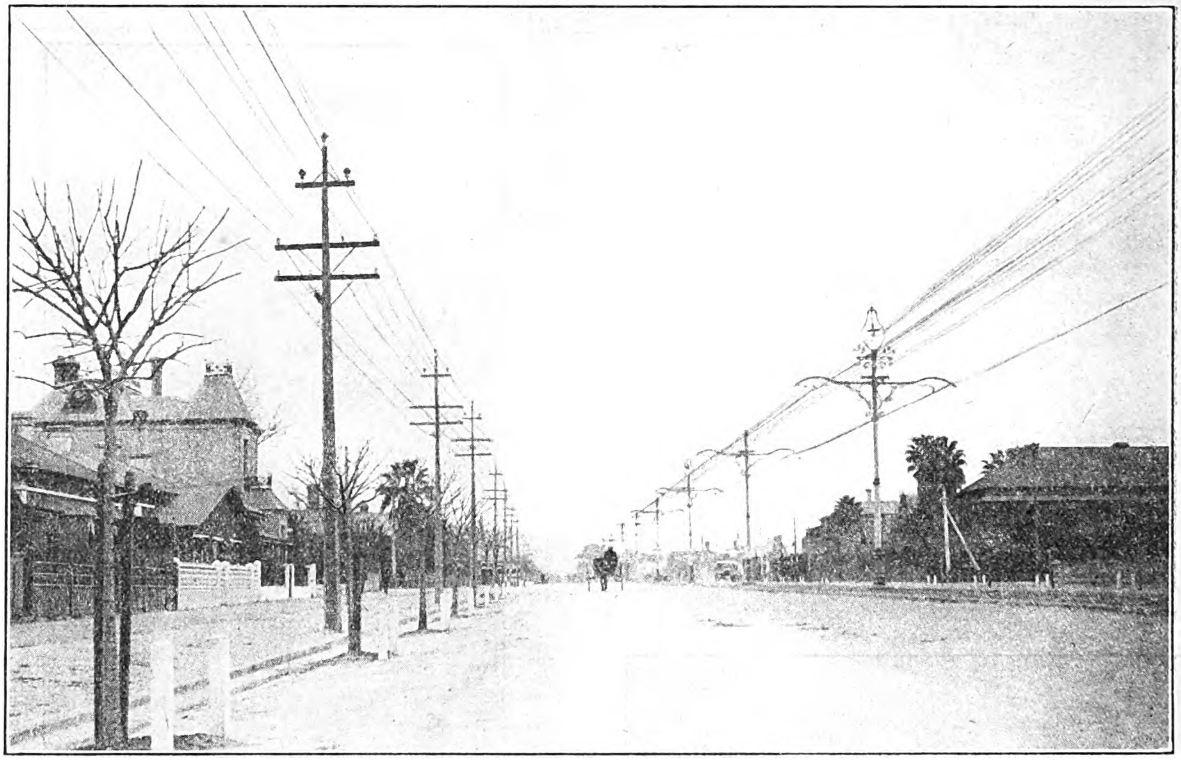

FIG. 9—COMBINATION STEEL AND CONCRETE POLE MADE UP OF TWO CHANNELS WITH CONCRETE BETWEEN THEM. 36 ft. pole supporting 11,000 volt, 7,000 volt and 400 volt lines. Adelaide Municipal Tramway Trust, Australia.

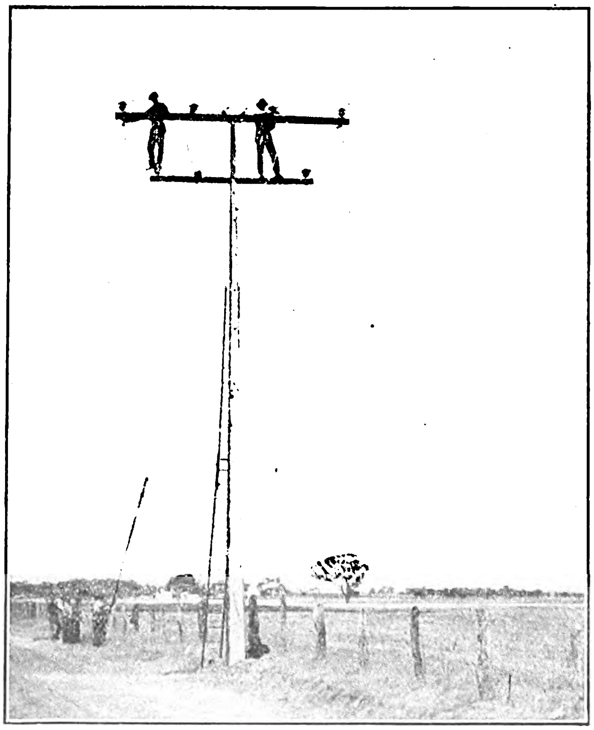

FIG. 10—COMBINATION STEEL AND CONCRETE POLE USED IN AUSTRALIA. THIS POLE IS FOR SUPPORTING 6 CONDUCTORS WITH 600 FT. SPAN.

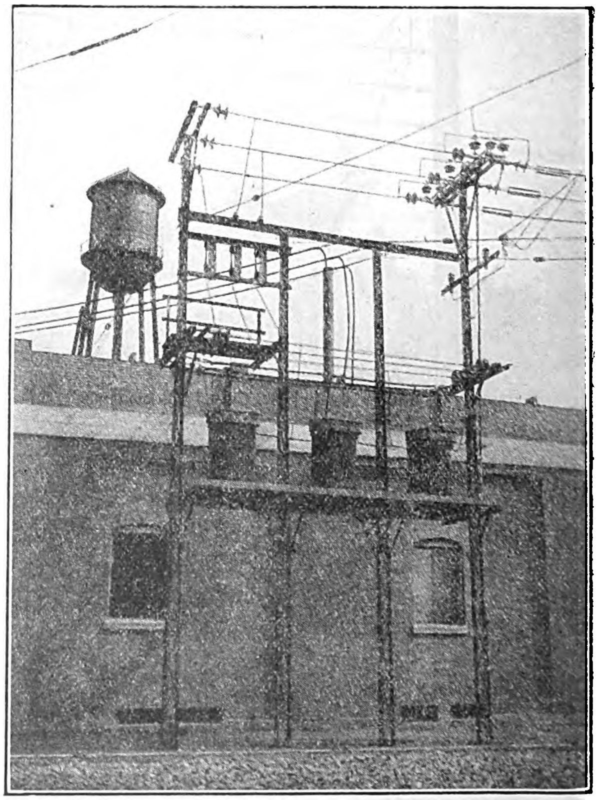

FIG. 11—CURB LINE CONSTRUCTION. THIS TYPE OF CONSTRUCTION HAS BEEN USED WITH 5 IN. POLES TO SUPPORT THREE 250 KV-A. TRANSFORMERS. NASHVILLE RAILWAY & LIGHT CO., NASHVILLE, TENN.

THE MANUFACTURE AND USE OF CONCRETE POLES

The increase in price of wood poles within the last ten years has caused most of the large pole using companies to consider the use of substitutes. Among the most interesting of these is reinforced concrete poles. The electric railway companies of this country have made considerable use of this type of pole, and it is coming into extended use in Europe, where the pressure for a timber substitute is even greater than in this country. There has been comparatively little use of reinforced concrete line poles by power companies in America, but the subject will undoubtedly be a very live one in the near future.

Information concerning the manufacture and use of concrete poles has been collected and summarized in this report with the hope that it may be of value, both to those companies already manufacturing concrete poles, and to those who wish to investigate their possibilities for future construction.

Replies to the questionnaire indicate that concrete poles have not been considered adaptable to general use in a distribution system. Most of the concrete poles now in use were made at the places where they are installed, and because of their great weight could not be moved economically with the equipment available in the past. Answers indicate that past installations have been limited to locations where there was good assurance it would not be necessary to move these poles, and to locations where requirements were for greater strength, improved appearance or longer life. In all cases which have come to the attention of the subcommittee, concrete poles have been used for distribution purposes where one or more of the above considerations were particularly urgent.

It seems probable that there is room for considerable improvement in the methods at present employed in manufacturing concrete poles. The use of waterproofed concrete and of rustproofed reinforcement may prove decidedly beneficial in increasing the life of reinforced concrete poles.

Over 300 questionnaires were sent out. Replies were received from approximately 200 representative public utility companies and the following information was gathered from these replies:

Question: Are concrete poles or standards used for any purpose?

Companies using concrete poles......	33
Companies not using concrete poles.	169
Total replies....................	202

List uses of concrete poles.

Are concrete poles manufactured or purchased?

If purchased give name of manufacturer.

	Mfs.	Purchased	Mfg. or Pur.	Total
Users of line poles..	11	5	..	16
Users of street lighting poles	5	9	5	19

Line poles were used for transmission, distribution, trolley, telegraph and street lighting purposes. All information furnished seemed to indicate a tendency to use concrete poles for fairly low voltage (600 volts).

The tabulation shown above indicates that line poles are being manufactured rather than purchased, probably because of the great weight and difficulty encountered in shipping them.

Question: Describe method of manufacture used, illustrating by photographs, if possible. Specifications and descriptions of procedure are especially important. Describe construction of concrete poles —drawings, dimensions, weights and method of reinforcing are especially important.

Virginia Electric & Power Co., Richmond:

Type of pole—Solid square with beveled corners 30 ft., 35 ft. and 40 ft. long, 8 in. top and taper 1 in. in cross section per 10 ft. of length.

Reinforcement—16 ½-in. square deformed steel bars 1 in. below surface, lengths as follows:

Size of pole........	30 ft.	35 ft.	40 ft.
4 rods	30 ft.	35 ft.	40 ft.
8 rods	25 ft.	30 ft.	35 ft.
4 rods	20 ft.	25 ft.	30 ft.

Forms—Wood, clamped to level concrete foundations, forms oiled with paraffin oil and mica dust.

Mix—1:1½:2 using washed sand and washed ¾ in. gravel, only enough water is used to mix properly.

General Procedure—All work is done outdoors, concrete is placed in 3 layers to allow placing of rods which are not bound together. Two men spade and tamp concrete with wooden paddles, this is *very important.*

Curing of Pole—In hot weather poles are covered. Curing wet for few days gives best results.

Virginia Electric & Power Co., Norfolk:

Type of Pole—Solid square with beveled corners, 30 ft., 35 ft. and 40 ft. long, 6 x 8 in. top, taper 1.5 in. in 10 ft. and 2 in. in 10 ft., giving square base.

Reinforcement 24 ⅝-in. deformed square bars buried 1½ in. below surface and kept 1 in. from end of pole. Lengths are given below:

Size of pole....	30 ft.	35 ft.	40 ft.
4 rods..........	29 ft. 10 in.	34 ft. 10 in.	39 ft. 10 in.
4 rods..........	23 ft.	28 ft.	33 ft.
8 rods..........	18 ft.	23 ft.	28 ft.
4 rods..........	11 ft.	11 ft.	11 ft.
4 rods..........	6 ft.	6 ft.	6 ft.

Mix—1:2:3, using gravel. No other information furnished.

Rochester Gas & Electric Corporation:

Type of Pole—Hollow square with beveled corners 22 ft., 25 ft. and 30 ft. long, 7 in. tops with taper of 1.66 in.-1.8 in. in 10 ft. length.

Reinforcement—8 deformed square steel bars held together by bands at intervals. Rods are buried ¾ in. below surface of pole. Lengths are given below:

Size of pole.......	22 ft.	25 ft.	30 ft.
4 ⅝-in. rods......	22 ft.	24 ft. 6 in.	29 ft. 6 in.
4 ¼-in. rods......	14 ft. 6 in.	12 ft.	18 ft.
Number of bands	9	9	14

Forms—Wood covered with sheet metal, with hollow steel core for the center opening, cores are tapered approximately the same as the pole, leaving from 2½ to 3 in. of concrete between the hollow center portion and the face of the pole. Lengths of cores are given below:

22 ft. pole	14 ft. core
25 ft. pole	17 ft. core
30 ft. pole	23 ft. core

The forms are oiled with a mixture of form oil and lard oil.

Mix—1:2¼:2¼, using bank run sand and washed crushed limestone ⅜ in. size. Enough water is used to give a 7 or 8 in. slump, which gives the concrete a compressive strength of about 2800 lb. per sq. in. in 28 days. The fineness modulus of the mixed aggregate is 4.2.

General Procedure—All work is done indoors in a special plant. The reinforcing cage is held in place by resting on cores for pole stop holes; these holes are later plugged up. Concrete is placed by dumping from a bucket carried by traveling crane.

Curing of Poles—Poles dry for 20 hours inside the plant, after which they are piled outside, where they lie for at least 30 days before being used.

Weight of poles:

22 ft.	1650 lb.
25 ft.	1850 lb.
30 ft.	2400 lb.

Kisse Pole (German Design)

Type of Pole—Shaped like a three-pointed star with hammer-shaped ends on each arm, 20 ft. to 60 ft. or more in length, taper varying for various poles.

Reinforcement—13 round steel rods, four in each arm and one in the center. Rods are of smaller size at top of pole than at bottom, to conform with decreasing bending modulus. Rods are butt welded together and spaced by triangular rings and bound together with spiral windings spaced 2 in. apart. Triangular rings about 3 ft. apart space the three legs of the pole and furnish climbing steps. The rods are spaced 0.59 in. from the surface.

Forms—Horizontal folding forms, with electric hammers arranged to vibrate them while concrete is being placed, giving very dense concrete.

Weights—See Table I.

General: In the mixing of the concrete used for these poles trass is used as an admixture to give increased strength and density as well as improving the weather resisting qualities.

TABLE I

WEIGHT OF KISSE POLES

Length in Feet	Strength of Pole				
	4000 lb.	3000 lb.	2000 lb.	1500 lb.	1000 lb.
20	1700 lb.	1350 lb.	990 lb.	880 lb.	680 lb.
25	2250	1830	1370	1175	900
30	2900	2400	1840	1600	1225
35	3700	3000	2330	2100	1570
40	4500	3700	2900	2600	1950
45	5400	4500	3560	3200	2425

Westinghouse Hollowspun Poles:

Type of Pole—Hollow round from 20 ft. to 45 ft. long, 5 3/5 to 8¼ in. tops, taper 2½ in. per 10 ft. of length.

Reinforcement—A steel cage composed of rods and bands wired together with a spiral wired to the rods, spacing of spiral varies with the strength of pole.

Forms—Cast iron split so that reinforcing can be placed inside, forms are capable of being revolved in horizontal position.

Mix—1:1:2, using sand and gravel by weight. Fineness modulus of aggregate is 4.5, enough water is added to give workable mix, the minimum time of mix being 5 minutes.

General Procedure—The reinforcing cage is placed in the form and supported by concrete buttons which hold rods 1 in. from surface. With the form in a vertical position, a definite amount of concrete is added, the form is rotated in a horizontal position for 10 or 15 minutes, after which the water is allowed to run out of the hollow center position, when it has collected, the resulting concrete is dense and dry, insuring high compressive strength.

Curing of Concrete—Poles are cured 3 hours in a steam pit at 150 to 170 deg. Fahr., then removed from the form and cured wet 14 days. After 28 days the pole is ready for shipment.

Weight—See Table II.

TABLE II

TECHNICAL DATA FOR THE VARIOUS TYPES OF HOLLOWSPUN CONCRETE POLES

Class No.	Length of Pole, Ft.	Diameter of Pole		Weight of Pole, lb.	Recommended Working Load Safety Factor —3.0			Maximum Working Load Safety Factor —1.5			Calculated Elastic Ult.	
		Top, In.	Butt, In.		Load, Lb.	Deflec., In.	Max. Bending Moment, Ft. Lb.	Load, Lb.	Deflec., In.	Max. Bending Moment, Ft. Lb.	Limit, Lb.	Load, Lb.
750	30	5¾	13¼	2,100	750	5.8	16,800	1,500	12.7	33,800	1,875	2,250
1000	30	7	14½	2,800	1,000	5.05	22,500	2,000	12.63	45,000	2,500	3,000
1500	30	7	14½	2,900	1,500	6.1	33,800	3,000	14.2	67,500	3,750	4,500
2000	30	8¼	15¾	3,600	2,000	4.68	45,000	4,000	11.25	90,000	5,000	6,000
750	35	5¾	13¼	2,500	750	6.83	20,200	1,500	16.4	40,500	1,875	2,250
1000	35	7	14½	3,600	1,000	5.53	27,000	2,000	14.6	54,000	2,500	3,000
1500	35	7	14½	4,000	1,500	7.27	40,500	3,000	16.58	81,000	3,750	4,500
2000	35	8¼	15¾	4,900	2,000	6.78	54,000	4,000	15.43	108,000	9,000	6,000
1250	45	7	18¼	5,900	1,250	8.91	45,000	2,500	22.13	90,000	3,150	3,750
1500	45	7	18¼	5,900	1,500	9.3	54,000	3,000	23.72	108,000	3,750	4,500
2000*	45	8¼	19½	7,100	2,000	9.6	72,000	4,000	22.9	144,000	5,000	6,000
2000†	30	5¾	13¼	2,100	750	3.93	16,800	1,500	10.27	33,800	1,875	2,250

Note: All deflections are on average of 3 tests.
*Only one test.
†Poles taken from stock one year old.
Ground line to butt end. 30′0″—5′6″
35′0″—6′0″
45′0″—7′0″

Adirondack Light & Power Co., of Schenectady:

Type of Pole—Solid square, 30 and 35 ft. lengths, taper 1 in. in 10 ft., with a 6 in. top.

Reinforcement—Twisted steel rods 1 in. below surface held by bands.

Size of pole	30 ft.	35 ft.
4 ⅝-in. rods	30 ft.	35 ft.
4 ½-in. rods		25½ ft.

Forms—Wood.
No other information furnished.

Philadelphia Electric Co:

Type—Solid round 40 ft. long, 8 in. top, taper 1¼ in. per 10 ft. of length.
Reinforcing—8 ¾-in. deformed bars.
Weight—3700 lb.

Toronto Hydro Co.:

Type of Pole—Solid square, beveled corners, 24 ft. long, 5 in. top, 8 in. bottom.
Reinforcement—4 ⅜-in. twisted steel rods ¾ in. from surface. Held together by 5 sets of diagonal braces. Held in forms by wire support.
Forms—Wood.
Mix—1:2:4, using sand and crushed stone ¼—¾ in. size.
Weight—1100 lb.

Pennsylvania Railroad:

Type of Pole—Solid square 35—55 ft. long, taper 1 in. for 10 ft. length.
Reinforcement—¾—1⅛ in. rods, depending on size of pole, banded together to form skeleton frame.
Weight—35 ft., 5,300 lb.
55 ft., 17,300 lb.

Question: What provisions are made during manufacture for crossarms, guys and other attachments?

Crossarms are provided for by gains, holes or bronze plates, cast in poles. Extra holes provide for other attachments. Holes are cast by means of cores of steel or paper. When paper tubes are used they are left in place after manufacture.

Question: Is provision made for removing pole steps or are they inserted at the time pole is cast?

Steps are not used in two-thirds of the cases, only one company casts steps in the pole, all others cast holes for removable steps but seldom use them, because the work is usually done from ladders and tower wagons.

The Kisse pole uses the spacer rings for steps. Although these rings are three feet apart, climbing is said to be easily accomplished by using one's knees to climb from one step to the next.

Question: What is the number of concrete poles used each year for each purpose?

Only five users could give data on yearly use of concrete poles. Eleven users have not made or purchased poles for a period of from 3 to 14 years. Yearly production is given below for various companies.

	Per Year
Bureau of Electric Service, Milwaukee	600
Rochester Gas & Electric Corp	1,600
Virginia Electric & Power Co., Richmond	55-310
Virginia Electric & Power Co., Petersburg	50
Virginia Electric & Power Co., Norfolk	35

Question: What has been your experience with regard to deterioration of concrete poles? Describe in detail, giving causes and any remedies adopted.

Twenty users reported on deterioration experience with various kinds of concrete poles. Thirteen users reported poles satisfactory, showing no deterioration in from 5 to 17 years. Two poles are reported in Schenectady which are 30 years old and are in good condition. Seven users reported some deterioration, the causes being as follows:

1. Steel reinforcing too close to the surface, i.e., less than ¾ in.
2. Porous concrete due to the use of too much water at time of mixing.
3. Voids in concrete due to insufficient working or puddling of concrete after placing in forms.
4. Improper curing, i.e., allowing poles to dry instead of keeping them wet for the first ten days after manufacture.
5. Overloading, which is shown up by the appearance of evenly distributed cracks across the pole on the tension side, usually at or slightly above the ground line.

The first 4 items all cause spalling or cracking of concrete away from the reinforcing. When cracking has commenced, frost action causes progressive deterioration.

The remedies for these causes of deterioration appear to be:

1. Steel should be at least ¾ in. below the surface, preferably 1 in.
2. Concrete mixture should be waterproof, this is done by designing the mix for a compressive strength of 3000 lb. per sq. in.
3. Concrete should be worked and puddled after placing in forms, to prevent voids.
4. Poles should be cured damp or wet for at least 10 days after initial set; this alone strengthens the concrete 75 per cent over dry unprotected curing.
5. Poles should not be loaded beyond the strength for which they are designed.

Question: Describe method used in transportation and setting concrete poles. Give depth of setting for various heights.

Concrete poles are generally transported on trailers, similar to wood poles. Long poles may have a stiff, wooden member placed between trailer and truck to prevent excessive deflection. Eight of the users reported poles are set by using a gin pole or derrick. Five of the users reported poles are set by the same method as used for wood poles. Depths used for setting concrete poles vary from 1/5 to 1/7 the pole height, the majority of the users set poles about 1/6 the pole height. One user reported 6 in. greater depth for concrete poles than for wood.

Question: Are any special precautions used by linemen working on concrete poles?

In the majority of cases no special safety precautions are used except that work is generally done from ladders or tower wagons. A man working on a pole is considered to be in contact with a fair ground.

Question: Are wooden arms used?

Seven of fifteen users of concrete poles use wooden arms. The remainder use the following:

5 use no arms,
1 uses 5 ft. channel arm,
1 uses concrete crossarm,
1 uses 10 pin crossarm.

Question: Are larger insulators used on concrete poles than for the same lines on wood poles?

Fifteen of sixteen users do not use larger insulators on concrete poles than on wood poles.

Question: Can you give data on actual strength of concrete poles used based on tests to destruction?

Deflection curves for two types of Westinghouse Hollowspun poles, furnished by the Bureau of Electric Service of Milwaukee, are included in this report. Tests conducted at Milwaukee using Westinghouse Hollowspun are described on pages 165-167 of the July, 1927, issue of "Concrete Highways and Public Improvements." Two sets of curves and one table of test data are included in this report. Curves showing results of tests on 22 ft. and 25 ft. hollow square concrete poles made by the Rochester Gas & Electric Corporation are included in this report. All test data indicate that the strength of the pole is entirely dependent upon the steel reinforcement. As long as the elastic limit is not exceeded, the pole will return from any given deflection without apparent damage to the pole.

An investigation conducted by the Power Distribution Committee of the American Electric Railway Engineering Association brings out the following facts in connection with the strength of concrete poles:

1. Failure of a pole is always due to stretching of the reinforcing rods of the tension side.
2. A failure is always preceded by the appearance of hairline cracks in the concrete on the tension side, at rather frequent intervals from the ground line up.
3. It is advantageous to use a high grade of reinforcing steel to secure the maximum tensile strength.
4. Plain round reinforcing rods are essentially as satisfactory as twisted or other rough rods, because, in general, the rods will elongate before they slip in the concrete.
5. A larger number of small rods is preferable to a small number of large rods, as a better distributed reinforcement may be secured for a given amount of steel, and a better bonding contact surface is presented to the concrete.
6. The reinforcement need not be uniform throughout the length of the pole, but may be stepped off as the top of the pole is approached.
7. A pole with uniform reinforcement will break at the ground line, while one with tapered reinforcement will break at some point above the ground, depending upon the taper of the reinforcement.
8. A concrete pole has an element of safety in it, as a failure of the pole will not, in general, allow it to fall to the ground. It is difficult at times to pull over a pole after failure, even though it is inclined at a large angle from the vertical.

Question: Are concrete poles occupied jointly with any communication companies? What is voltage limit for electric lines in such joint occupancy?

Five of fifteen companies report joint occupation with communication companies, although two of these were fire alarm and police signal systems. The voltage limits for three cases of joint occupancy are 300 volts, secondary, 120-240 volts and 2300 volts.

Question: Has the use of concrete poles enabled you to defer underground construction in cities and villages? Explain how.

Three of fourteen companies report that concrete poles have helped defer underground construction by providing an overhead distribution system of satisfactory appearance. The majority report that concrete poles have not helped to defer underground construction.

Question: What are relative costs on wood and concrete poles?

Concrete poles appear to cost 1½ to 3 times as much as wood poles. One user reports cost as $30 more than wood poles, another reports from 3 to 15 times the cost of wood poles. Westinghouse Hollowspun poles are reported to cost approximately the same as tubular steel poles.

Table III indicates the estimated cost of furnishing Kisse poles, costs are estimated inasmuch as a pole plant has not yet been built in this country.

TABLE III

ESTIMATED COST OF KISSE POLES F.O.B. NEW YORK CITY

Length in Feet	Strength				
	4000 lb.	3000 lb.	2000 lb.	1500 lb.	1000 lb.
20	$28.50	$25.00	$20.50	$17.50	$15.00
25	39.00	34.50	28.00	24.00	22.00
30	51.50	44.00	36.50	30.50	28.00
35	64.50	56.50	46.00	39.00	36.00
40	78.00	69.50	55.50	49.00	43.00
45	97.00	82.50	66.00	60.00	53.00

One eastern company reports the cost of hollow square reinforced concrete poles as follows:

Size	Cost
22 ft.	$16.10
25 ft.	18.40
30 ft.	21.85

Question: Why do you consider concrete poles superior to steel or wood poles?

Reasons for considering concrete poles superior to wood or steel poles are given below:

1. Good appearance.
2. Durability if properly manufactured and loaded.
3. Low maintenance.

One user reports concrete poles are unsuitable for use in city streets because of changing street lines, the poles being unhandy to move. Our reply from Fall River, Mass., reports that concrete poles cannot be used because of a State law which states that any type of pole other than wood which carries wires of over 500 volts must be marked "Dangerous."

In the design and manufacture of concrete poles the following factors should be considered.

1. It is an advantage to use high grade reinforcing steel.
2. Poles should be designed so that the maximum load carried will be below the elastic limit.
3. The concrete used gives the pole its enduring properties, and the design and manufacture of the mixture should be carried out carefully. A mixture designed for 3000 lb. per sq. in. compressive strength will be watertight and will not be affected by the elements. The materials used should be of the best, and placing and curing of the concrete should be done with the greatest care.

In conclusion, it is apparent that concrete poles properly designed and manufactured give a very satisfactory product with an indefinitely long life. To insure successful manufacture of concrete poles it is recommended that "Specifications for the Manufacture of Reinforced Concrete Poles" be consulted. These specifications were the work of the Power Distribution Committee of the American Electric Railway Association in 1925. Also for successful production and manipulation of concrete, it is suggested that "Design and Control of Concrete Mixtures" (Second Edition) be consulted. This practical pamphlet is published by the Portland Cement Association. The principles covering the design of concrete poles have been collected and published by the American Electric Railway Engineers Association.

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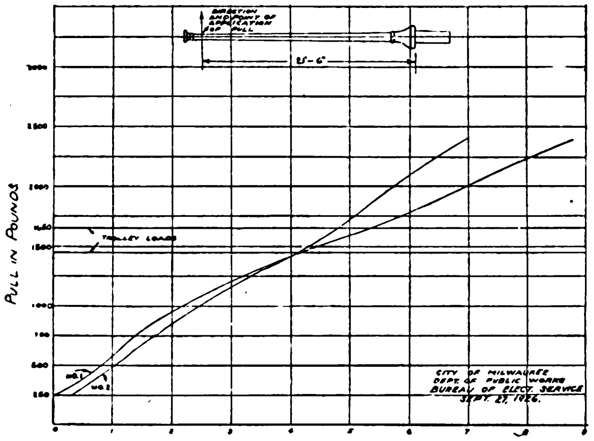


FIG. 12—DEFLECTION TEST ON TYPE "K T" HOLLOW-SPUN CONCRETE POLES.

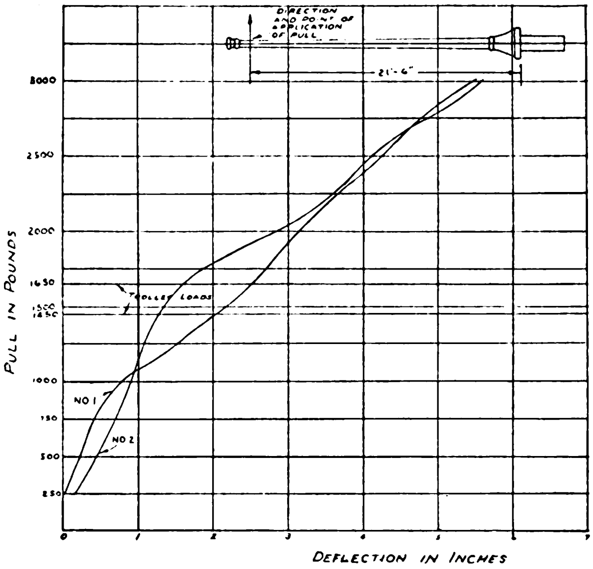


FIG. 13—DEFLECTION TEST ON TYPE "K Q" HOLLOW-SPUN CONCRETE POLES.

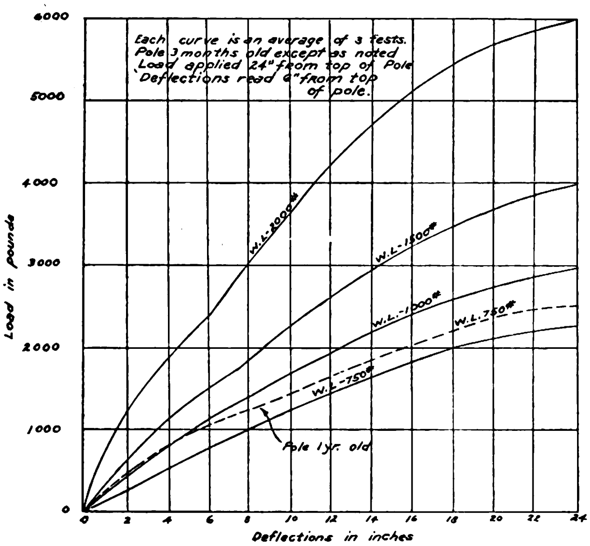


FIG. 14—DEFLECTION CURVES FOR 30 FT. CONCRETE POLES WITH RECOMMENDED WORKING LOADS AS SHOWN. Poles over a year old have increased in strength and show less deflection for corresponding loads. Tests made by Westinghouse Electric & Mfg. Co. at Milwaukee, from April 18 to May 12, 1927.

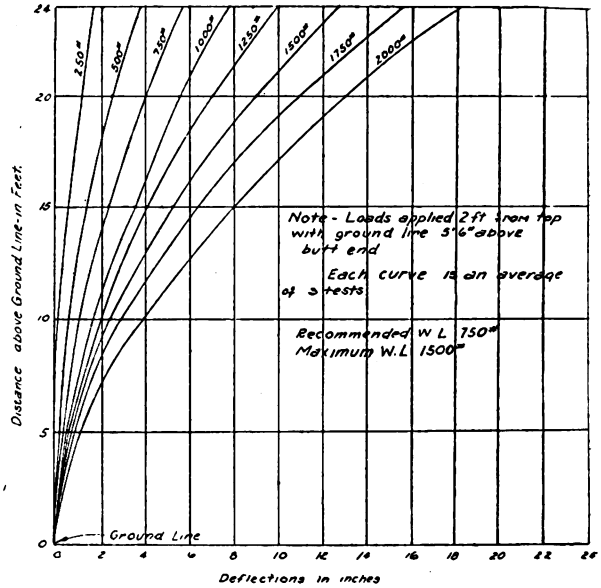


FIG. 15—GRAPHIC REPRESENTATION OF 30 FT. CONCRETE POLE WITH RECOMMENDED WORKING LOAD OF 750 LB. Note uniformity with which pole bends under each 250 lb. loading. Tests made by Westinghouse Electric & Mfg. Co. at Milwaukee from April 18 to May 12, 1927.

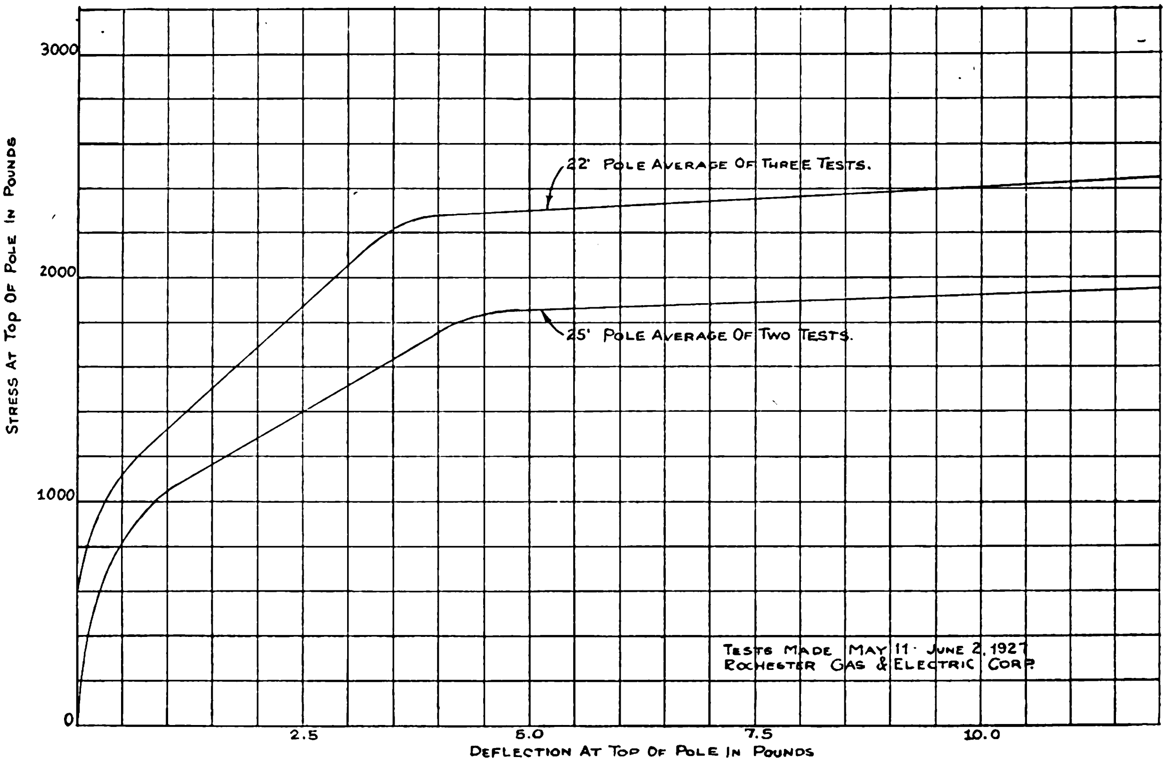
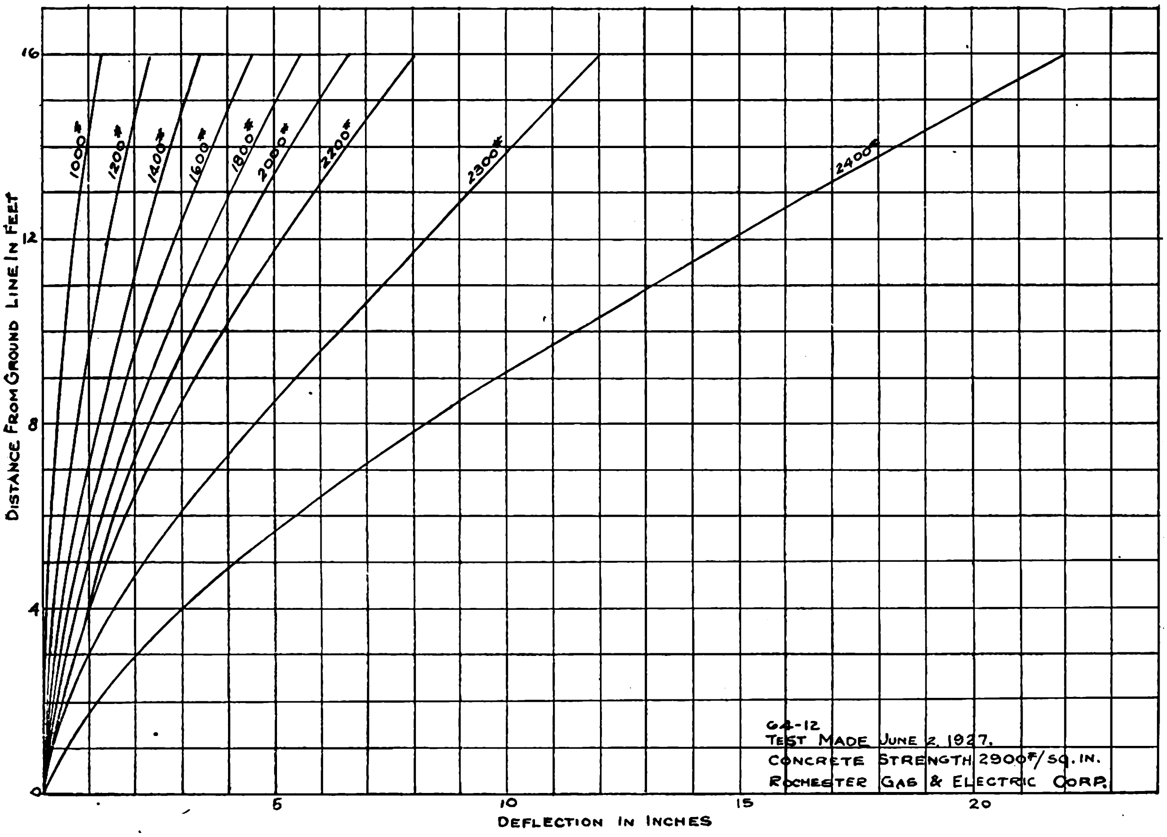


FIG. 16—STRESS-DEFLECTION CURVES FOR 22 FT. AND 25 FT. CONCRETE POLES.



64-12
Test Made June 2, 1927.
Concrete Strength 2900#/sq. in.
Rochester Gas & Electric Corp.

FIG. 17—Graphic Representation of Test on 22 Ft. Concrete Pole.

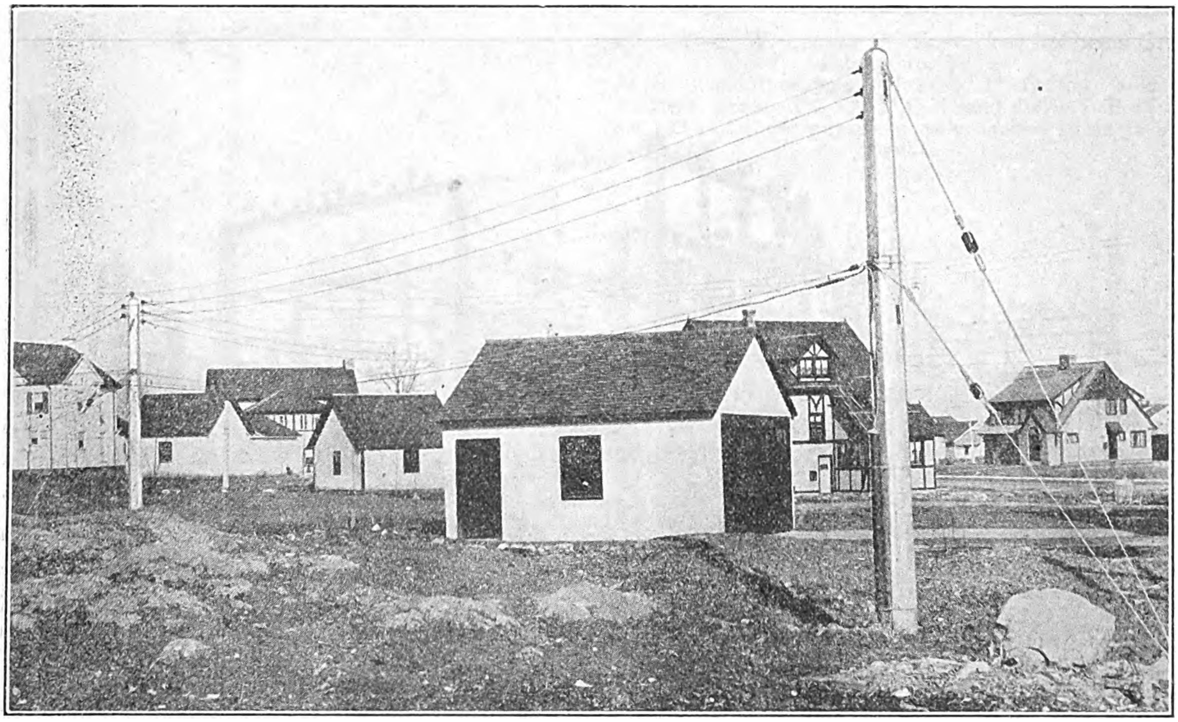


FIG. 18—Joint Pole Line Construction in Rear Lot Line Using 25 Ft. Concrete Poles. Bel Air Tract. Cor. Oakdale and Wilshire Drives. Rochester Gas & Electric Corp. 3-11-27.

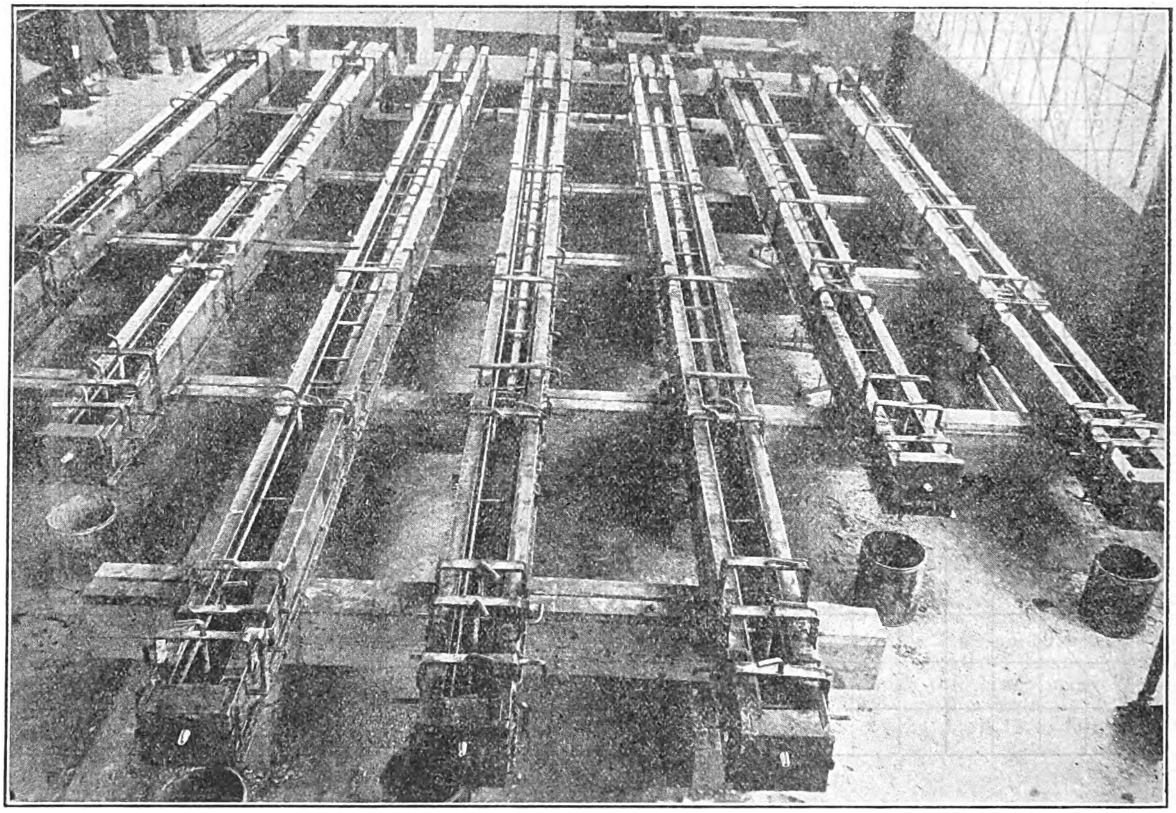


FIG. 19—INTERIOR VIEW OF ATLANTIC AVENUE POLE PLANT SHOWING FORMS FOR CONCRETE LINE POLES, WITH REINFORCING RODS AND CORES IN PLACE, READY FOR CONCRETE TO BE PLACED. ROCHESTER GAS & ELECTRIC CORPORATION.

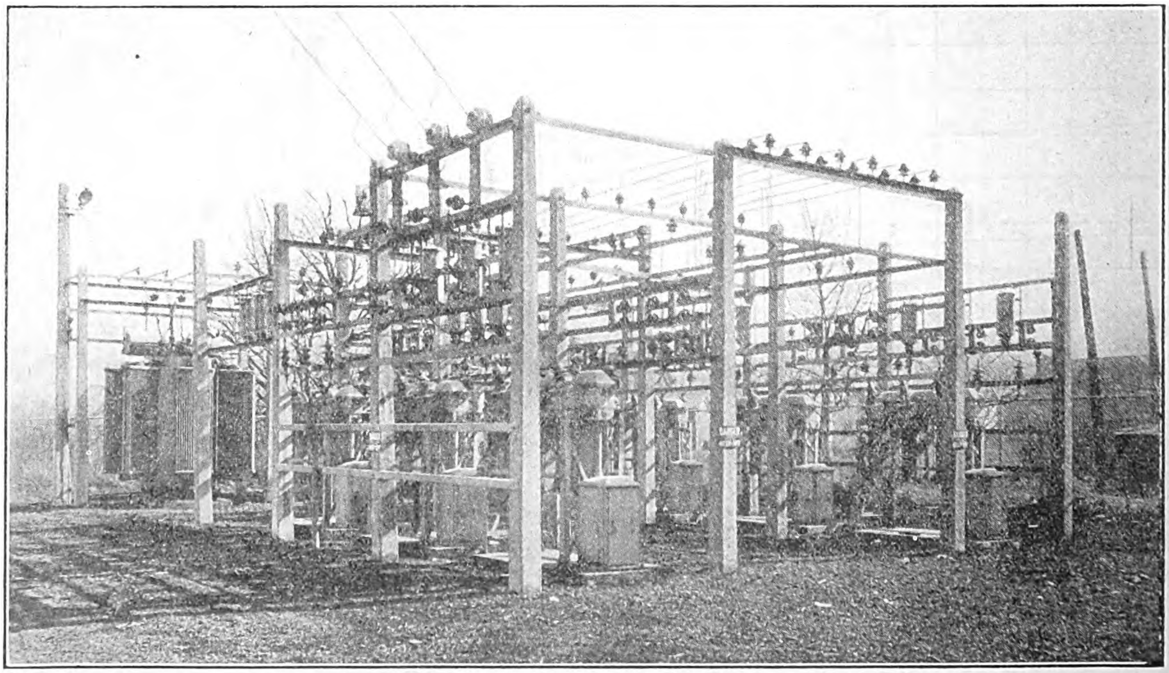


FIG. 20—11,000 VOLT OUTDOOR SUBSTATION AT STATION 36, CHARLOTTE, SHOWING CONCRETE POLE CONSTRUCTION. ROCHESTER GAS & ELECTRIC CORP. 3-11-27.

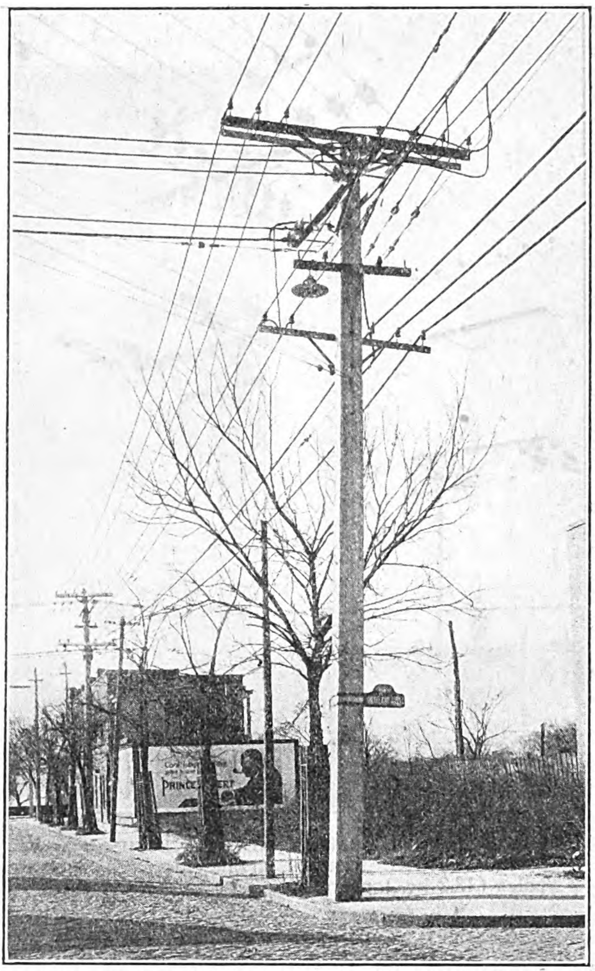


FIG. 22—S. W. CORNER GRAYLAND AND ROBINSON STS., RICHMOND, VA.
40 ft. strain type pole (11 ft. x 11 ft. top) holding dead-end strain of 2-500 M.C.M. and 4-4/0 T B W P conductors, where guying of pole against strain is impossible.

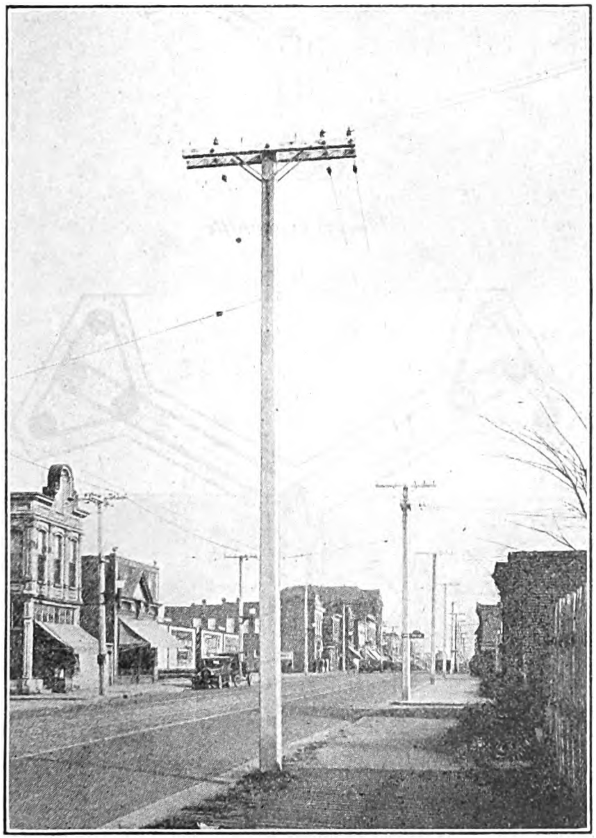


FIG. 21—EAST OF HULL ST. AT 20TH ST., RICHMOND, VA., LOOKING NORTH.

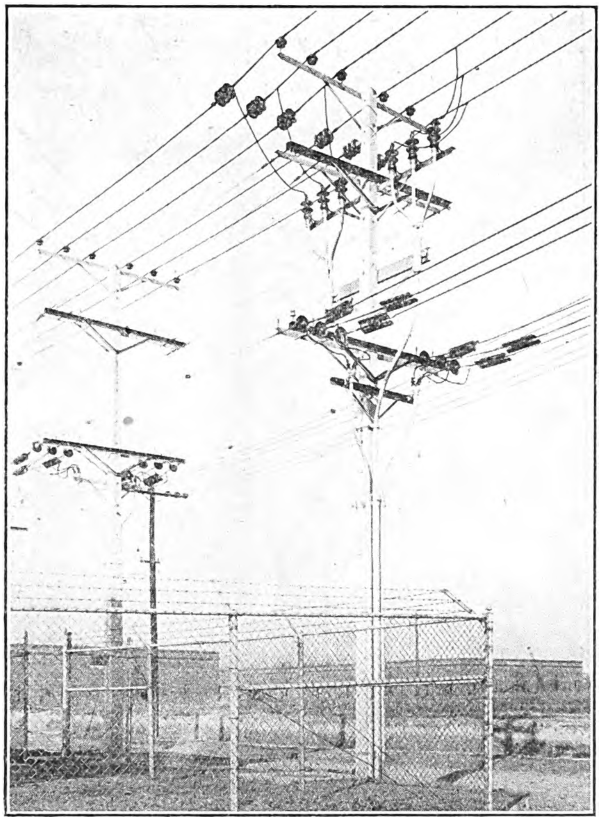


FIG. 23—HOWARD ROAD SUBSTATION, RICHMOND, VA. Showing O.H.U.G. terminal arrangement on concrete poles (13.2 kv. top arms), 2.3 kv. on bottom arms.

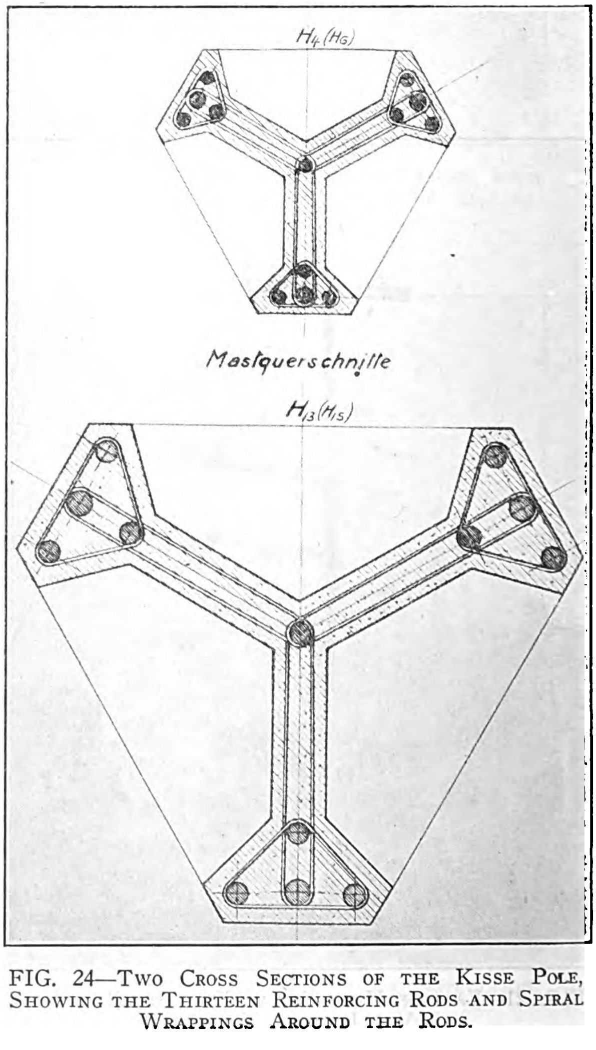

H4 (H6)
Mastquerschnitte
H13 (H15)

FIG. 24—TWO CROSS SECTIONS OF THE KISSE POLE, SHOWING THE THIRTEEN REINFORCING RODS AND SPIRAL WRAPPINGS AROUND THE RODS.

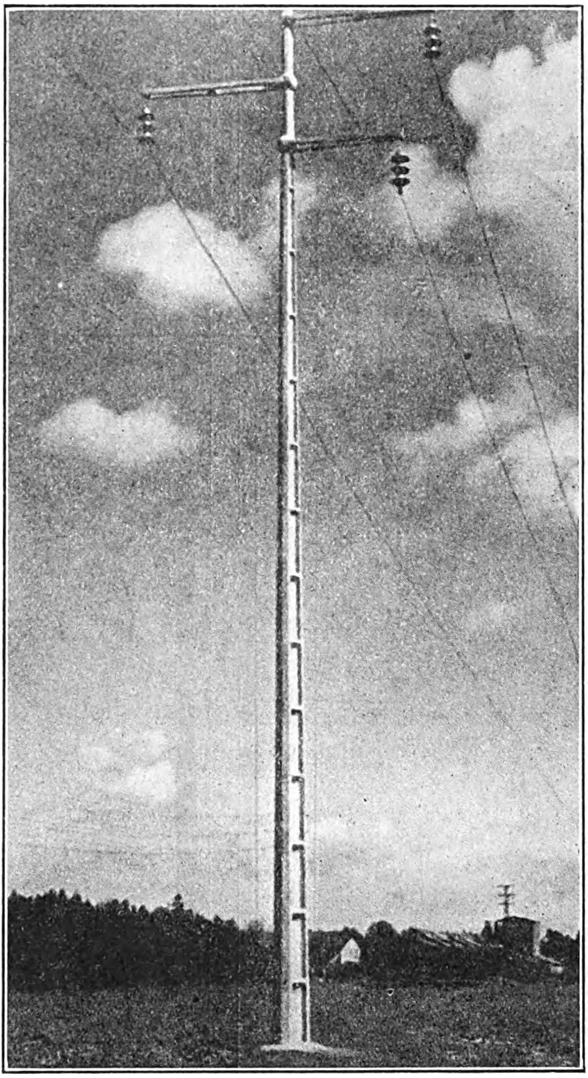


FIG. 25—A KISSE POLE IN SERVICE ON A 50 KV. TRANSMISSION LINE. THE TOP OF THIS POLE IS APPROXIMATELY 50 FT. ABOVE GROUND.

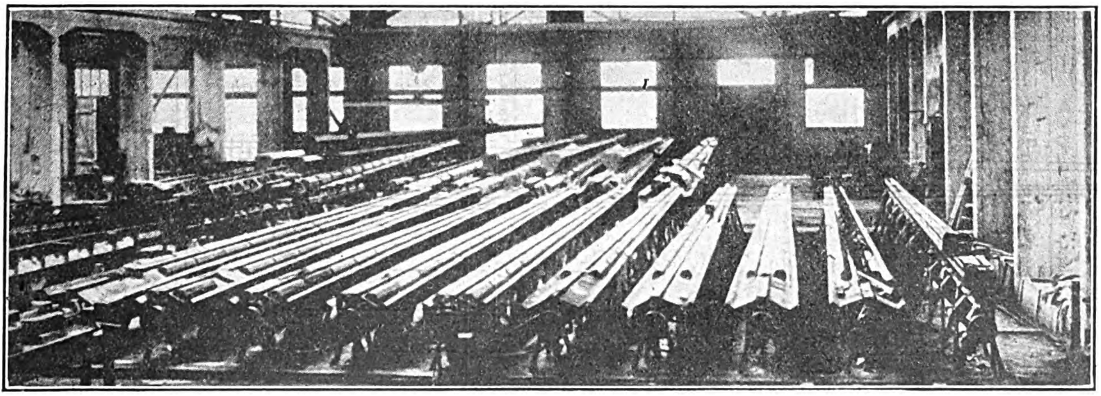


FIG. 26—VIEW OF THE INTERIOR OF THE KISSE POLE PLANT.

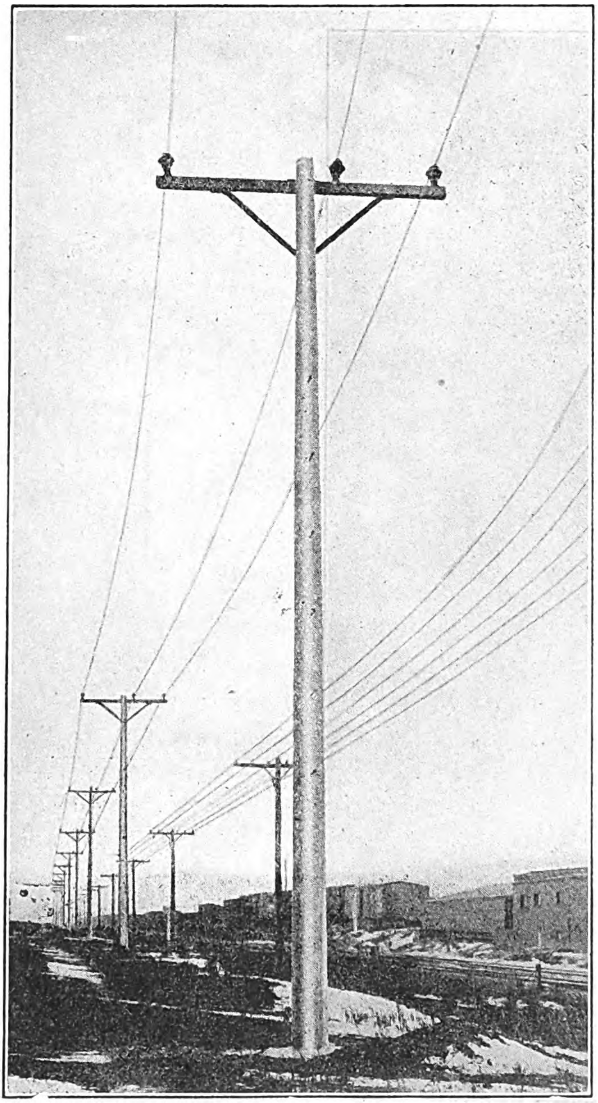


FIG. 27—WESTINGHOUSE HOLLOWSPUN CONCRETE POLES FOR HIGH VOLTAGE TRANSMISSION LINES. INSTALLATION BY ILLINOIS STEEL CO., SOUTH CHICAGO, ILL.

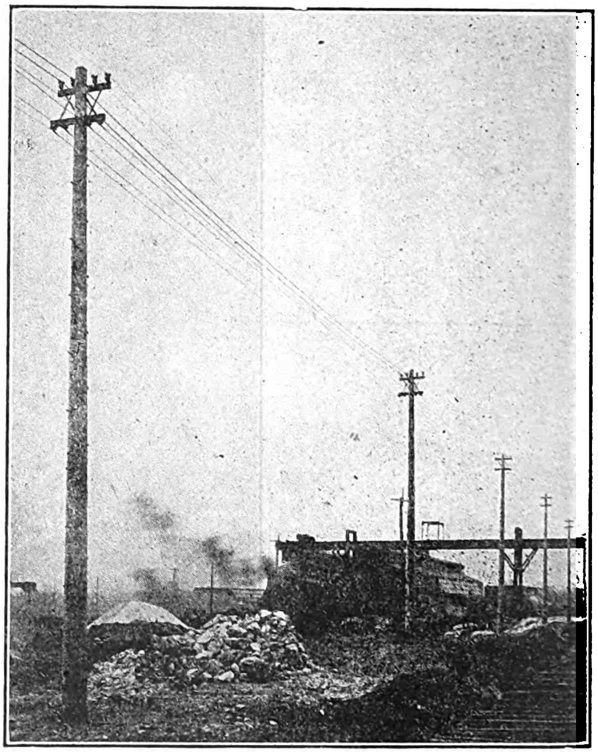


FIG. 28—WESTINGHOUSE HOLLOWSPUN CONCRETE POLES IN USE AT SCUBBEN STEEL WORKS, ST. LOUIS, MO.

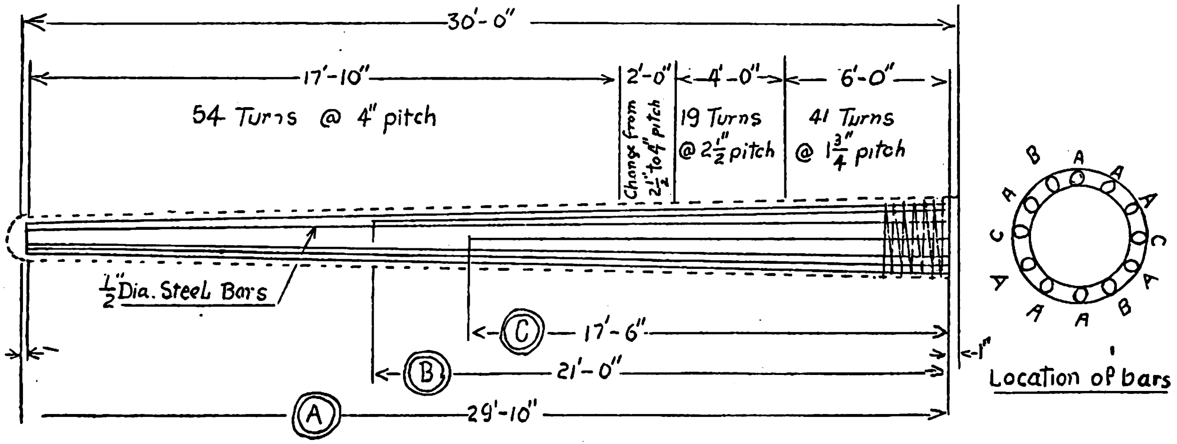

30'-0"
17'-10"
2'-0"
4'-0"
6'-0"
54 Turns @ 4" pitch
Change from 2½" to 4" pitch
19 Turns @ 2½" pitch
41 Turns @ 1¾" pitch
½" Dia. Steel Bars
C 17'-6"
B 21'-0"
A 29'-10"
1"
B A A A C A B A A A C A
Location of bars

FIG. 29—REINFORCING CAGE FOR CLASS 750-30 FT. HOLLOWSPUN CONCRETE POLE.

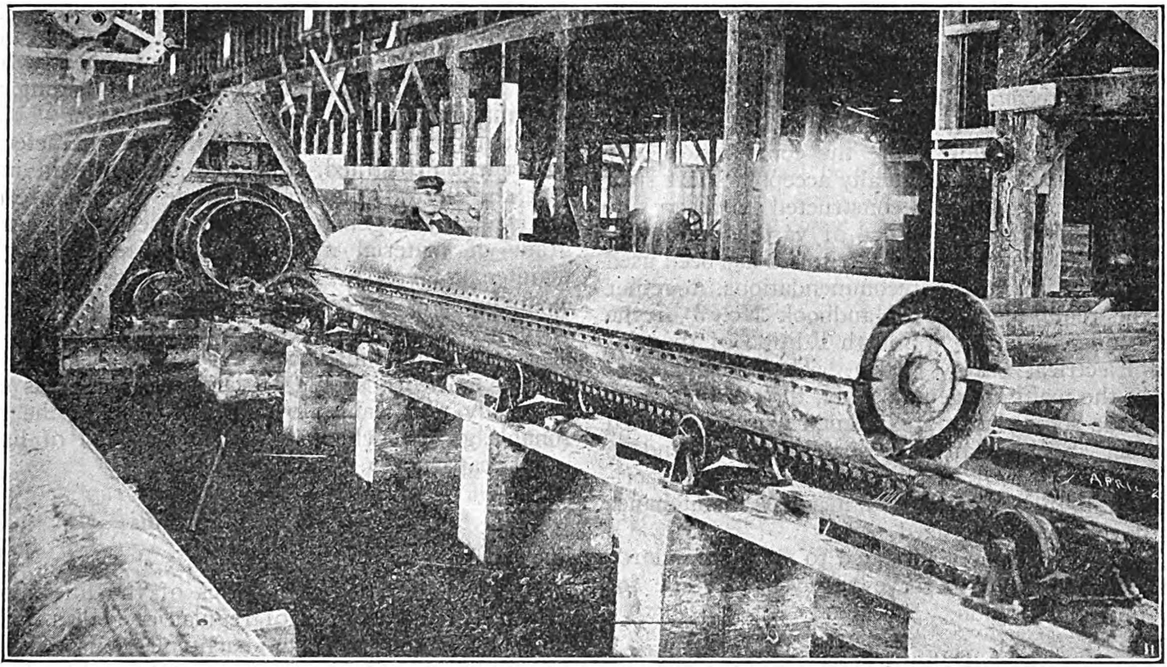


FIG. 30—CONCRETE POLE SPINNING MACHINE. WESTINGHOUSE ELEC. & MFG. CO., MILWAUKEE, WIS.

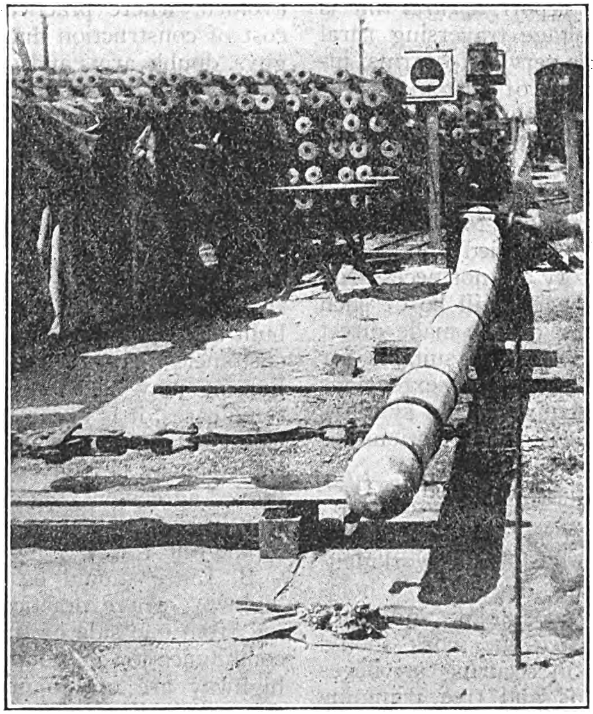


FIG. 31—SHOWING METHOD USED IN TESTING WESTINGHOUSE HOLLOWSPUN CONCRETE POLES.

RECOMMENDED PRACTICES FOR DESIGN AND CONSTRUCTION OF RURAL LINES

Scope of Work

A. These recommendations, while not complete, are intended to embody the general features of rural lines and to point out where the construction may differ from that of the generally accepted short span construction used in lines constructed in urban territories. The present practice of various operating companies now serving rural territories has been used as the basis for these recommendations, together with the requirements of Handbook No. 3 of the Bureau of Standards. (Fourth Edition of the National Electrical Safety Code). The recommendations in the main are general only, though they have been made somewhat more detailed where it seemed desirable. Such details of construction as tend to decrease the cost of the line without unduly sacrificing strength or tending to increase maintenance costs have been emphasized.

B. This report is not intended to set up standards of construction, but to serve purely as a guide for rural line construction.

Definitions

A. The definitions as given in Handbook No. 3 of the Bureau of Standards (Fourth Edition of the National Electrical Safety Code) apply to the terms used in these recommendations. In addition, the following definitions are given for terms not included in the Code List.

B. For the purpose of this report, a *rural line* is a line of low or medium voltage traversing rural territory and supplying electric service to farms, individual customers, small groups of customers, villages or other scattered enterprises located in rural territory. Such lines may be constructed within the corporate limits of cities when the character of the load so warrants, and the construction of the generally accepted short span line used for urban distribution is not economically justified; and, conversely, all lines in rural territory are not necessarily rural lines. Rural lines in general will be of such voltage that one transformation can be made direct from the primary voltage to a voltage suitable for the customer's use. Rural lines may be extensions of existing urban or suburban distribution systems, or may be independent circuits from stations or substations.

General Considerations

A. In general, all construction work should be of a permanent character and of good workmanship. Any skimping of guying, digging pole holes to insufficient depth, making poor joints and other temporary make-shifts to hasten the work should be avoided, as should laxity in securing privileges for pole and anchor locations and tree trimming rights, which cost more for repairs and rebuilding and cause more annoyance than permanently built lines for which rights are secured in a binding and workmanlike manner.

B. In making a decision as to the character of construction justified, it should be borne in mind that the use of the higher grade material results in longer life in general, while the use of the cheaper grade of material means shorter life and higher maintenance costs. The various factors should be evaluated and an economic balance reached in determining the grade of construction for rural lines in any particular instance.

C. New work should be laid out, as far as economically practicable, to take into account the reasonable growth which may occur, instead of limiting its capacity to immediate needs.

Specific Considerations

Lines, General

A. The construction features of the line should conform with the rules of regulatory bodies having jurisdiction; and where no such rules exist the provisions of Part 2 of the National Electrical Safety Code for the appropriate grade of construction may be used as a guide.

B. Lines should consist of straight sections with as few angles as possible, and these angles, where they are necessary, should be turned on the minimum number of poles. Long curves should be avoided, where practicable, because of the greater cost of construction due to the increased number of guys, double arms and dead ends.

C. These recommendations in general apply to rural lines when alone. When such lines are concerned with crossings, conflicts or joint use with communication lines, or with crossings over railroad tracks, such additional requirements as may be necessary should be complied with.

Location of Lines

A. Where at all practicable rural lines should be built along highways so that the greatest number of customers may be reached, and so that highway lighting may be supplied as required later. If, in some cases, it is deemed advisable to build over private right-of-way, it is recommended that all private right-of-way be fully protected by easements or approved agreement, the clauses of which should in no way be detrimental to the operation or construction of the line.

B. Lines should be located on one side of the highway, where practicable, thereby avoiding crossing from one side of the road to the other. Where communication and supply line circuits on the same highway are not to occupy joint poles, or where the supply line is alone on a highway, the supply line should be placed on one side of the highway throughout as far as practicable, so that one side

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Publication No. 289-16, Serial Report, Overhead Systems Committee.

of any section of a highway will be available as the communication side and one side as the supply side.

C. Where it is necessary for supply and communication lines to occupy the same side of a highway, joint use is generally preferable to over-building, where such joint use is justified by considerations of safety, economy and convenience, and the condition and character of the circuits permit, and where satisfactory agreement between the parties concerned as to terms and conditions can be reached.

D. In making a decision as to the location of a rural line on a highway, or as to the allocation of costs when the construction of both communication and supply lines along the highway make necessary changes in existing lines, general principles should be followed as outlined in the reports of the Joint General Committee of the National Electric Light Association and the Bell Telephone System on the "Physical Relations Between Electrical Supply and Communication Systems."

E. If it becomes necessary to locate more than one line of poles on the same side of a highway, the pole locations should be such that no conductors of any line will come within 3 ft. of the pole of another line, nor within 4 ft. of a conductor of another line, at 60 deg. fahr. and no wind. These clearances do not apply when the conductors of both lines are attached to the same poles; under such conditions the clearances for jointly used lines apply.

For some conditions of span length or conductor sags it may be necessary to increase the above clearances. Under any condition the clearance requirements of Rule 234 of the National Electrical Safety Code, Fourth Edition, which also provides for minimum safe clearances from line conductors to buildings and bridges, should be complied with.

Location of Poles

A. Poles located on public highways should be set as near as practicable to the edge of the right-of-way or property line, in order to allow for future widening of the highway. Poles should always be located so as not to obstruct the flow in drainage ditches, and preferably should be set between the ditch and the property line. Where the ditch consists of a wide borrow-pit from which material was taken to grade the roadway, it may be necessary for the poles to stand in the back edge of the ditch, or close to the foot of the back slope, adjacent to the property line. Whenever local statutes or ordinances govern the location of pole lines on public highways, the necessary advance authority or approval should be obtained from the proper State, county, town or municipal officials.

B. In order to obtain the maximum clearance of line and service wires from trees and above ground, especially in long span lines, poles should be located on the top or shoulder of a rise of ground rather than in a hollow; as near as practicable to any tree in the line, unavoidably passed through or over; and at such points as to make service drops as short as possible.

C. Poles at crossings, angles and other points where guys will be necessary should be located so that there will be no obstruction to guying, and where the guy anchor may be placed well away from the pole. Where possible, guy anchors should be placed at a distance from the pole equal to or greater than the height from the ground to the point of attachment of the guy on the pole.

D. In general, corners should be turned on a minimum number of poles, in accordance with the following sketches. Poles for corners or angles should be located so as to obtain good guying facilities; guys should be attached to anchors in preference to guying to a stub or to the adjacent pole, except where proper clearances cannot be obtained otherwise.

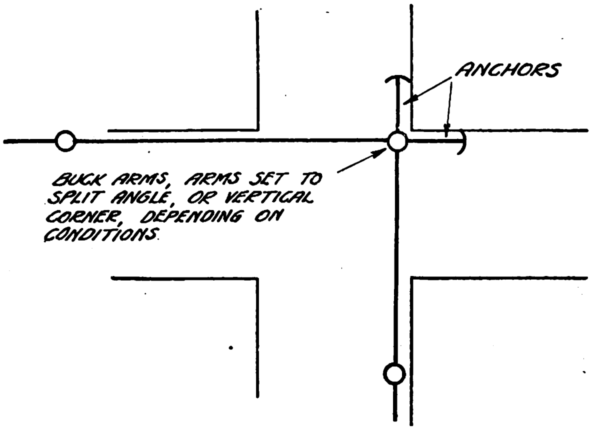

ANCHORS
BUCK ARMS, ARMS SET TO SPLIT ANGLE, OR VERTICAL CORNER, DEPENDING ON CONDITIONS

FIG. 1.

For more detailed information on corner construction and guying, see Section 11, Overhead Systems Reference Book, as issued by the Overhead Systems Committee, Engineering National Section, National Electric Light Association.

The one pole corner construction, as shown in Fig. 1, is used in general where the length of the curve of the line is short, and where the angle turned is such that the complete turn can be made on one pole. The mechanical loads imposed and the clearance necessary between phases of the circuit will determine whether buck arm construction, a single or double arm set to split the line angle, or vertical construction at the corner will be necessary.

In the construction shown in Fig. 2, two main corner poles are located at an equal distance from the center of the curve, and the adjacent poles spaced as nearly equal as practicable. This construction is

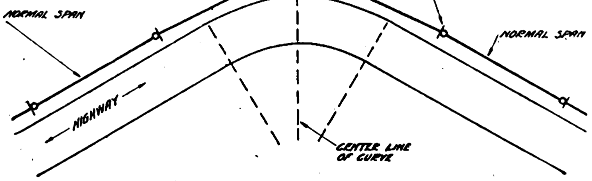


FIG. 2.

used where the length of the curve of the line is great enough so that the corner cannot be turned on one pole. It may also be necessary where short spans are required at a corner to prevent overhanging of private property and other cases of this nature. The type of construction required is determined as in Fig. 1.

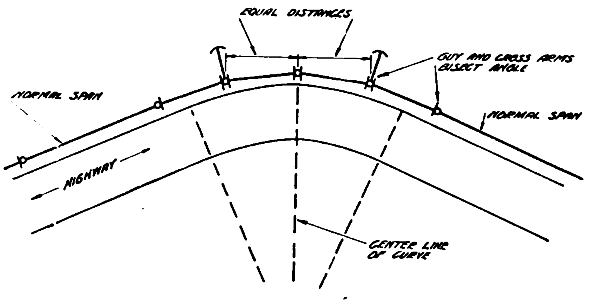


FIG. 3.

In the construction shown in Fig. 3, the main corner pole is located at the center of the curve, and adjacent poles are spaced as nearly equal from the main corner pole as practicable. This is a variation of the construction shown in Fig. 2.

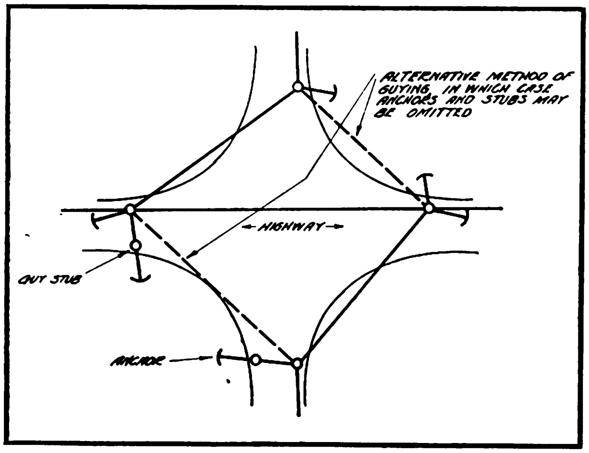

ALTERNATIVE METHOD OF GUYING, IN WHICH CASE ANCHORS AND STUBS MAY BE OMITTED
HIGHWAY
GUY STUB
ANCHOR

FIG. 4.

The type of construction shown in Fig. 4 is used at long radius road intersections.

The type of construction shown in Fig. 5 is used where it is necessary to cross from one side of the highway to the other.

For further detail as to construction and guying, refer to Section 11, Overhead Systems Reference Book.

Voltage

A. In general, it is impossible to establish a uniform voltage for rural lines, as the selection of voltage to be used will often be governed by the local line voltages available in that vicinity. Rural lines built as extensions of existing feeders should usually operate at the voltage of the feeder, provided such voltage is adequate to handle the load.

B. It is recommended that, with all rural lines of any considerable extent, or possible of extension to such, consideration be given to building for ultimate operation at one of the higher voltages, 6900 or above, according to the future load possibilities and standards of the company concerned.

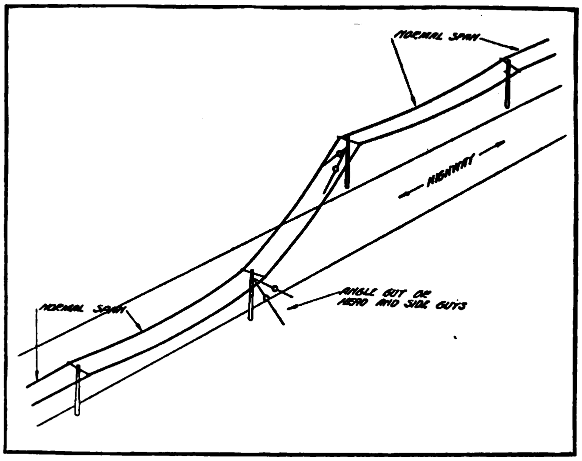


FIG. 5.

C. It is also recommended that each company operating rural lines give consideration to establishing a standard voltage not lower than 6900 as a basis for the ultimate operation of lower voltage rural lines, and as the operating voltage of rural lines built as new projects whose voltage is not governed by that of an existing system.

D. The voltages given in Table I may be considered as available for rural circuits. The voltages are based upon 115/230 volts being available for the customer, and transformer ratios of 10 to 1, or multiples thereof. These voltages correspond to the ratings of transformers usually supplied by the manufacturers for customers' service.

TABLE I

Single Phase or Three Phase Delta	Three Phase Star
2,300	4,000
4,600	8,000
6,900	11,950
11,500	.....
13,800	.....

E. Table II, showing loads and distances for various sizes of conductors and voltages is given as a guide to the selection of voltage and size of conductor for any particular situation to be considered. This table shows the limitations of the lower voltages in amount of load which can be handled at the usual rural distances, and also shows the great advantage of selecting the higher voltages especially for the ultimate loads which will develop in rural territory.

Span Lengths

A. In general, within certain limits, any increase in span length of a line will decrease the first cost of construction because of the smaller amount of

TABLE II

TABLE OF LOADS AND DISTANCES SHOWING KILOWATT-MILES FOR VARIOUS CONDUCTOR SIZES AND VOLTAGES

Voltages		Product of Kilowatts and Miles for Different Conductor Sizes			
Single Phase	Three Phase	No. 6 Copper, No. 4 A.C.S.R.	No. 4 Copper, No. 2 A.C.S.R.	No. 2 Copper, No. 0 A.C.S.R.	No. 0 Copper, No. 3/0 A.C.S.R.
2,300	......	48	69	96	128
	2,300	96	137	189	251
4,600	......	193	277	384	511
	4,000	290	415	572	760
	4,600	384	548	756	1,004
6,900	......	434	625	864	1,150
	6,900	864	1,235	1,702	2,260
	8,000	1,160	1,656	2,285	3,060
11,500	......	1,207	1,735	2,400	3,200
	11,500	2,400	3,430	4,730	6,280
	11,950	2,590	3,700	5,110	6,780
13,800	......	1,737	2,500	3,456	4,600
	13,800	3,460	4,940	6,820	9,040

NOTE: The above table is based upon 5% line drop and 80% power factor with load concentrated at the end of the line. Conductor separations of 30" single phase and 29½" three phase have been used, as illustrated in Fig. 6.

To obtain the concentrated load which can be carried with a given conductor at any distance, divide the corresponding value from the table above by the distance in miles, which will give the desired result in kilowatts.

For uniformly distributed total loads use twice the values shown in the above table for concentrated loads.

material and labor required for supporting structures. There are certain factors which affect the situation, however, and certain limits beyond which it is inadvisable to go. For instance, longer spans require greater conductor sags to keep the conductor stresses within allowable limits; greater sags in turn may require greater separation of the conductors on the crossarm and hence larger and more costly crossarms; or the sags may be great enough to require longer poles to maintain the necessary clearance above ground, thus resulting in higher costs. Sags in long span lines may be reduced somewhat by the use of conductors having higher tensile strength than hard-drawn copper. However, the difference in conductivity of conductors of different tensile strengths must be considered in order that the allowable voltage drop will not be exceeded. All of these factors must be taken into consideration in deciding on span lengths.

B. Lines having normal span lengths of 250 and 300 ft. have been, and are now being, successfully operated by companies in various parts of the country; under some conditions even greater span lengths are feasible. These span lengths sometimes must be decreased in certain parts of the line, such as crossings, angles in the line, at points where there is excessive tree interference, and other similar cases.

C. Lines may be originally built having spans on the order of 250 and 300 ft. in length, and later, when additional conductors must be added, additional poles may be set at the mid-span points, thus cutting span lengths to about the average used for urban distribution.

D. For lines built for joint use with communication companies, the span lengths must be such as to satisfy the requirements of both types of line.

E. Table III gives the minimum gage sizes for supply line conductors, in accordance with the requirements of Handbook No. 3 of the Bureau of Standards (Fourth Edition of the National Electrical Safety Code) for rural lines.

TABLE III

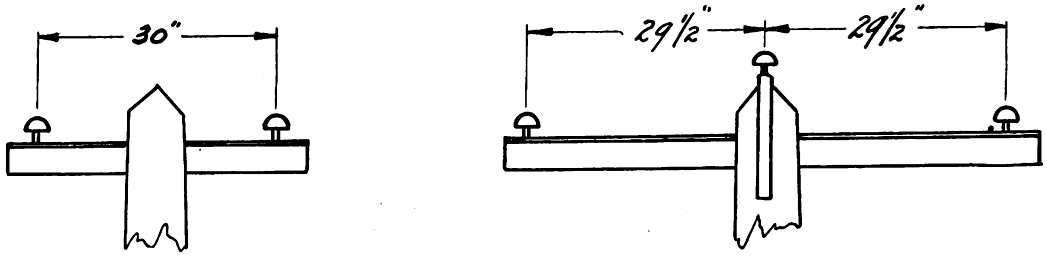
MINIMUM GAGE SIZES FOR SUPPLY LINE CONDUCTORS

Material	Urban	Rural
Soft copper....................	6	8
Medium or hard drawn copper..	8	8
Steel..........................	9	9
	Urban and Rural	
	Spans 150 Feet or Less	Spans Exceeding 150 Feet
Stranded Aluminum:		
Not reinforced..............	1	0
Steel reinforced..............	6	4

The Handbook recommends that, except as modified in Table 23, Rule 261F2 of the Handbook, these minimum sizes of copper and steel be not used in spans longer than 150 ft. for heavy-loading districts, and 175 ft. for medium and light-loading districts.

Poles, Type and Size

A. Poles constitute one of the largest individual items of expense in the construction of overhead



SINGLE PHASE SPACING THREE PHASE SPACING

FIG. 6.

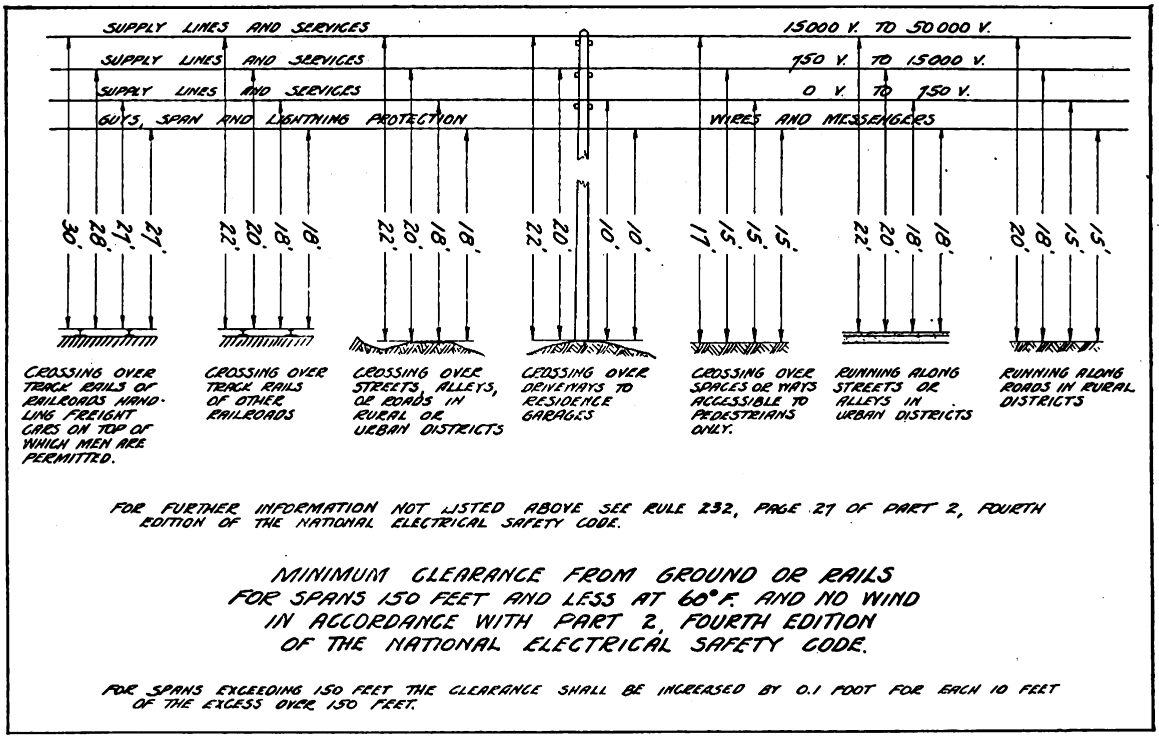

SUPPLY LINES AND SERVICES
15000 V. TO 50000 V.
SUPPLY LINES AND SERVICES
750 V. TO 15000 V.
SUPPLY LINES AND SERVICES
0 V. TO 750 V.
GUYS, SPAN AND LIGHTNING PROTECTION
WIRES AND MESSENGERS
30' 28' 27' 27'
22' 20' 18' 18'
22' 20' 18' 18'
22' 20' 10' 10'
17' 15' 15' 15'
22' 20' 18' 18'
20' 18' 15' 15'
CROSSING OVER TRACK RAILS OF RAILROADS HANDLING FREIGHT CARS ON TOP OF WHICH MEN ARE PERMITTED.
CROSSING OVER TRACK RAILS OF OTHER RAILROADS
CROSSING OVER STREETS, ALLEYS, OR ROADS IN RURAL OR URBAN DISTRICTS
CROSSING OVER DRIVEWAYS TO RESIDENCE GARAGES
CROSSING OVER SPACES OR WAYS ACCESSIBLE TO PEDESTRIANS ONLY.
RUNNING ALONG STREETS OR ALLEYS IN URBAN DISTRICTS
RUNNING ALONG ROADS IN RURAL DISTRICTS
FOR FURTHER INFORMATION NOT LISTED ABOVE SEE RULE 232, PAGE 27 OF PART 2, FOURTH EDITION OF THE NATIONAL ELECTRICAL SAFETY CODE.
MINIMUM CLEARANCE FROM GROUND OR RAILS FOR SPANS 150 FEET AND LESS AT 60° F. AND NO WIND IN ACCORDANCE WITH PART 2, FOURTH EDITION OF THE NATIONAL ELECTRICAL SAFETY CODE.
FOR SPANS EXCEEDING 150 FEET THE CLEARANCE SHALL BE INCREASED BY 0.1 FOOT FOR EACH 10 FEET OF THE EXCESS OVER 150 FEET.

FIG. 7.

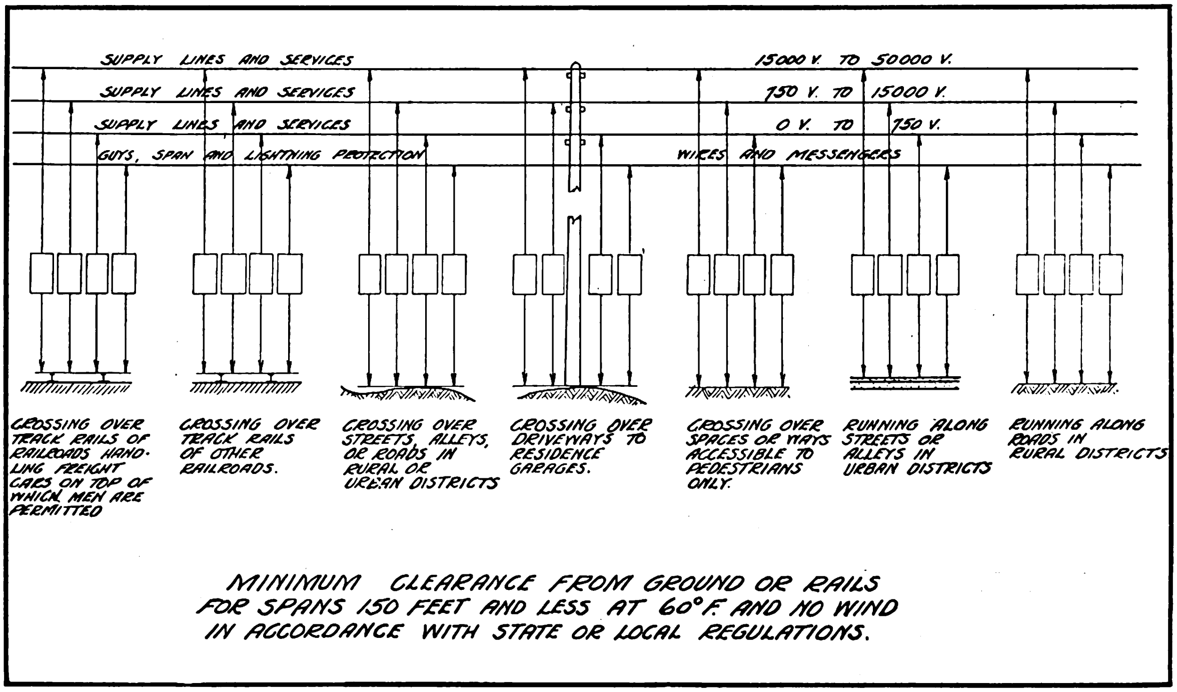
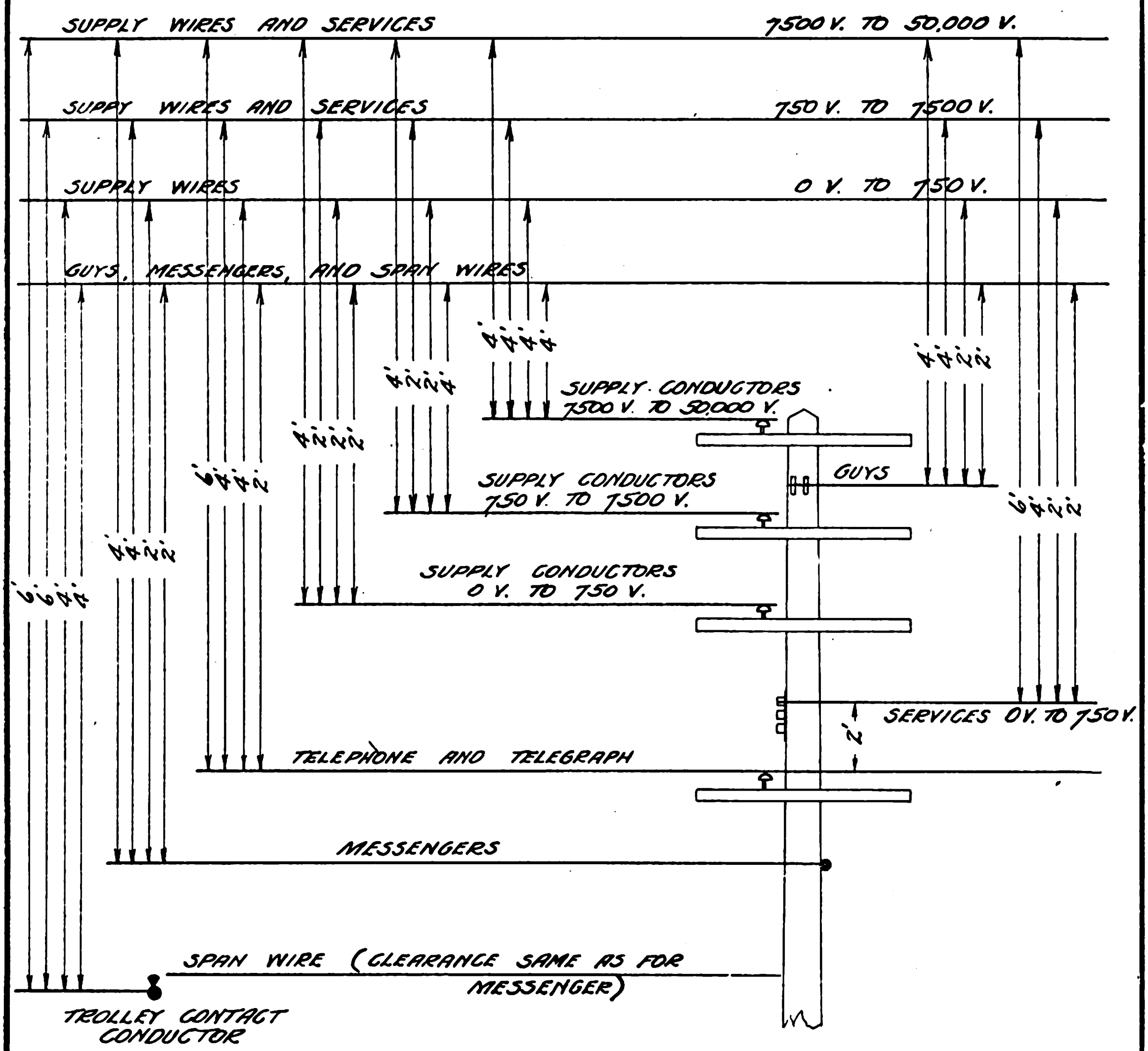

SUPPLY LINES AND SERVICES
15000 V. TO 50000 V.
SUPPLY LINES AND SERVICES
750 V. TO 15000 V.
SUPPLY LINES AND SERVICES
0 V. TO 750 V.
GUYS, SPAN AND LIGHTNING PROTECTION
WIRES AND MESSENGERS
CROSSING OVER TRACK RAILS OF RAILROADS HANDLING FREIGHT CARS ON TOP OF WHICH MEN ARE PERMITTED
CROSSING OVER TRACK RAILS OF OTHER RAILROADS.
CROSSING OVER STREETS, ALLEYS, OR ROADS IN RURAL OR URBAN DISTRICTS
CROSSING OVER DRIVEWAYS TO RESIDENCE GARAGES.
CROSSING OVER SPACES OR WAYS ACCESSIBLE TO PEDESTRIANS ONLY.
RUNNING ALONG STREETS OR ALLEYS IN URBAN DISTRICTS
RUNNING ALONG ROADS IN RURAL DISTRICTS
MINIMUM CLEARANCE FROM GROUND OR RAILS FOR SPANS 150 FEET AND LESS AT 60° F. AND NO WIND IN ACCORDANCE WITH STATE OR LOCAL REGULATIONS.

FIG. 8.


SUPPLY WIRES AND SERVICES
7500 V. TO 50,000 V.
SUPPY WIRES AND SERVICES
750 V. TO 7500 V.
SUPPLY WIRES
0 V. TO 750 V.
GUYS, MESSENGERS, AND SPAN WIRES
4' 4' 4' 4'
4' 2' 2' 4'
4' 2' 2' 2'
6' 4' 4' 2'
4' 4' 2' 2'
6' 6' 4' 4'
4' 4' 2' 2'
6' 4' 2' 2'
SUPPLY CONDUCTORS 7500 V. TO 50,000 V.
GUYS
SUPPLY CONDUCTORS 750 V. TO 7500 V.
SUPPLY CONDUCTORS 0 V. TO 750 V.
SERVICES 0 V. TO 750 V.
2'
TELEPHONE AND TELEGRAPH
MESSENGERS
SPAN WIRE (CLEARANCE SAME AS FOR MESSENGER)
TROLLEY CONTACT CONDUCTOR

WHERE THE SUM OF THE DISTANCES FROM THE POINT OF INTERSECTION OF TWO CROSSING WIRES TO THE NEARER SUPPORTING STRUCTURE OF EACH SPAN DOES NOT EXCEED 100 FEET.

FOR FURTHER INFORMATION NOT LISTED ABOVE SEE RULE 233, PAGE 30 OF PART 2, FOURTH EDITION OF THE NATIONAL ELECTRICAL SAFETY CODE.

MINIMUM WIRE CROSSING CLEARANCE IN FEET WITH SAGS AT 60° F. AND NO WIND IN ACCORDANCE WITH PART 2, FOURTH EDITION OF THE NATIONAL ELECTRICAL SAFETY CODE.

FIG. 9.

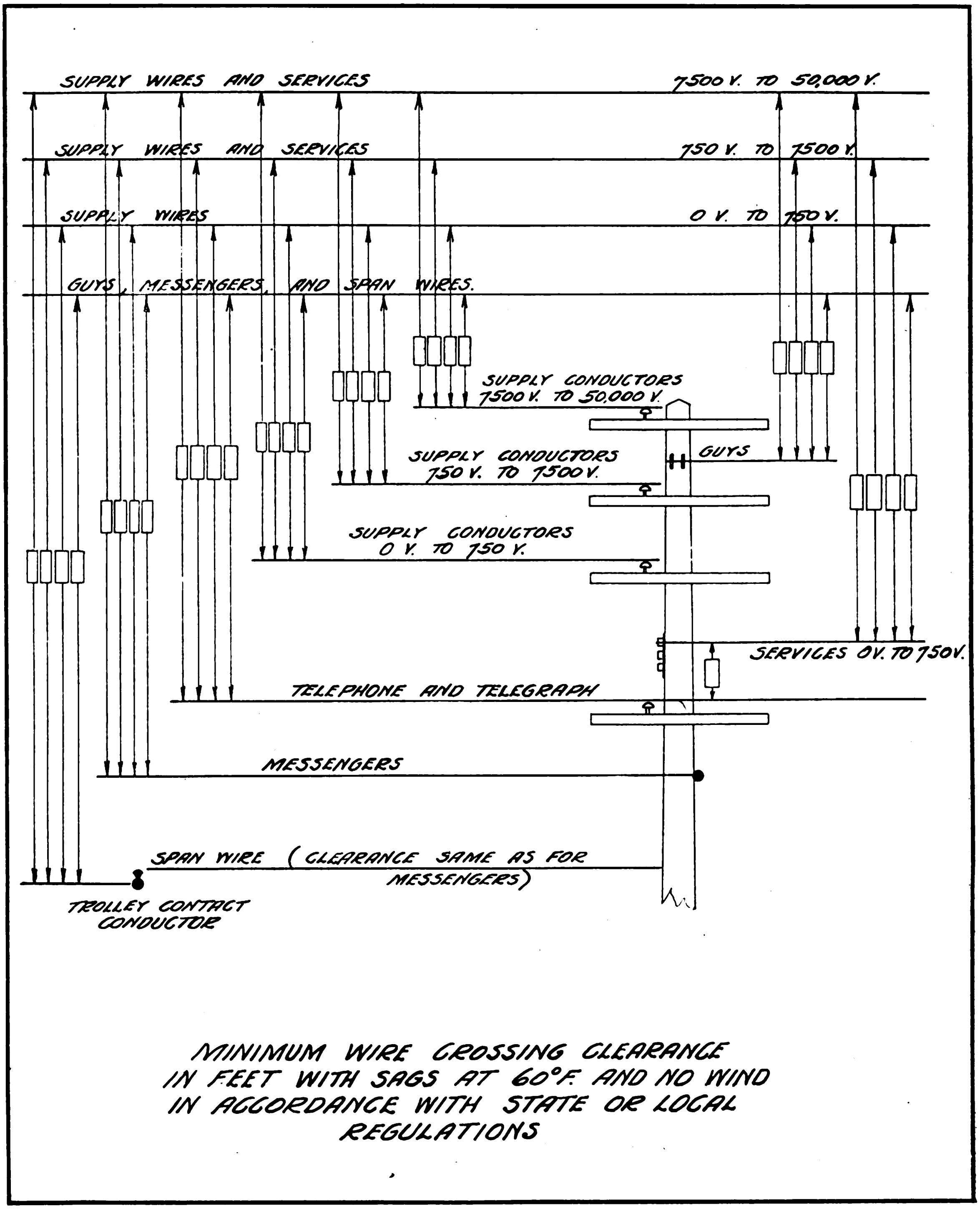

SUPPLY WIRES AND SERVICES
7500 V. TO 50,000 V.
SUPPLY WIRES AND SERVICES
750 V. TO 7500 V.
SUPPLY WIRES
0 V. TO 750 V.
GUYS, MESSENGERS, AND SPAN WIRES.
SUPPLY CONDUCTORS 7500 V. TO 50,000 V.
SUPPLY CONDUCTORS 750 V. TO 7500 V.
GUYS
SUPPLY CONDUCTORS 0 V. TO 750 V.
SERVICES 0 V. TO 750 V.
TELEPHONE AND TELEGRAPH
MESSENGERS
SPAN WIRE (CLEARANCE SAME AS FOR MESSENGERS)
TROLLEY CONTACT CONDUCTOR
MINIMUM WIRE CROSSING CLEARANCE IN FEET WITH SAGS AT 60° F. AND NO WIND IN ACCORDANCE WITH STATE OR LOCAL REGULATIONS

FIG. 10.

lines. The type of pole best suited for use by one operating company is not necessarily the best for another operating company in a different geographic location, because of the varying climatic conditions and the availability of material.

B. Poles of such length should be selected so as to provide the clearances from ground or track rails, and from poles and conductors of another line, as illustrated in the following drawings (Fig. 7-10, inclusive). In building lines along roads having a large amount of tree interference, it should be borne in mind that short poles under the trees or the use of side arm construction, or both, will often be satisfactory and will save the extra expense of poles long enough to carry the conductors above the trees.

C. In choosing poles, both strength requirements and expected life of the pole should be considered. The use of the better grades of poles is advisable in general where probable future growth will require more circuits or circuits of larger conductors to be installed on the poles within a reasonable time. Treatment of poles with a preservative against decay is of advantage in prolonging their life, and consideration should be given to the use of treated poles.

D. Poles should be selected which give adequate strength to meet local conditions. Several States have rules governing the strength of supporting structures, and where such rules exist their requirements should be complied with. In localities where there are no rules establishing pole strengths for lines used in providing rural electric service, the following may be used as a basis for determining the strength of poles to be used:

1. Ultimate fiber stresses of wood poles—

	Lb. per sq. in.
a. Southern yellow pine............	6,800
b. Western red cedar................	5,600
c. Northern white cedar............	3,600
d. Chestnut	6,000

2. When crossings, conflicts or joint use of poles are involved, pole strengths should be greater than the minimum required when lines are alone. The proper percentage of ultimate strengths for crossings, conflicts or joint use will depend on the character of the line concerned.

Table IV gives resisting moments in pound-feet for different ground line circumferences of poles usually used for rural lines, based upon the above values of fiber stress and using 100 per cent of the ultimate strength.

The resisting moment for other values of fiber stress may be determined by multiplying the resisting moment as shown in the table above by the ratio of the allowable fiber stress to the fiber stress used in the table. Values for other pole circumferences and for other fiber stresses may be found in Handbook No. 3 of the Bureau of Standards (Fourth Edition of the National Electrical Safety Code).

TABLE IV

RESISTING MOMENTS FOR WOOD POLES

Circumference at Ground Line in Inches	Resisting Moment for Fiber Stress of (lb. per sq. in.)			
	3600	5600	6000	6800
	lb. ft.	lb. ft.	lb. ft.	lb. ft.
22	10,100	15,750	16,850	19,100
23	11,550	18,000	19,250	21,850
24	13,150	20,400	21,900	24,800
25	14,850	23,100	24,750	28,000
26	16,700	25,950	27,800	31,550
27	18,700	29,100	31,150	35,300
28	20,850	32,450	34,750	39,400
29	23,150	36,050	38,600	43,750
30	25,650	39,900	42,750	48,450
31	28,300	44,000	47,150	53,450
32	31,100	48,400	51,850	58,800
33	34,150	53,100	56,900	64,450
34	37,350	58,050	62,200	70,500
35	40,700	63,350	67,850	76,900
36	44,300	68,900	73,850	83,700

The moment in foot-pounds of the forces acting on a pole should not be greater than the value of the resisting moment of the pole in pound-feet, as determined in accordance with the previous paragraph. To determine the moment in foot-pounds of the forces acting on the pole, multiply together for each conductor the wind pressure in pounds per linear foot of conductor, the span length in feet, and the height in feet above ground of the point of attachment of the conductor to the pole or crossarm. The sum of these values for all conductors will be the transverse bending moment on the pole due to the wind pressure on the conductors. To this value must be added the bending moment due to wind pressure on the pole itself, in order to get the total bending moment which the pole must withstand. To determine the moment in foot-pounds due to the wind pressure on the pole itself, multiply together one-half the height of the pole above ground in feet, the average diameter of the pole in feet, the height of the pole above ground in feet, and the wind pressure in pounds per square foot.

The values of horizontal wind pressure used in the above calculations will depend upon the loading conditions encountered in the locality under consideration. In southern territory where glaze (ice formation on wires) storms do not occur, the loading should be based on the maximum horizontal wind pressure acting upon the actual projected area of the wire. In territory subject to glaze formation the loading should be based upon the maximum horizontal wind pressure acting upon the projected area of the wires when covered with ice.

Tables of loading on wires of various sizes and kinds for different values of wind pressure, with and without ice loading, may be found in Handbook No. 3 of the Bureau of Standards and in other published form. The values given in these tables may be proportionately modified to correspond to the values which it is desired to apply to any particular situation. For example, it has been found in certain localities in the territory classed as the "heavy loading" district that a wind pressure of 4 lb. per sq. ft. of projected area, acting against a conductor covered with ½ in. radial thickness of ice, represents the maximum condition which is likely to occur.

Grading of Line

A. The length of poles in the line should be so chosen that no change of grade will occur in the line which will result in an up-pull of the line wires on the insulators, as shown in Fig. 11, unless the line wires are dead ended.

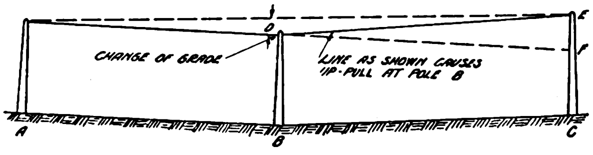


FIG. 11.

B. On level ground and in only slightly hilly country, no abrupt change in line level of more than 5 ft. for 125 ft. spans or 10 ft. for 250 ft. spans should normally be made; in other words, in grading from 35 ft. poles to 50 ft. poles in 125 ft. spans, the order should normally be 35 ft., 40 ft., 45 ft., 50 ft. on level ground. In slightly hilly country or uneven ground, poles of such lengths as to give the same grade should be chosen. This recommendation cannot always be adhered to in very hilly or mountainous country; where such conditions exist, the line grade should follow the general conformation of the ground and should comply as nearly as practicable with Paragraph A above. Unnecessary grading is a waste of money and should be avoided.

C. The change of grade is measured as shown at D, Fig. 11, which, as shown on pole B, is approximately equal to one-half the distance E-F on pole C. The point F may be located by sighting between corresponding marks on sighting rods, which are painted with 1 ft. stripes, and noting the difference on the center sighting rod as shown in Fig. 12 below.

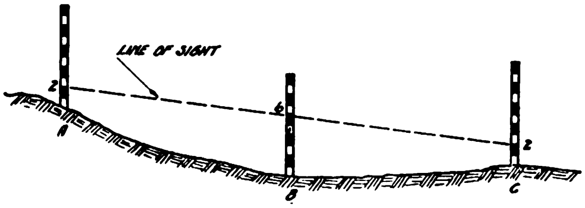


FIG. 12.

Place sighting rods at the pole locations. Sight between corresponding marks on rods A and C, so that the line of sight will cut rod B. In the illustration the 2 ft. mark is selected as a convenient point for sighting on rods A and C, and the line of sight cuts rod B at the 6 ft. mark. This indicates that there is a change of grade of 4 ft. (6 ft. less 2 ft.) at pole B. Variations of the method described may be used to determine the pole heights necessary to eliminate up-pull, to give necessary clearance above high points in the ground between poles, and other cases of this nature.

Pole Framing

A. Poles should have the loose bark removed and all projecting knots trimmed, but they should not ordinarily be shaved. Butts should be sawed off square.

B. All poles should be roofed at angle of 45 deg., where climatic conditions warrant, to guard against the accumulation of water, which is one of the elements necessary to decay.

C. In general only a very shallow gain should be cut. Deep gains should be avoided, as on the small top poles a deep gain materially affects the strength of the pole. It is advisable to cut additional gains or bolt holes on poles treated throughout their entire length, before the poles have received treatment.

D. Before setting, all single pole construction should be completely framed and fitted with crossarms, braces, pins, racks and other fittings wherever practicable. This is usually feasible on rural lines and saves considerable construction expense, as all work on the pole is then done on the ground.

Excavation for Poles

A. Holes for straight line poles should be dug, and the poles set to the minimum depths as shown in Table V.

TABLE V

Length of Pole, Feet	Depth of Pole Setting	
	Setting in Soil, Feet	Setting in Rock, Feet
25	5.0	3.5
30	5.5	3.5
35	6.0	4.0
40	6.0	4.0
45	6.5	4.5
50	7.0	4.5
55	7.0	5.0
60	7.5	5.0
65	8.0	6.0

B. Poles subject to excessive strain, such as stubs, poles at curves and corners and poles set at points where additional strength is required, shall be set 6 in. deeper than specified in the table above for poles 60 ft. and less, and 12 in. deeper for poles over 60 ft. in length.

C. The depth shown in the table should be increased for poles having small ground line circumferences, and poles set on the slope of banks, in marshy ground, in quicksand or in soil having poor bearing qualities. The depths of holes on steep banks should be measured from the low or downhill side of the hole.

D. Where there is any probability of the ground level at the pole location being lowered within a short time, set the poles so that they will be in the ground not less than the specified depths after the new grade is established.

Back Filling and Tamping

A. Care should be taken in back filling to insure a thorough tamping of the fill. Back filling should be carefully supervised as the strength of the line and its appearance after the first few rains depend upon uniform back filling and firm tamping. Only one shoveler should be used, while *two or more* tampers continuously tamp down the filling. When available or where the soil is soft or unstable, small sized rock, coarse earth or gravel should be used for filling, care being taken to fill all the crevices with earth. After the hole is completely filled, soil should be banked firmly around the pole to provide for settling. If it is necessary at the time of the original back filling to fill the hole with frozen earth, the hole should later be refilled and retamped.

B. Where the depth of the hole has been reduced in accordance with the table for "Setting in Rock" the back fill should be made by wedging in with the digging bar a layer of the larger rock placed edgeways between the pole and the side of the hole, and then firmly tamping smaller rock and gravel or coarse earth into the crevices between the larger rock until all the voids have been filled to near the top of the layer. Continue filling the hole by layers, wedging in as many of the larger rock as possible, until the back fill is completed. Loose earth should be piled around the base of the pole to provide for settling caused by the rain washing the dirt into unfilled crevices in the rock. Where rock is available, this method should be used for settings in soft or unstable earth.

C. In addition to the extra depth of setting in marshy soil or quicksand, it will sometimes be necessary to use various methods to provide sufficient stability where good firm foundation cannot be obtained. These methods may be guying, the use of rock, or of bog shoes. If the soil is quicksand, it is often necessary to use a sand barrel in sinking the holes, the barrel being used to prevent cave-ins.

D. All pole holes should be dug as small in diameter as practicable, and in general shall be only large enough to receive the butt of the pole without forcing and to allow the use of a tamping bar around the pole for the full depth of the hole after the pole is set in place. The holes should be of the same diameter throughout their entire depth. The disturbance of too great an area of earth in digging the pole holes will result in the failure of poles to remain lined up.

Pole Setting and Erecting

A. Poles should be set to stand perpendicularly except at corners, curves and other points of exceptional strain, where they may be given a slight rake against the strain. Where practicable, angle and dead end poles should be raked by setting the butts in toward the strain. When placing guys, pull the tops of the poles a little out of line so that when the load is put on and the guys have settled, the pole tops will come back into line, as shown in Fig. 13.

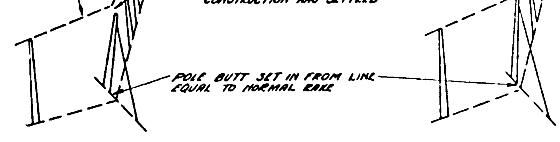

PULL TOP OF POLE OUT OF LINE WHEN PLACING GUYS
LINE OF LEAD
POLE TOP SHALL BE IN LINE AFTER CONSTRUCTION HAS SETTLED
POLE BUTT SET IN FROM LINE EQUAL TO NORMAL RAKE

FIG. 13.

Crossarms

A. Crossarms used should conform in dimension and material with those illustrated in the Overhead Systems Reference Book and subsequent reports prepared by the Overhead Systems Committee of the N. E. L. A., and they should be securely supported so as to withstand safely a vertical load of 225 lb. at either extremity in addition to the weight of the conductors.

B. For single phase construction it is recommended that two-pin crossarms be used, except where it is planned to add additional conductors later or where additional horizontal clearance between conductors is necessary, in which case either a pole top pin should be provided for or a longer crossarm used.

C. For three-phase, three- or four-wire circuits of flat construction, it is recommended that four-pin crossarms be used, except where sags are such that greater separation at the supports is required. In such cases a six-pin crossarm may sometimes be used. For three-phase, three-wire triangular construction in lines of these voltages, arrangement of the wires in a triangle with equal spacing between conductors is not necessary, and somewhat flat triangular construction, using a pole top pin and either a two- or four-pin crossarm, as shown in the accompanying drawings, may be used. This construction gives greater clearance above ground for a given height of pole than the equilateral type of triangular construction.

D. Double crossarms are recommended at dead ends, corners and other places where extra strength is required.

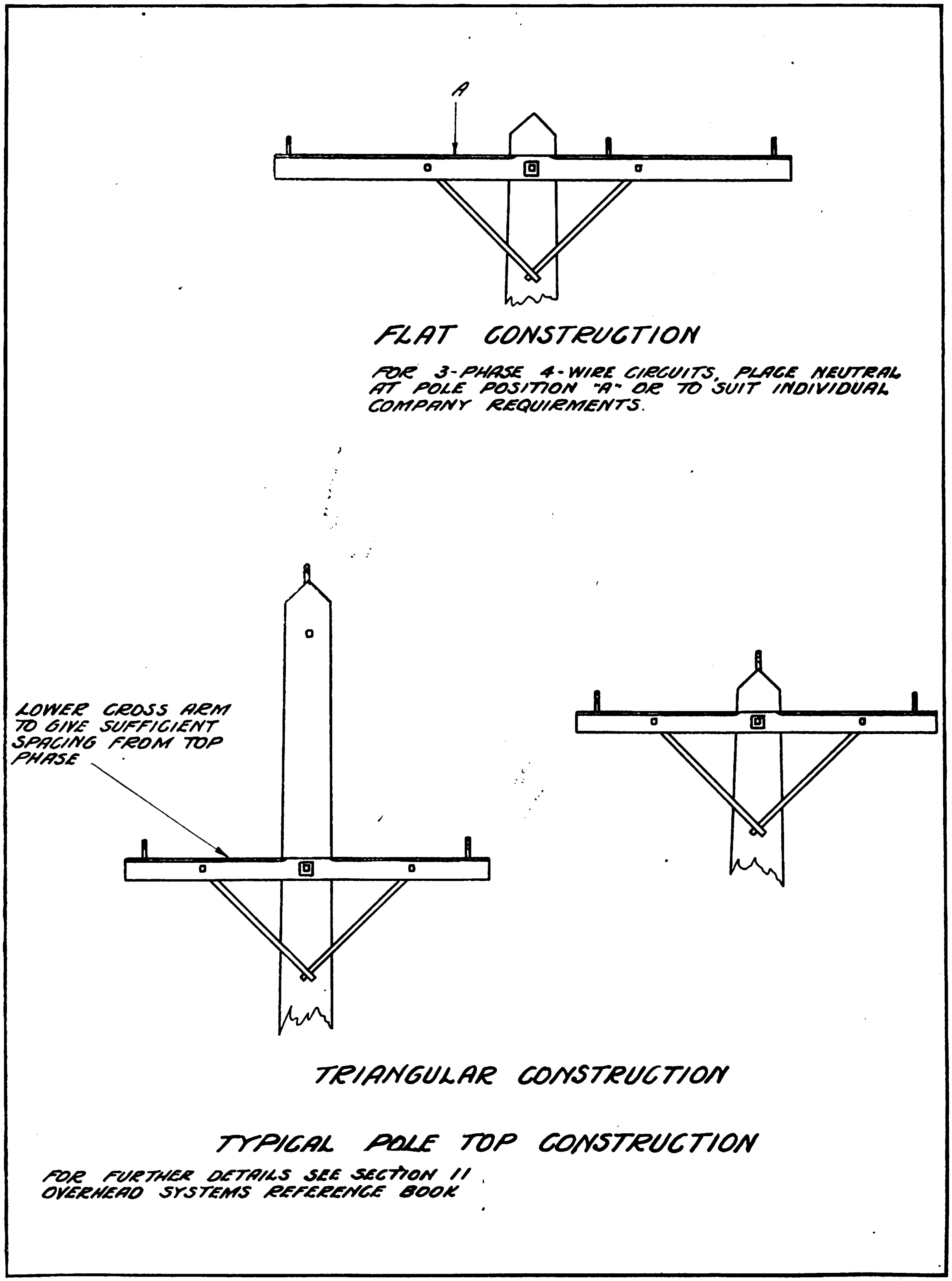
Pins

A. Either wood or metal pins may be used and should comply with the requirements as shown in Section 11 of the Overhead Systems Reference Book and subsequent reports of the Overhead Systems Committee of the N. E. L. A.

Insulators

A. Insulators, if of porcelain, should be made by the wet process. Glass or other material, which will give satisfactory results in respect to mechanical and electrical performance and durability, may be used. All line insulators should conform to the specifications of the American Institute of Electrical Engineers. Experience indicates that it is advisable to use top groove insulators for long span lines.

B. Guy insulators should have a dry flashover voltage at least double the normal line voltage, and a wet flashover at least as high as the normal line voltage between conductors. They should have a mechanical strength at least equal to that required of the guys in which they are installed.



FLAT CONSTRUCTION

FOR 3-PHASE 4-WIRE CIRCUITS, PLACE NEUTRAL AT POLE POSITION "A" OR TO SUIT INDIVIDUAL COMPANY REQUIRMENTS.

LOWER CROSS ARM TO GIVE SUFFICIENT SPACING FROM TOP PHASE

TRIANGULAR CONSTRUCTION

TYPICAL POLE TOP CONSTRUCTION

FOR FURTHER DETAILS SEE SECTION 11 OVERHEAD SYSTEMS REFERENCE BOOK

FIG. 14.

C. An insulator should be located in each guy, which is attached to a pole or structure carrying any supply conductors of more than 300 volts to ground and not more than 15,000 volts between conductors, or in any guy which is exposed to such voltages. This guy insulator should be located from 8 to 10 ft. above the ground.

D. Where a guy attached to a pole is carried over or under overhead supply conductors of more than 300 volts to ground, and where hazard would otherwise exist, two or more guy insulators should be placed so as to include the exposed section of the guy between them as far as practicable. Neither insulator should be within 8 ft. of the ground.

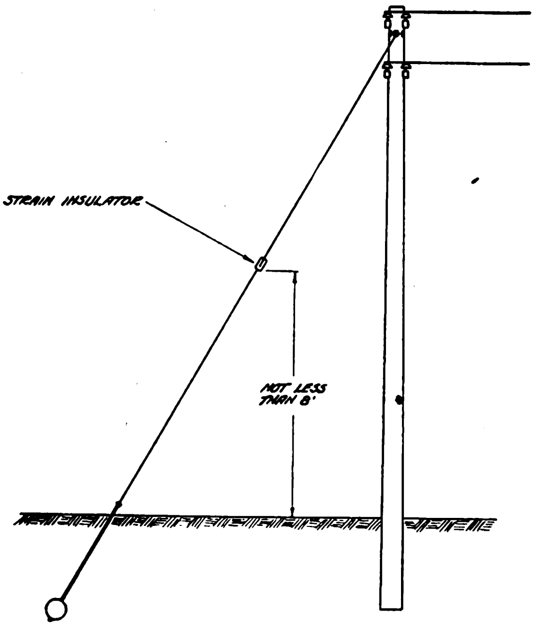
Guys

A. Guys should be installed when the loads imposed are greater than can be safely carried by the poles, and guys will furnish the necessary additional strength, and wherever necessary to counteract any unusual strain which tends to pull the pole or crossarm out of place, as at dead ends, corners, angles in the line and other similar cases.

B. Guys should be used in preference to push braces wherever practicable.

C. In view of the fact that many rural lines must be constructed economically, storm guys may be omitted except where the line traverses a territory for many miles in a straight line; guys at curves and corners often render storm guying unnecessary. When storm guys are attached, dead ends are unnecessary.

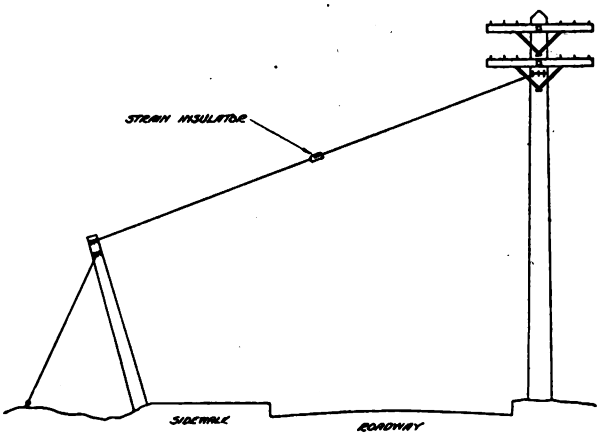
D. The ground end of all guys attached to ground anchors should be provided with a substantial and conspicuous wood or metal guard not less than 8 ft. long where traffic or other conditions warrant.



WHEN INSTALLING TWO STRAIN INSULATORS IN A GUY, ALWAYS MAKE CERTAIN THAT IF A GUY BREAKS AND SWINGS IN TO THE POLE THERE WILL BE AT LEAST ONE INSULATOR BETWEEN ALL LIVE WIRES AND A POINT 8' ABOVE THE GROUND

ANCHOR GUY INSTALLATION

FIG. 15.



WHEN INSTALLING TWO STRAIN INSULATORS IN A GUY, ALWAYS MAKE CERTAIN THAT IF A GUY BREAKS AND SWINGS IN TO THE POLE THERE WILL BE AT LEAST ONE INSULATOR BETWEEN ALL LIVE WIRES AND A POINT 8' ABOVE THE GROUND.

STUB GUY INSTALLATION

FIG. 16.

Anchors

A. Anchors should be set at a distance from the pole at least equal to the height of attachment of the guy above ground, if practicable, and should never be set so that the slope (ratio of lead to the height) is less than 0.33. The nearer the anchor is set to the pole, the less strain it will hold.

B. In locating anchors, good judgment should be exercised. Guys located at property lines, fence corners or other convenient points will be more acceptable to the owners of adjacent property. Anchor locations should be such as to avoid interference with traffic.

C. Either patent anchors or log anchors may be used. The log anchor should be at least 8 in. in diameter and 4 ft. long, and of good sound timber.

Conductors

A. Conductors should be of copper, aluminum cable steel reinforced (A. C. S. R.), copper covered steel, or other material which will not corrode excessively under the prevailing conditions.

B. The use of bare wire is recommended for rural lines. The use of aluminum cable steel reinforced, copper covered steel or other high strength material should be given consideration for long span lines. Conductivity should be taken into account in the selection of conductors.

C. If A. C. S. R. is used, all connections between aluminum conductors and copper conductors should be made with suitable clamps designed for the purpose. At all points where clamps of any type must be used with A. C. S. R., only clamps designed for the purpose should be used.

D. Bare wire may be used for secondaries when on crossarms or when on vertical racks, if the proper spacings are used. In general, where shorter spans are necessary covered wire on vertical rack may be used.

E. Secondary circuits should be of not less carrying capacity than No. 6 A. W. G. copper or No. 4 A. W. G. aluminum cable steel reinforced.

F. Service drops should be not less than No. 8 A. W. G. copper or its equivalent.

Position of Circuits

A. It is preferable that secondary conductors be not placed on the same crossarm with primary conductors.

Sagging of Conductors

A. Table VI gives sags for those sizes of medium and hard drawn bare copper conductors that are likely to be used in the construction of supply lines suitable for rural distribution. These sags are taken from Bureau of Standards Handbook No. 3, Fourth Edition of National Electrical Safety Code.

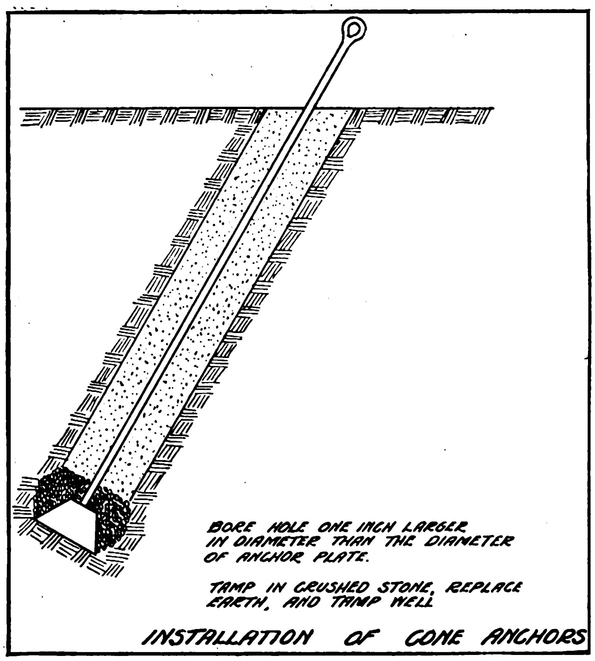

BORE HOLE ONE INCH LARGER IN DIAMETER THAN THE DIAMETER OF ANCHOR PLATE.
TAMP IN CRUSHED STONE, REPLACE EARTH, AND TAMP WELL
INSTALLATION OF CONE ANCHORS

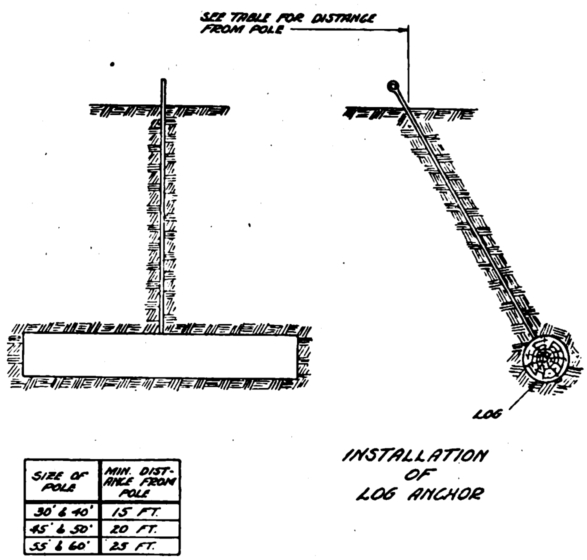
FIG. 17.

B. The sags given herewith are such that under the weather loading conditions specified in the National Electrical Safety Code, the conductor tension will not exceed 60 per cent of its ultimate strength. When lines are involved in crossings with communication lines or railroad tracks, or where they conflict with or are on the same poles with communication lines, sags in accordance with the requirements specified for those cases should be used.

C. Table VII gives the sags for A. C. S. R. (aluminum cable steel reinforced) recommended by the manufacturer for rural line construction.

Ties

A. Conductors should be properly tied to the insulators. Tie wires must have a surface of the same material as the line conductor in order to prevent electrolytic action; should have no sharp edges or burrs at contacts with the conductors; and should be of a size proportionate to the size of the line conductor.


SEE TABLE FOR DISTANCE FROM POLE
LOG
INSTALLATION OF LOG ANCHOR

SIZE OF POLE	MIN. DISTANCE FROM POLE
30' & 40'	15 FT.
45' & 50'	20 FT.
55' & 60'	25 FT.

FIG. 18.

B. Copper line conductors should be tied with annealed copper ties; aluminum conductors should be tied with aluminum tie wires only, and before tying the conductor must be wrapped with aluminum armor wire. For details of the copper ties, see Section 11, Overhead Systems Reference Book.

Lightning Arresters

A. In localities subject to frequent lightning disturbances, the installation of lightning arresters will materially reduce the blowing of fuses at transform-

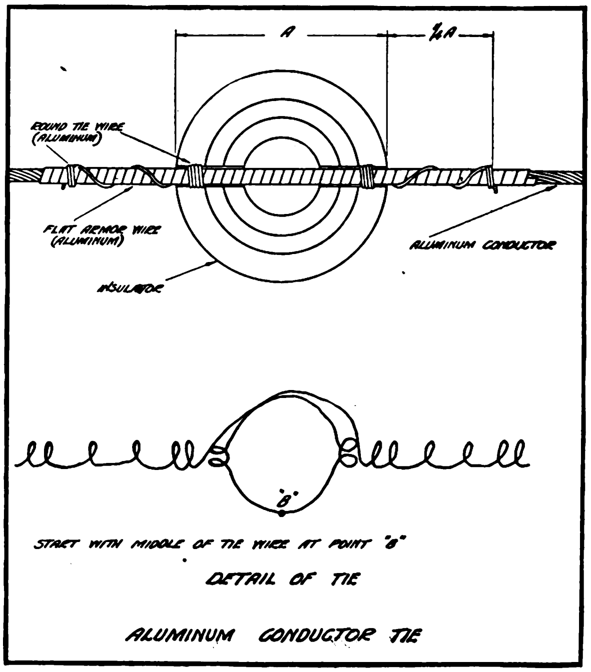

A
¼A
ROUND TIE WIRE (ALUMINUM)
FLAT ARMOR WIRE (ALUMINUM)
INSULATOR
ALUMINUM CONDUCTOR
B
START WITH MIDDLE OF TIE WIRE AT POINT "B"
DETAIL OF TIE
ALUMINUM CONDUCTOR TIE

FIG. 19.

TABLE VI

SAGS FOR HARD AND MEDIUM DRAWN BARE COPPER WIRE FOR DIFFERENT SPAN LENGTHS

Size A.W.G.	Solid and Stranded	Temp. °F.	Sags in Inches for Span Length of 100	125	150	175	200	250	300	400	500
		HEAVY LOADING DISTRICT									
8	Solid	30	4.4	15.6	36.5	....	....	....	....	....	....
		60	6.5	20.4	40.7	....	....	....	....	....	....
		90	9.7	24.6	44.5	....	....	....	....	....	....
6	Solid	30	2.6	5.1	10.6	22.7	....	....	....	....	....
		60	3.1	6.8	14.8	28.6	....	....	....	....	....
		90	4.1	9.4	19.8	34.2	....	....	....	....	....
4	Solid	30	2.2	3.6	6.1	9.4	15.1	37.2	71.0	....	....
		60	2.6	4.5	7.2	11.9	19.4	44.7	79.0	....	....
		90	3.1	5.7	9.5	16.2	25.2	52.2	86.0	....	....
4	Stranded	30	2.2	3.6	5.7	....	14.9	36.0	....	....	....
		60	2.6	4.2	7.2	....	19.2	43.8	....	....	....
		90	3.1	5.4	9.4	....	25.0	51.6	....	....	....
2	Solid	30	2.1	3.4	5.4	7.6	11.0	21.0	38.9	97	172
		60	2.6	4.2	6.5	9.5	13.4	26.4	46.8	106	191
		90	3.1	5.3	7.9	11.8	17.3	33.3	55.4	117	202
2	Stranded	30	2.2	3.3	5.0	....	10.1	19.8	....	....	176
		60	2.4	3.9	5.7	....	12.5	25.2	....	....	186
		90	2.9	4.8	7.5	....	15.8	31.2	....	....	196
1	Solid	30	2.2	3.3	5.0	7.6	10.1	18.3	31.7	77.8	148
		60	2.6	3.9	6.5	9.0	12.5	22.8	38.9	88.4	157
		90	3.2	5.2	7.9	11.3	15.8	28.8	46.8	98.4	168
1	Stranded	30	2.2	3.3	5.0	....	10.1	17.4	....	....	146
		60	2.6	3.9	6.1	....	12.0	23.4	....	....	157
		90	3.1	5.1	7.9	....	15.4	27.6	....	....	167
0	Solid	30	2.2	3.3	5.2	7.6	10.1	17.4	28.4	65.8	122
		60	2.6	4.2	6.5	8.8	12.5	21.6	34.9	75.8	135
		90	3.4	5.3	7.9	11.6	15.6	26.7	42.5	86.4	146
0	Stranded	30	2.2	3.3	5.0	....	9.1	15.6	....	....	113
		60	2.4	3.9	5.8	....	11.0	19.8	....	....	119
		90	2.9	4.8	6.8	....	13.4	23.4	....	....	137
00	Solid	30	2.3	3.6	5.2	7.6	10.1	16.8	26.6	58.1	106
		60	2.8	4.3	6.3	9.0	12.2	21.0	32.4	68.2	117
		90	3.4	5.4	8.1	11.3	15.1	26.1	39.6	77.8	129
00	Stranded	30	2.2	3.3	4.7	....	9.1	15.0	....	....	96
		60	2.6	3.9	5.8	....	10.6	18.0	....	....	107
		90	3.1	4.8	7.2	....	13.0	22.2	....	....	120
		MEDIUM LOADING DISTRICT									
8	Solid	30	2.0	3.3	5.6	....	....	....	....	....	....
		60	2.3	3.9	6.7	....	....	....	....	....	....
		90	2.8	4.9	8.8	....	....	....	....	....	....
6	Solid	30	1.9	3.1	4.7	6.7	....	....	....	....	....
		60	2.2	3.4	5.4	8.0	....	....	....	....	....
		90	2.6	4.3	6.5	9.7	....	....	....	....	....
4	Solid	30	1.9	3.0	4.5	6.1	8.2	13.5	21.9	53.8	....
		60	2.2	3.3	5.0	6.9	9.4	16.2	26.6	63.4	....
		90	2.6	3.9	5.9	8.2	11.3	19.5	32.4	74.4	....
4	Stranded	30	1.9	3.0	4.3	....	8.2	13.2	....	....	....
		60	2.2	3.3	5.0	....	9.1	15.6	....	....	....
		90	2.4	3.9	5.7	....	11.0	19.8	....	....	....
2	Solid	30	1.9	3.0	4.5	6.1	8.2	12.6	19.8	41.3	75.0
		60	2.2	3.5	5.0	6.9	9.1	15.3	23.0	49.0	86.4
		90	2.6	4.0	5.9	8.4	11.3	18.3	28.1	57.1	98.4
2	Stranded	30	1.9	3.0	4.3	....	7.7	12.6	....	....	74.4
		60	2.2	3.3	5.0	....	9.1	14.4	....	....	85.2
		90	2.6	3.9	5.7	....	11.0	17.4	....	....	97.2
1	Solid	30	2.0	3.1	4.3	5.7	8.2	13.2	19.4	38.4	68.4
		60	2.3	3.4	5.0	7.1	9.1	15.0	23.0	45.1	78.6
		90	2.8	4.2	6.3	8.4	11.3	18.6	27.3	53.2	90.0
1	Stranded	30	1.9	3.0	4.3	....	7.7	12.6	....	....	68.4
		60	2.2	3.3	5.0	....	9.1	15.0	....	....	79.2
		90	2.6	4.2	6.1	....	11.0	17.4	....	....	90.0
0	Solid	30	2.0	3.1	4.5	6.3	8.4	13.2	19.4	37.4	64.8
		60	2.4	3.6	5.2	7.3	9.6	15.6	23.0	44.2	74.4
		90	2.9	4.5	6.5	8.8	11.5	19.2	27.4	51.8	86.4
0	Stranded	30	1.9	3.0	4.3	....	7.7	12.0	....	....	60.0
		60	2.2	3.3	5.0	....	8.6	14.4	....	....	69.6
		90	2.6	3.9	5.8	....	10.6	16.8	....	....	79.2
00	Solid	30	2.2	3.3	4.7	6.3	8.4	13.5	19.8	37.4	62.4
		60	2.5	3.7	5.4	7.6	10.1	15.9	23.4	44.6	72.0
		90	3.0	4.6	6.7	9.0	12.0	19.2	28.1	51.8	82.8
00	Stranded	30	1.9	3.0	4.3	....	7.7	12.6	....	....	58.8
		60	2.4	3.3	5.0	....	9.1	14.4	....	....	67.2
		90	2.9	4.2	6.1	....	11.0	16.8	....	....	76.8
		LIGHT LOADING DISTRICT									
8	Solid	30	1.6	2.5	3.6	5.0	....	....	....	....	....
		60	1.9	2.8	4.3	5.7	....	....	....	....	....
		90	2.2	3.3	4.8	6.3	....	....	....	....	....
6	Solid	30	1.7	2.7	4.0	5.0	6.7	....	....	....	....
		60	2.0	3.0	4.5	5.9	7.7	....	....	....	....
		90	2.2	3.4	4.9	6.7	8.6	....	....	....	....
4	Solid	30	1.7	2.8	3.8	5.0	6.7	10.8	15.1	27.8	45.0
		60	1.9	3.0	4.5	6.1	7.9	12.0	17.3	31.7	51.0
		90	2.3	3.4	5.0	6.7	8.9	13.8	20.2	36.5	58.8
4	Stranded	30	1.7	2.4	3.6	....	6.7	10.2	....	....	45.6
		60	1.9	3.0	4.3	....	7.2	11.4	....	....	52.8
		90	2.2	3.3	4.7	....	8.6	13.8	....	....	60.0
2	Solid	30	1.7	2.7	4.3	5.5	7.0	10.8	15.8	28.8	45.6
		60	2.0	3.3	4.7	6.1	8.2	12.6	18.0	33.1	52.2
		90	2.4	3.4	5.2	7.1	9.1	15.3	20.9	37.9	60.0
2	Stranded	30	1.7	2.4	4.0	....	6.7	10.2	....	....	45.6
		60	1.9	3.0	4.3	....	7.7	12.0	....	....	51.6
		90	2.4	3.6	5.0	....	9.1	13.8	....	....	60.0
1	Solid	30	1.8	2.7	4.1	5.5	7.2	11.1	15.8	29.3	46.2
		60	2.2	3.3	4.7	6.3	8.2	12.9	18.7	33.6	53.4
		90	2.5	3.8	5.4	7.4	9.6	15.0	22.0	39.4	61.2
1	Stranded	30	1.9	2.7	4.0	....	7.2	10.8	....	....	46.8
		60	2.2	3.0	4.3	....	8.2	12.6	....	....	54.0
		90	2.4	3.6	5.0	....	9.6	14.4	....	....	61.2
0	Solid	30	1.9	3.0	4.3	5.7	7.4	11.4	16.6	29.7	47.4
		60	2.2	3.3	4.9	6.5	8.6	13.5	19.1	34.5	54.6
		90	2.5	3.9	5.8	7.8	10.1	15.6	22.3	40.8	63.0
0	Stranded	30	1.7	2.7	4.0	....	6.7	10.8	....	....	45.6
		60	1.9	3.3	4.7	....	7.7	12.6	....	....	52.8
		90	2.4	3.6	5.4	....	9.1	14.4	....	....	60.0
00	Solid	30	1.9	3.2	4.5	5.9	7.7	12.0	17.3	30.7	48.6
		60	2.2	3.4	5.0	6.7	8.9	13.8	19.4	36.0	55.8
		90	2.6	4.1	5.9	8.0	10.6	16.2	23.0	41.3	64.2
00	Stranded	30	1.9	3.0	4.3	....	7.2	10.8	....	....	46.8
		60	2.2	3.3	4.7	....	8.2	12.6	....	....	52.8
		90	2.4	3.6	5.4	....	9.6	15.0	....	....	60.0

TABLE VII

SAGS FOR ALUMINUM CABLE STEEL REINFORCED (A. C. S. R.) FOR DIFFERENT SPAN LENGTHS

A.C.S.R. Gauge No. (A.W.G.)	Temp., °F.	Sags in Feet for Span Lengths of										
		100	150	200	250	300	350	400	500	600	700	800
		HEAVY LOADING DISTRICT										
8	−20	0.3	0.7	3.6	9.0	....	....	....	....	....	....	....
	0 Loaded	2.9	4.8	8.5	13.5	....	....	....	....	....	....	....
	0	0.3	0.6	3.5	9.0	....	....	....	....	....	....	....
	32	0.3	0.6	3.8	9.1	....	....	....	....	....	....	....
	60	0.7	0.9	4.3	9.7	....	....	....	....	....	....	....
	120	0.8	1.2	4.7	9.8	....	....	....	....	....	....	....
6	−20	0.3	0.5	0.7	2.5	6.2	....	....	....	....	....	....
	0 Loaded	2.5	4.0	5.6	8.8	12.7	....	....	....	....	....	....
	0	0.3	0.6	0.8	2.5	6.5	....	....	....	....	....	....
	32	0.3	0.6	0.8	2.8	6.7	....	....	....	....	....	....
	60	0.7	0.9	1.2	3.5	7.3	....	....	....	....	....	....
	120	0.8	1.2	1.7	3.8	7.8	....	....	....	....	....	....
4	−20	0.3	0.5	0.7	0.8	1.7	3.6	6.5	....	....	....	....
	0 Loaded	2.2	3.4	4.7	6.4	8.5	11.7	15.3	....	....	....	....
	0	0.3	0.6	0.8	1.0	1.7	3.7	6.7	....	....	....	....
	32	0.3	0.6	0.8	1.2	2.0	3.8	7.0	....	....	....	....
	60	0.7	0.9	1.2	1.5	2.3	4.3	7.6	....	....	....	....
	120	0.8	1.2	1.7	2.2	2.7	5.1	8.4	....	....	....	....
2	−20	0.3	0.5	0.7	0.8	1.1	1.3	2.2	6.6	....	....	....
	0 Loaded	1.8	2.8	4.0	5.3	6.6	8.2	10.5	16.5	....	....	....
	0	0.3	0.6	0.8	1.0	1.2	1.4	2.5	7.0	....	....	....
	32	0.3	0.6	0.8	1.2	1.4	1.7	3.1	7.5	....	....	....
	60	0.7	0.9	1.2	1.5	1.8	2.3	3.8	8.3	....	....	....
	120	0.8	1.2	1.7	2.2	2.6	3.0	4.4	9.2	....	....	....
1	−20	0.3	0.5	0.7	0.8	1.1	1.3	1.7	4.0	8.9	....	....
	0 Loaded	1.7	2.6	3.7	4.8	6.0	7.4	8.8	13.7	19.7	....	....
	0	0.3	0.6	0.8	1.0	1.2	1.4	1.8	4.4	9.1	....	....
	32	0.3	0.6	0.8	1.2	1.4	1.7	2.2	5.2	10.3	....	....
	60	0.7	0.9	1.2	1.5	1.8	2.2	2.7	6.2	11.4	....	....
	120	0.8	1.2	1.7	2.2	2.6	3.0	3.6	7.0	12.2	....	....
1/0	−20	0.3	0.5	0.7	0.8	1.1	1.3	1.5	2.7	5.7	....	....
	0 Loaded	1.6	2.4	3.4	4.4	5.5	6.7	8.0	11.7	17.0	....	....
	0	0.3	0.6	0.8	1.0	1.2	1.4	1.7	3.1	6.4	....	....
	32	0.3	0.6	0.8	1.2	1.4	1.7	1.9	3.7	7.7	....	....
	60	0.7	0.9	1.2	1.5	1.8	2.2	2.4	4.7	8.6	....	....
	120	0.8	1.2	1.7	2.2	2.6	3.0	3.5	5.8	9.7	....	....
2/0	−20	0.3	0.5	0.7	0.8	1.1	1.3	1.5	2.2	4.0	7.2	....
	0 Loaded	1.5	2.3	3.1	4.0	5.1	6.2	7.3	10.0	14.3	19.5	....
	0	0.3	0.6	0.8	1.0	1.2	1.4	1.7	2.3	4.5	8.2	....
	32	0.3	0.6	0.8	1.2	1.4	1.7	1.9	2.8	5.3	9.7	....
	60	0.7	0.9	1.2	1.5	1.8	2.2	2.4	3.5	6.6	11.0	....
	120	0.8	1.2	1.7	2.2	2.6	3.0	3.5	5.1	8.2	12.5	....
3/0	−20	0.3	0.5	0.7	0.8	1.1	1.3	1.5	1.8	3.3	5.6	8.8
	0 Loaded	1.4	2.0	2.8	3.7	4.6	5.6	6.5	8.6	12.4	17.0	22.0
	0	0.3	0.6	0.8	1.0	1.2	1.4	1.7	2.1	3.6	6.0	9.8
	32	0.3	0.6	0.8	1.2	1.4	1.7	1.9	2.5	4.2	7.3	....
	60	0.7	0.9	1.2	1.5	1.8	2.2	2.4	3.1	5.5	8.8	....
	120	0.8	1.2	1.7	2.2	2.6	3.0	3.5	4.5	7.2	10.7	....
4/0	−20	0.3	0.5	0.7	0.8	1.1	1.3	1.5	1.8	2.7	4.3	6.7
	0 Loaded	1.3	1.8	2.5	3.4	4.2	5.0	5.9	7.7	10.6	14.5	19.0
	0	0.3	0.6	0.8	1.0	1.2	1.4	1.7	2.1	3.2	4.9	7.7
	32	0.3	0.6	0.8	1.2	1.4	1.7	1.9	2.5	3.7	6.0	9.1
	60	0.7	0.9	1.2	1.5	1.8	2.2	2.4	3.1	4.6	7.1	10.5
	120	0.8	1.2	1.7	2.2	2.6	3.0	3.5	4.4	6.5	9.5	....
		MEDIUM LOADING DISTRICT										
8	15 Loaded	2.2	3.6	5.3	8.0	11.6	....	....	....	....	....	....
	0	0.3	0.6	0.8	2.8	6.4	....	....	....	....	....	....
	32	0.4	0.7	1.0	3.2	6.8	....	....	....	....	....	....
	60	0.5	0.8	1.4	3.5	7.2	....	....	....	....	....	....
	120	0.7	1.2	1.7	4.2	7.9	12.3	....	....	....	....	....
6	15 Loaded	1.8	3.0	4.3	5.8	7.9	10.8	14.2	....	....	....	....
	0	0.3	0.6	0.8	1.0	1.7	4.3	7.7	....	....	....	....
	32	0.4	0.7	1.0	1.2	2.5	5.0	8.2	....	....	....	....
	60	0.5	0.8	1.2	1.5	3.0	5.5	8.7	....	....	....	....
	120	0.7	1.2	1.7	2.2	3.7	6.3	9.6	....	....	....	....
4	15 Loaded	1.5	2.6	3.7	5.0	6.3	7.6	9.7	15.3	....	....	....
	0	0.3	0.6	0.8	1.0	1.2	1.5	2.3	6.5	....	....	....
	32	0.4	0.7	1.0	1.2	1.5	1.7	3.1	8.0	....	....	....
	60	0.5	0.8	1.2	1.5	1.7	2.2	3.9	8.8	....	....	....
	120	0.7	1.2	1.7	2.2	2.6	3.5	5.2	10.0	....	....	....
2	15 Loaded	1.4	2.2	3.2	4.2	5.2	6.4	7.5	10.9	15.8	....	....
	0	0.3	0.6	0.8	1.0	1.2	1.5	1.7	3.0	6.1	....	....
	32	0.4	0.7	1.0	1.2	1.5	1.7	2.0	3.8	7.6	....	....
	60	0.5	0.8	1.2	1.5	1.7	2.1	2.4	4.7	9.0	....	....
	120	0.7	1.2	1.7	2.2	2.6	3.1	3.8	7.1	11.4	....	....
1	15 Loaded	1.3	2.0	2.9	3.8	4.8	5.7	6.7	9.3	13.4	18.3	....
	0	0.3	0.6	0.8	1.0	1.2	1.5	1.7	2.5	4.6	8.0	....
	32	0.4	0.7	1.0	1.2	1.5	1.7	2.0	3.1	5.7	9.7	....
	60	0.5	0.8	1.2	1.5	1.7	2.1	2.4	3.7	6.8	11.2	....
	120	0.7	1.2	1.7	2.2	2.6	3.1	3.5	5.9	9.6	....	....
1/0	15 Loaded	1.2	1.9	2.7	3.5	4.4	5.3	6.2	8.0	11.7	15.9	20.8
	0	0.3	0.6	0.8	1.0	1.2	1.5	1.7	2.2	3.7	6.4	....
	32	0.4	0.7	1.0	1.2	1.5	1.7	2.0	2.7	4.6	7.7	....
	60	0.5	0.8	1.2	1.5	1.7	2.1	2.4	3.2	5.5	9.0	....
	120	0.7	1.2	1.7	2.2	2.6	3.1	3.5	5.0	8.2	12.2	....
2/0	15 Loaded	1.1	1.7	2.5	3.2	4.0	4.8	5.6	7.3	10.2	13.8	18.0
	0	0.3	0.6	0.8	1.0	1.2	1.5	1.7	2.2	3.3	5.3	8.0
	32	0.4	0.7	1.0	1.2	1.5	1.7	2.0	2.5	4.0	6.4	9.7
	60	0.5	0.8	1.2	1.5	1.7	2.1	2.4	3.0	4.8	7.5	11.1
	120	0.7	1.2	1.7	2.2	2.6	3.1	3.5	4.6	7.3	10.5	....
3/0	15 Loaded	1.0	1.6	2.2	2.8	3.5	4.3	5.0	6.5	9.0	12.2	16.0
	0	0.3	0.6	0.8	1.0	1.2	1.5	1.7	2.2	3.1	4.7	6.8
	32	0.4	0.7	1.0	1.2	1.5	1.7	2.0	2.5	3.7	5.7	8.2
	60	0.5	0.8	1.2	1.5	1.7	2.1	2.4	3.0	4.3	6.5	9.6
	120	0.7	1.2	1.7	2.2	2.6	3.1	3.5	4.5	6.7	9.5	....
4/0	15 Loaded	1.0	1.5	2.0	2.7	3.3	4.0	4.5	5.9	8.0	10.8	14.1
	0	0.3	0.6	0.8	1.0	1.2	1.5	1.7	2.2	2.9	4.2	6.0
	32	0.4	0.7	1.0	1.2	1.5	1.7	2.0	2.5	3.5	5.1	7.2
	60	0.5	0.8	1.2	1.5	1.7	2.1	2.4	3.0	4.1	5.8	8.5
	120	0.7	1.2	1.7	2.2	2.6	3.1	3.5	4.5	6.0	8.6	11.6
		LIGHT LOADING DISTRICT										
8	32 Loaded	1.4	2.2	3.2	4.3	5.5	6.7	8.5	13.3	....	....	....
	32	0.5	0.7	1.0	1.2	1.5	1.7	2.7	6.5	....	....	....
	60	0.5	0.8	1.2	1.4	1.8	2.1	3.5	7.7	....	....	....
	120	0.7	1.2	1.7	2.2	2.6	3.8	5.7	10.2	....	....	....
6	32 Loaded	1.2	2.0	3.0	3.9	4.9	6.0	7.0	10.7	....	....	....
	32	0.5	0.7	1.0	1.2	1.5	1.7	2.0	4.1	7.4	....	....
	60	0.5	0.8	1.2	1.4	1.8	2.1	2.4	5.2	....	....	....
	120	0.7	1.2	1.7	2.2	2.6	3.1	4.2	8.0	....	....	....
4	32 Loaded	1.1	1.8	2.6	3.5	4.2	5.2	6.1	8.5	12.4	....	....
	32	0.5	0.7	1.0	1.2	1.5	1.7	2.0	3.0	5.2	....	....
	60	0.5	0.8	1.2	1.4	1.8	2.1	2.4	3.7	6.4	....	....
	120	0.7	1.2	1.7	2.2	2.6	3.1	3.5	5.8	9.3	....	....
2	32 Loaded	1.0	1.6	2.4	3.1	3.8	4.6	5.4	7.1	10.2	14.0	....
	32	0.5	0.7	1.0	1.2	1.5	1.7	2.0	2.6	4.3	6.7	....
	60	0.5	0.8	1.2	1.4	1.8	2.1	2.4	3.2	5.2	8.1	....
	120	0.7	1.2	1.7	2.2	2.6	3.1	3.5	5.1	8.0	11.5	....
1	32 Loaded	0.9	1.6	2.2	2.9	3.6	4.2	5.0	6.5	9.3	12.7	....
	32	0.5	0.7	1.0	1.2	1.5	1.7	2.0	2.5	4.1	6.2	....
	60	0.5	0.8	1.2	1.4	1.8	2.1	2.4	3.1	4.8	7.4	....
	120	0.7	1.2	1.7	2.2	2.6	3.1	3.5	4.8	7.4	10.5	....
1/0	32 Loaded	0.9	1.5	2.1	2.7	3.4	4.0	4.7	6.0	8.6	11.7	....
	32	0.5	0.7	1.0	1.2	1.5	1.7	2.0	2.5	3.9	5.8	....
	60	0.5	0.8	1.2	1.4	1.8	2.1	2.4	3.0	4.6	6.8	....
	120	0.7	1.2	1.7	2.2	2.6	3.1	3.5	4.6	7.0	9.8	....
2/0	32 Loaded	0.8	1.4	2.0	2.6	3.2	3.7	4.3	5.7	7.8	10.7	....
	32	0.5	0.7	1.0	1.2	1.5	1.7	2.0	2.5	3.8	5.7	....
	60	0.5	0.8	1.2	1.4	1.8	2.1	2.4	3.0	4.5	6.5	....
	120	0.7	1.2	1.7	2.2	2.6	3.1	3.5	4.5	6.7	9.4	....
3/0	32 Loaded	0.7	1.3	1.8	2.4	3.0	3.5	4.1	5.2	7.2	9.9	13.0
	32	0.5	0.7	1.0	1.2	1.5	1.7	2.0	2.5	3.7	5.4	7.3
	60	0.5	0.8	1.2	1.4	1.8	2.1	2.4	3.0	4.3	6.2	8.5
	120	0.7	1.2	1.7	2.2	2.6	3.1	3.5	4.5	6.4	9.0	....
4/0	32 Loaded	0.7	1.2	1.7	2.2	2.7	3.2	3.7	4.8	6.7	9.2	12.0
	32	0.5	0.7	1.0	1.2	1.5	1.7	2.0	2.5	3.6	5.2	7.0
	60	0.5	0.8	1.2	1.4	1.8	2.1	2.4	3.0	4.2	6.0	8.2
	120	0.7	1.2	1.7	2.2	2.6	3.1	3.5	4.5	6.2	8.6	11.5

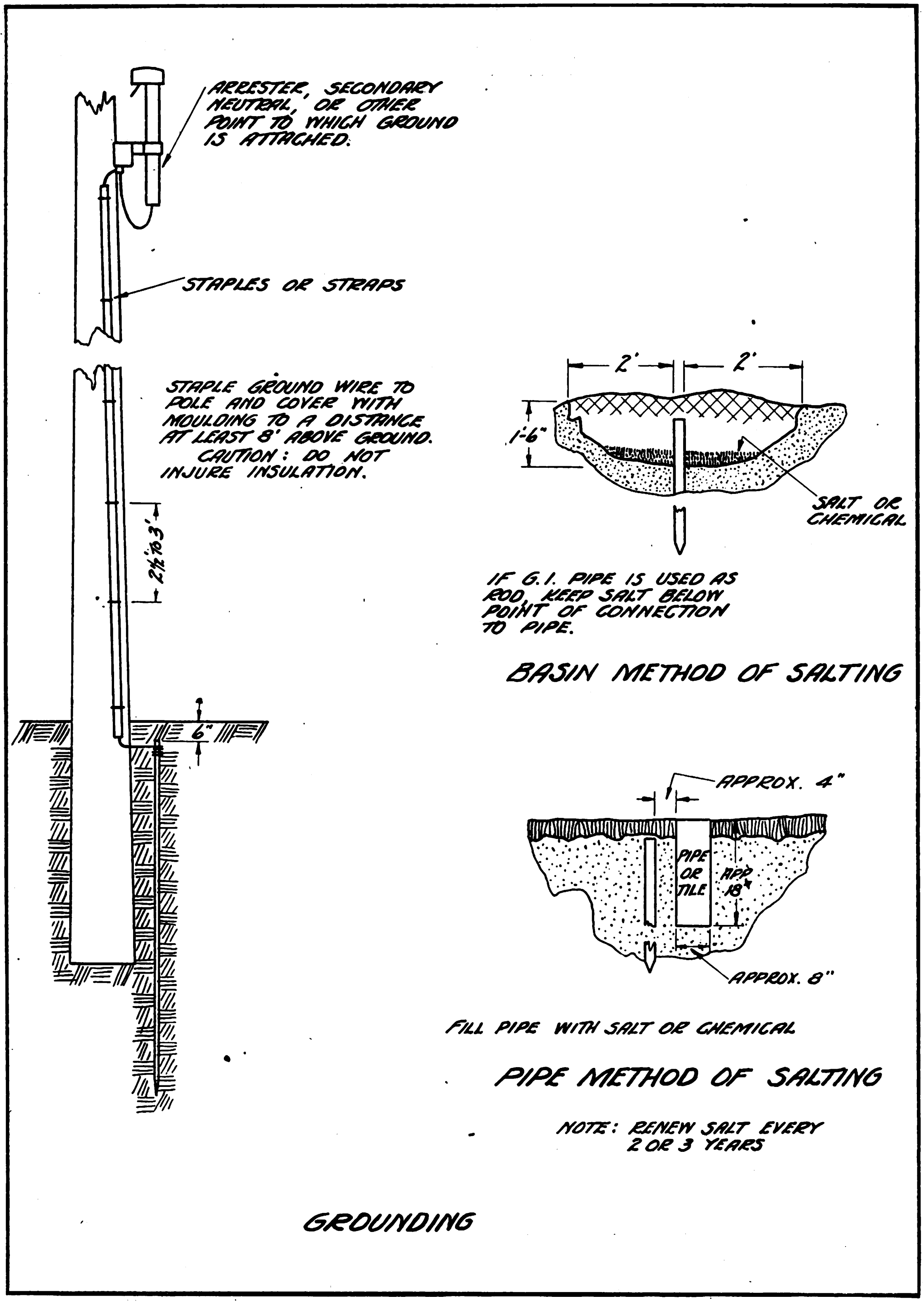

ARRESTER, SECONDARY NEUTRAL, OR OTHER POINT TO WHICH GROUND IS ATTACHED.
STAPLES OR STRAPS
STAPLE GROUND WIRE TO POLE AND COVER WITH MOULDING TO A DISTANCE AT LEAST 8' ABOVE GROUND.
CAUTION: DO NOT INJURE INSULATION.
2½' TO 3'
6"
2'
2'
1'-6"
SALT OR CHEMICAL
IF G.I. PIPE IS USED AS ROD, KEEP SALT BELOW POINT OF CONNECTION TO PIPE.
BASIN METHOD OF SALTING
APPROX. 4"
PIPE OR TILE
APP. 18"
APPROX. 8"
FILL PIPE WITH SALT OR CHEMICAL
PIPE METHOD OF SALTING
NOTE: RENEW SALT EVERY 2 OR 3 YEARS
GROUNDING

FIG. 20.

ers and will also give limited protection against injury to the transformers. No definite recommendation as to the installation of lightning arresters can be given, except that they should be placed on the same pole with the equipment they are to protect. Experience is the chief factor in determining where and when to install arresters.

Branch Line Cutouts

A. Branches may be connected to the main line through fused cutouts to facilitate main line operation. Fuses should not be installed in the cutout for the neutral or grounded conductor of the primary. No definite recommendations can be made regarding the size of fuse, as conditions vary greatly; the size fuse to be used is largely a matter of experience.

Grounding

A. Grounds should be installed on all lightning arresters, on the cases of all the transformers mounted on the ground or mounted on steel framework; and on the neutrals of secondaries of all transformers operating at a potential of 230 volts or less, except that they may be omitted in the case of transformer banks for strictly power purposes.

B. Lightning arresters should not make use of the same ground connection which serves for the secondary except where a grounded common neutral system is used.

C. Grounding wires should have a conductivity at least equal to that of No. 6 A. W. G. copper and should be protected from mechanical injury for a distance of at least 8 ft. above the ground with wood molding or its equivalent.

D. The ground resistance should preferably be not more than 3 ohms for water pipes and 25 ohms for artificial or driven grounds. Driven or artificial grounds, particularly in light dry soil, may be uncertain, and consequently efforts should always be made to have the rod or pipe extend far enough into the earth to reach permanently moist soil. If the ground resistance is too high, it may be lowered by the installation of additional rods or pipes, or by the use of zinc chloride or salt, a solution of which is used to saturate the earth around the ground rod and additional quantities of the salt periodically placed in a hollow dug in the earth around the rod near the top.

E. For further information on the subject of protective grounding methods, refer to Section 9 of Handbook No. 3 of the Bureau of Standards, Fourth Edition of the National Electrical Safety Code.

Transformer Installations

A. A method of mounting transformers is shown in the following drawing. For further information refer to Section 11, Overhead Systems Reference Book.

B. In making transformer installations, particular care should be exercised to provide supports strong enough to keep the transformer in position and to so locate the transformer, its fuses and wiring, that the installation will be accessible, safe to work on and will present a neat appearance.

C. Transformers should be mounted high enough so that no live parts shall be less than 15 ft. from the ground, except that large transformers may be mounted lower than this, provided the location permits building a protective fence at least 8 ft. high.

D. Primary leads should be brought down the pole in such a manner as to properly clear all other wires and attachments and to leave ample room for working safely on the pole.

E. Fuse boxes or cutouts should be mounted on the side of the crossarm or pole opposite the transformer, should be so located that they can be pulled from below, and should also be so located as to keep the climbing space clear.

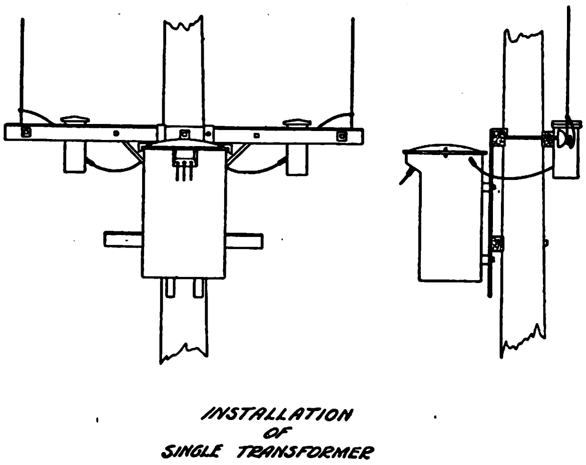


FIG. 21.

F. Lightning arresters to protect the transformer installation should be mounted on the crossarm with the transformer, if practicable.

Services

A. In order to provide capacity for future growth of load and also to reduce voltage drop in the secondary, service and entrance, it is strongly urged that three-wire entrances for 115/230 volts be installed for all service connections, and that service wires be preferably not less than No. 8 A. W. G.

Economical Use and Spacing of Rural Line Transformers

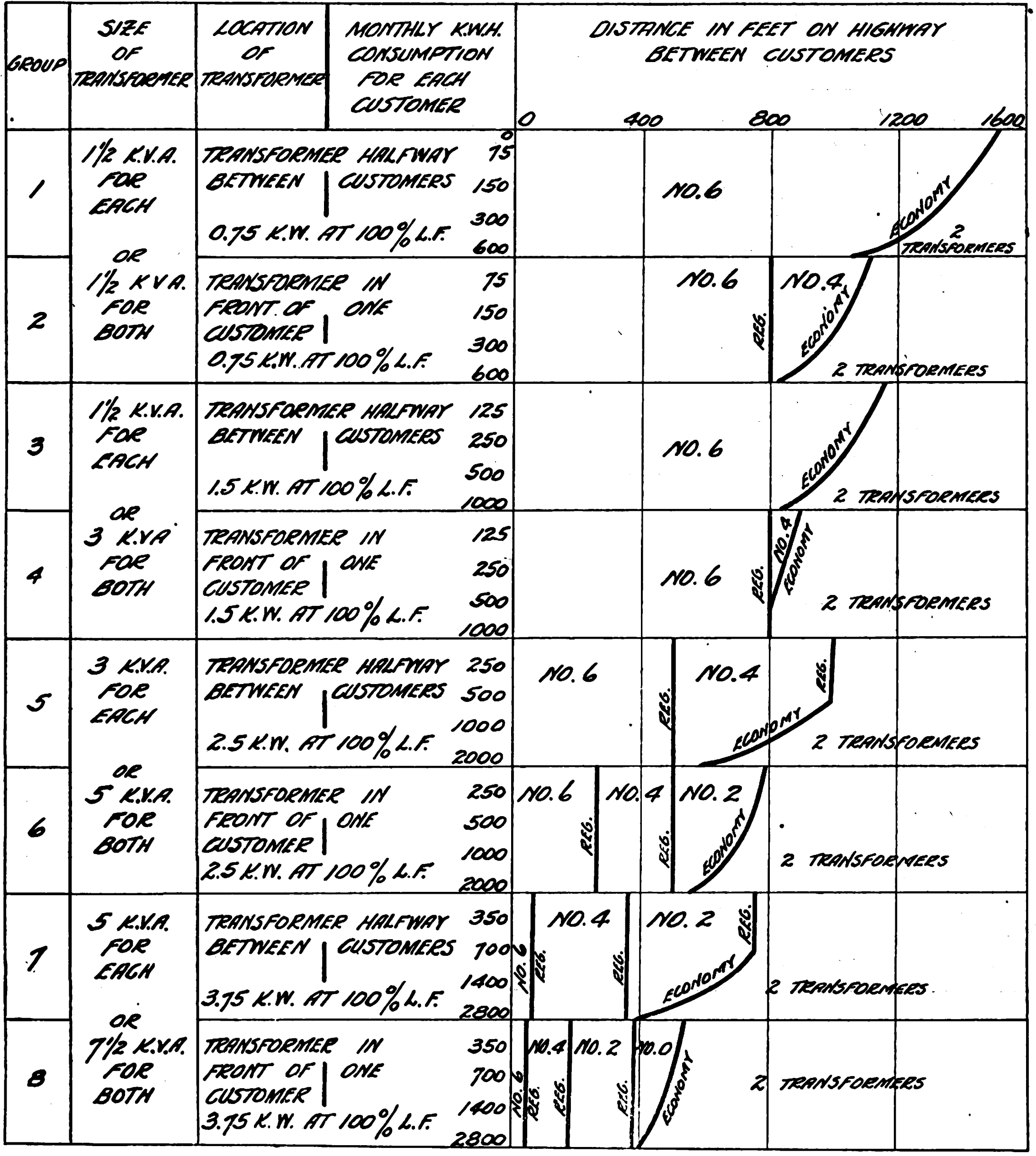
A. Following is a discussion of the economy of extending secondaries versus installing additional transformers on rural lines. The return, fixed charges and cost figures quoted are intended to be illustrative only. It should be understood that such figures cannot be representative of costs generally, for all territories and local conditions, or for all present or future dates. In individual instances the operating company concerned can substitute its own actual costs, and therefrom draw conclusions which will apply accurately to its own conditions.

B. Fig. 22 and 23 and instructions given below cover the above subject and have been drawn up primarily for use in the field. With the data at hand, additional typical problems can be added if desired.

ECONOMICAL USE & LOCATION OF RURAL TRANSFORMERS

THE 3% LIMIT OF REGULATION USED IS THAT ON THE LOADED SIDE OF A 3 WIRE SECONDARY WITH CURRENT IN ONE OUTSIDE WIRE EQUAL TO FULL LOAD ON THE SIZE TRANSFORMER NECESSARY TO SERVE CUSTOMER SEPARATELY, WITH 30% CURRENT IN NEUTRAL AND 70% CURRENT IN OTHER OUTSIDE WIRE WITH LOAD AT 80% POWER FACTOR. ON THIS BASIS IT IS ASSUMED THAT THE WINTER PEAK LOAD MIGHT OVERLOAD TRANSFORMER 50% FOR SHORT INTERVALS GIVING 4.5% SECONDARY REGULATION AS A MAXIMUM. IT IS ASSUMED, THEREFORE, THAT THE SELECTION OF TRANSFORMER SIZE WILL BE GOVERNED ACCORDINGLY. TO GAIN HIGHEST ECONOMY AND ALSO TO KEEP THE VOLTAGE REGULATION IN SECONDARY AND SERVICE WITHIN 3%, THE FOLLOWING SIZE OF WIRE IS REQUIRED.

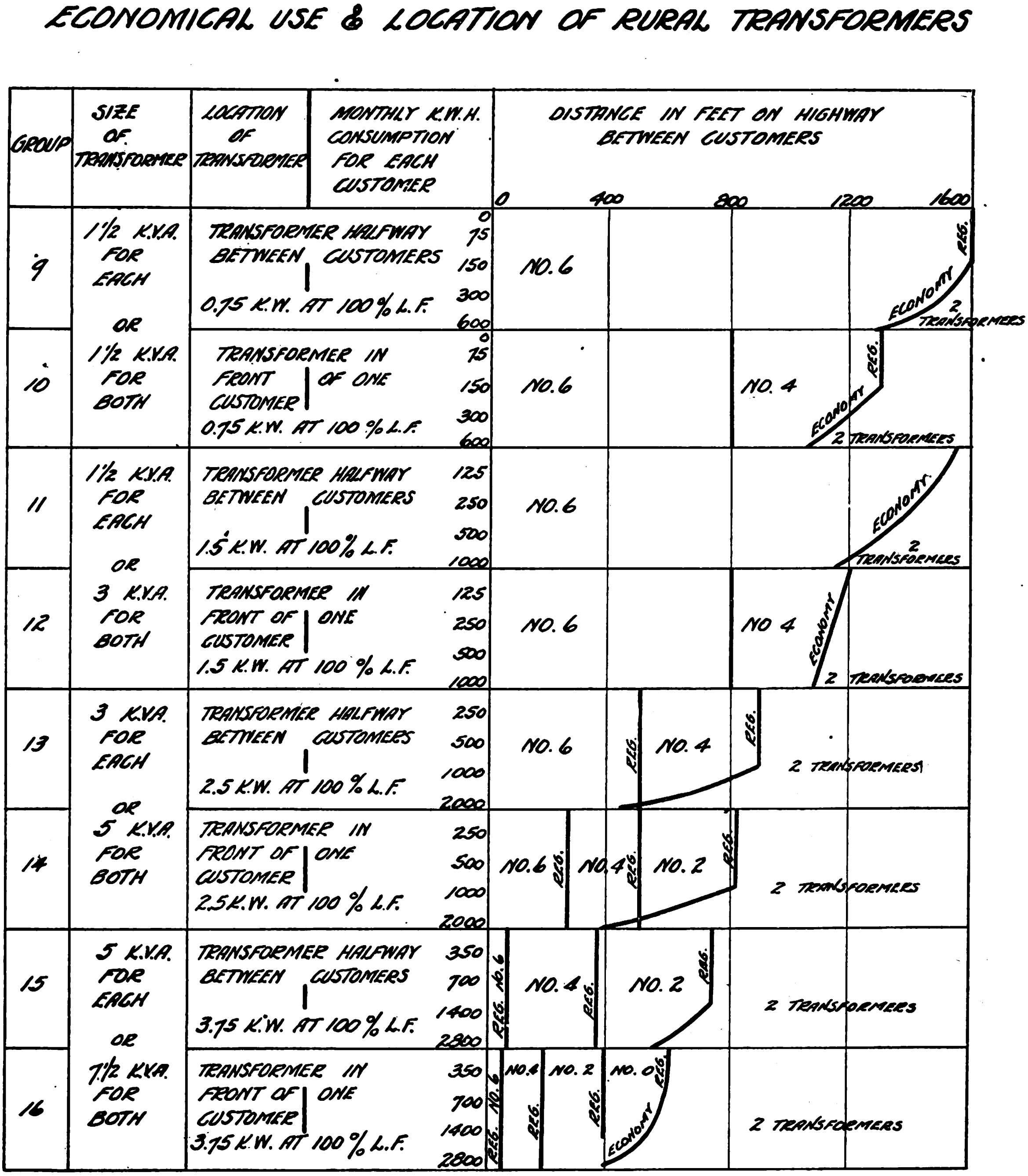
ASSUME EACH CUSTOMER HAS A 115-230 VOLT, 3 WIRE SERVICE.



GROUP	SIZE OF TRANSFORMER	LOCATION OF TRANSFORMER	MONTHLY K.W.H. CONSUMPTION FOR EACH CUSTOMER	DISTANCE IN FEET ON HIGHWAY BETWEEN CUSTOMERS 0 400 800 1200 1600
1	1½ K.V.A. FOR EACH OR	TRANSFORMER HALFWAY BETWEEN CUSTOMERS 0.75 K.W. AT 100% L.F.	0 75 150 300 600	NO.6 ECONOMY 2 TRANSFORMERS
2	1½ K V A. FOR BOTH	TRANSFORMER IN FRONT OF ONE CUSTOMER 0.75 K.W. AT 100% L.F.	75 150 300 600	NO.6 REG. NO.4 ECONOMY 2 TRANSFORMERS
3	1½ K.V.A. FOR EACH OR	TRANSFORMER HALFWAY BETWEEN CUSTOMERS 1.5 K.W. AT 100% L.F.	125 250 500 1000	NO.6 ECONOMY 2 TRANSFORMERS
4	3 K.V.A FOR BOTH	TRANSFORMER IN FRONT OF ONE CUSTOMER 1.5 K.W. AT 100% L.F.	125 250 500 1000	NO.6 REG. NO.4 ECONOMY 2 TRANSFORMERS
5	3 K.V.A. FOR EACH OR	TRANSFORMER HALFWAY BETWEEN CUSTOMERS 2.5 K.W. AT 100% L.F.	250 500 1000 2000	NO.6 REG. NO.4 REG. ECONOMY 2 TRANSFORMERS
6	5 K.V.A. FOR BOTH	TRANSFORMER IN FRONT OF ONE CUSTOMER 2.5 K.W. AT 100% L.F.	250 500 1000 2000	NO.6 REG. NO.4 REG. NO.2 ECONOMY 2 TRANSFORMERS
7	5 K.V.A. FOR EACH OR	TRANSFORMER HALFWAY BETWEEN CUSTOMERS 3.75 K.W. AT 100% L.F.	350 700 1400 2800	NO.6 REG. NO.4 REG. NO.2 REG. ECONOMY 2 TRANSFORMERS
8	7½ K.V.A. FOR BOTH	TRANSFORMER IN FRONT OF ONE CUSTOMER 3.75 K.W. AT 100% L.F.	350 700 1400 2800	NO.6 REG. NO.4 REG. NO.2 REG. NO.0 ECONOMY 2 TRANSFORMERS

PRIMARY VOLTAGE IS 2300 VOLTS

FIG. 22.



ECONOMICAL USE & LOCATION OF RURAL TRANSFORMERS

GROUP	SIZE OF TRANSFORMER	LOCATION OF TRANSFORMER	MONTHLY K.W.H. CONSUMPTION FOR EACH CUSTOMER	DISTANCE IN FEET ON HIGHWAY BETWEEN CUSTOMERS 0 400 800 1200 1600
9	1½ K.V.A. FOR EACH OR 1½ K.V.A. FOR BOTH	TRANSFORMER HALFWAY BETWEEN CUSTOMERS 0.75 K.W. AT 100% L.F.	0 75 150 300 600	NO. 6 ECONOMY REG. 2 TRANSFORMERS
10		TRANSFORMER IN FRONT OF ONE CUSTOMER 0.75 K.W. AT 100 % L.F.	0 75 150 300 600	NO. 6 NO. 4 ECONOMY REG. 2 TRANSFORMERS
11	1½ K.V.A. FOR EACH OR 3 K.V.A. FOR BOTH	TRANSFORMER HALFWAY BETWEEN CUSTOMERS 1.5 K.W. AT 100% L.F.	125 250 500 1000	NO. 6 ECONOMY 2 TRANSFORMERS
12		TRANSFORMER IN FRONT OF ONE CUSTOMER 1.5 K.W. AT 100 % L.F.	125 250 500 1000	NO. 6 NO 4 ECONOMY 2 TRANSFORMERS
13	3 K.V.A. FOR EACH OR 5 K.V.A. FOR BOTH	TRANSFORMER HALFWAY BETWEEN CUSTOMERS 2.5 K.W. AT 100% L.F.	250 500 1000 2000	NO. 6 REG. NO. 4 REG. 2 TRANSFORMERS
14		TRANSFORMER IN FRONT OF ONE CUSTOMER 2.5 K.W. AT 100 % L.F.	250 500 1000 2000	NO. 6 REG. NO. 4 REG. NO. 2 REG. 2 TRANSFORMERS
15	5 K.V.A. FOR EACH OR 7½ K.V.A. FOR BOTH	TRANSFORMER HALFWAY BETWEEN CUSTOMERS 3.75 K.W. AT 100% L.F.	350 700 1400 2800	REG. NO. 6 NO. 4 REG. NO. 2 REG. 2 TRANSFORMERS
16		TRANSFORMER IN FRONT OF ONE CUSTOMER 3.75 K.W. AT 100% L.F.	350 700 1400 2800	REG. NO. 6 NO. 4 REG. NO. 2 REG. NO. 0 REG. ECONOMY 2 TRANSFORMERS

FIG. 23.

C. In working up these charts the following factors have been taken into account:

1. Return and fixed charges on investment.
2. Transformer core losses at 2.5 cents per kw-hr.
3. Transformer and secondary copper losses at 2.5 cents per kw-hr.
4. Estimated kw-hr. consumption.
5. Voltage regulation.

D. Return and fixed charges have been assumed as follows:

	Per Cent
1. Depreciation of transformers and arresters	3.00
2. Depreciation of other equipment	2.32
Note: Depreciation is on the 4% sinking fund basis.	
3. Taxes and insurance	2.00
4. Maintenance on transformers and arresters	5.00
5. Maintenance on other equipment	3.00
6. Return	7.00

E. Material and labor costs have been figured as follows:

(1) *Two Transformer Installations Exclusive of Guying*

	Size	Quantity	Approx. Cost per Unit	Cost
Crossarm—4 pin	3½" x 4½" x 5'-7"	4	$0.73	$2.92
Braces	¼" x 1¼" x 28"	8	.10	.80
Machine bolts	⅝" x 16"	2	.09	.18
Spacing bolts	⅝" x 16"	4	.13	.52
Carriage bolts	⅜" x 4½"	8	.02	.16
Square washers	2¼" x 2¼" x ¼"	20	.016	.32
Lag screws	½" x 4"	8	.03	.24
Pins—locust	1½" x 9"	16	.04	.64
Insulators		9	.10	.90
Wire—weatherp'f	No. 6—60 ft.	6.72 lb.	.17	1.15
Transformer	6900-230/115 volts, 3 kv-a.	1	64.83	64.83
Lightning arrester	7500 volts	2	18.25	36.50
Fuse switch	7500 volts	2	8.75	17.50
Ground point, cap, rod, molding		2	1.50	3.00
Solder, tape, etc.				.75
Total				$130.41
Stores department charges, 10%				13.04
Labor				25.00
Total				$168.45
General office sup., 10%				16.84
Total estimated cost				$185.29
Cost of two transformer installations				$370.58

(2) *One Transformer Installation, Exclusive of Guying*

Total of 3 kv-a. transformer installations	$130.41
Minus cost of 3 kv-a. transformer	64.83
Total	$65.58
Plus cost of 5 kv-a. transformer	79.40
Total	$144.98
Stores department charges, 10%	14.50
Labor	25.00
Total	$184.48
General office sup., 10%	18.45
Total estimated cost	$202.93

(3) *A Guy at Each End of Secondary Lead*

	Size	Quantity	Approx. Cost per Unit	Cost
Anchor rods	¾" x 6'	2	$1.17	$2.34
Anchors, cone	8"	2	.70	1.40
Lag screws	½" x 4"	4	.03	.12
Guy hooks	4" x ⅜" x 1¾"	4	.075	.30
Strain plates	14 gage	2	.072	.144
3-bolt clamps	6"	12	.205	2.460
Guy thimbles	½"	2	.048	.096
Guy wire protector	8'	2	1.650	3.300
Guy wire	⅜"	100 ft.	18.10M	1.810
Strain insulator		2	.350	.700
Total				$12.67
Stores department charges, 10%				1.27
Labor				10.00
Total				$23.94
General office sup., 10%				2.39
Total estimated cost				$26.33
Cost of 5 kv-a. transformer installation				202.93
Total				$229.26
Minus one single crossarm in place				1.85
Total cost of fixed equipment				$227.41

(4) *Variable Equipment on Secondary Run*

Investment in one 150 ft. span of 3 No. 6 T. B. W. P. conductors:

	Size	Quantity	Approx. Cost per Unit	Cost
Crossarm—4 pin	3½" x 4½" x 5'-7"	1	$0.73	$0.73
Braces	¼" x 1¼" x 28"	2	.10	.20
Machine bolt	⅝" x 12"	1	.07	.07
Carriage bolts	⅜" x 4½"	2	.02	.04
Square washers	2¼" x 2¼" x ¼"	2	.016	.032
Lag screw	½" x 4"	1	.03	.03
Pins—locust	1½" x 9"	4	.04	.16
Insulators		3	.10	.30
Wire, weatherp'f	No. 6	52 lb.	.17	8.85
Total				$10.41
Stores department charges, 10%				1.04
Labor				4.25
Total				$15.70
General office sup., 10%				1.57
Cost of secondary per span, total				$17.27

F. Transformer costs and losses have been assumed as follows:

2300 *Volt*

Size	Approx. Cost	Core Loss at 115 Volts	Copper Loss at Full Load
1½ kv-a.	$30.00	21.5 watts	43 watts
3 kv-a.	43.00	32 watts	75 watts
5 kv-a.	58.00	40 watts	99 watts
7½ kv-a.	75.00	54 watts	126 watts

6900 *Volt*

1½ kv-a.	$53.00	27 watts	55 watts
3 kv-a.	65.00	36 watts	87 watts
5 kv-a.	80.00	50 watts	170 watts
7½ kv-a.	100.00	69 watts	200 watts

Core losses were increased by 10 per cent for customary farm line voltages.

G. Assuming that a customer uses a certain number of kw-hr. per month, the copper losses were figured on the assumption that this amount of energy was used at the rate of one-half load on the size of transformer required to serve the customer individually. This probably gives results nearer to the actual copper losses than would be obtained under any other method.

H. The estimated kw-hr. is considered only because of its influence on copper loss.

I. For any particular set of conditions there is a certain relation between primary, transformer, secondary and house wiring drop that gives the highest overall efficiency and lowest annual costs. It is with this point in mind that 3 per cent regulation has been allowed for the secondary and service in working up the results shown on the attached sheets. Allowing 8 per cent regulation at the customer's cutout leaves 5 per cent for primary and transformer drop.

The 3 per cent limit of regulation allowed for secondary and service drop is that on the loaded side of a three-wire secondary with current in one outside wire equal to full load on the size transformer necessary to serve customer separately, with 30 per cent current in neutral and 70 per cent current in other outside wire with load at 80 per cent power factor. On this basis it is assumed that the winter peak load might overload the transformer 50 per cent for short intervals, giving 4.5 per cent secondary regulation between the transformer and the customer's service entrance as a maximum. It is assumed, therefore, that the selection of transformer size will be governed accordingly.

J. In general the problem is to decide whether two rural customers should be served from one or from two separate transformers. If they are served separately, each may require a certain size of transformer. However, if served jointly, the size of transformer required may not be equal to the sum of the individual requirements. After taking into consideration the type and size of farm to be served, together with the means and desires of the prospective customers, probable future connected load and the best size of transformer can be determined. In the following charts the column headed "Size of Transformer" covers nearly all the combinations that might arise. For example, groups (1) and (2) cover the condition where the combined load could be served from a 1½ kv-a. transformer. Groups (3) and (4) represent the condition where each would require separately 1½ kv-a., but 1½ kv-a. would be too small for their combined load. Other similar cases are also shown.

For each one of these combinations of transformer size, there are several probable locations for the transformer. One of the customers may be getting service and may already have a transformer installed in front of his place; or neither one may be getting service at present, and it will then be possible to install the transformer wherever it may best be placed. The next column on the charts, headed "Location of Transformers," is designed to cover those two situations. For the sake of simplicity, it has been assumed in all cases that the primary line for other reasons extends in each direction beyond each customer under consideration, that each customer's service entrance is 300 ft. back from the primary line, and that both secondaries and services are three wire and of the same size wire. It has also been assumed that the transformers are always placed on the highway and not back on the customer's premises.

The next item to be considered is the monthly consumption. This is shown in the next column on the chart, and is assumed to be the same for each customer. The kw-hr. consumption affects only the cost of copper losses in transformers and secondaries.

The next variable item is the distance between customers measured along the primary line. This does not include the 300 ft. service drop for each customer, nor does it depend upon the number of wires considered. This distance is 600 ft. less than the distance between the two customers' service entrance switches measured along the secondary lead. The distance measured along the highway (primary line) between customers is plotted as ordinates across the top of the chart.

The only physical item left is the size of the wire required. With the conditions as already given, there are only two factors left which can determine the size of wire; these are economy and voltage regulation. Mechanical strength limits the size to number 6 A. W. G. or larger. The wire size is shown in the body of the chart.

Assume the conditions which are fixed are as given under Group 5. A 3 kv-a. transformer could serve each customer separately; 5 kv-a. will be required to serve the combined load, and neither is being served at present. If only one transformer is used, it can be placed halfway between them. By reference to the chart, it can be seen that, if the distance between customers measured along the highway (primary lead) does not exceed 500 ft., No. 6 wire will be adequate regardless of the amount of energy consumed. However, if this distance exceeds 500 ft. and is less than 1000 ft., and the estimated consumption per customer is 450 kw-hr. or less per month, No. 4 wire will be required. If the estimated consumption should exceed 450 kw-hr. per month for each customer and not exceed 750, No. 4 could be used up to distances between customers not exceeding 900 ft. Also, if the estimated consumption should exceed 750 kw-hr. per month for each customer, No. 4 wire could be used up to distances between customers not exceeding 600 ft. For distances greater than these, qualified by the estimated consumptions, two transformers should be used.

The vertical lines marked "Reg." dividing the areas indicate that voltage regulation is the determining factor in limiting the distance to which service can be supplied from one transformer. The curved lines marked "Economy" dividing the areas indicate that a balance between losses and fixed charges determines the limiting distance.

The following problems and their discussion show the use to which the charts may be put:

PROBLEM No. 1

A rural customer desires service and another customer nearby has a transformer in front of his residence. In this case the problem involved is to determine whether the present transformer should be replaced by a larger one and secondary extended, or whether a new transformer should be hung for the prospective customer.

Assume that the primary voltage is 6900; that 1½ kv-a. would adequately serve the prospective customer, that the present transformer is a 1½ kv-a. and that it would require a 3 kv-a. to serve both. Also assume that each customer's service would be about 300 ft. long and that the distance between the service drops measured along the primary is 900 ft.

Assuming that each customer might use 80 kw-hr. per month, the most economical procedure, according to Group 12 on the chart, is to replace the 1½ kv-a. with a 3 kv-a. unit, and extend a No. 4 three-wire secondary to the prospective customer. If the distance had been 1200 ft., it would have been more economical to hang separate transformers, for even if an attempt had been made to relocate the original transformer halfway between the customers to take advantage of the greater distance allowed in Group 11 on the chart, the charges resulting from moving the protective and auxiliary equipment would have overbalanced the leeway of 350 ft., shown in Group 11 on the chart.

PROBLEM No. 2

Assume two prospective customers are 800 ft. apart on a 2300 volt primary. One requires a 5 kv-a. and will use 300 kw-hr. per month; the other requires a 1½ kv-a. and will use 80 kw-hr. per month. Assume each has a service drop of 300 ft. of the same size wire as that to be used in the secondary.

Although the consumption influences the results only slightly, it is considered only to show just what influence it has. The size and length of service drops alter the results only by virtue of the effect upon voltage regulation and do not affect the balance of economy involved.

If it is eventually found that these customers should be served on one transformer the logical location for the transformer is such that the distances to the customers exclusive of service drop are inversely proportional to the respective demands, provided the secondary wire size is the same to each customer. Therefore, the distance from the transformer to the smaller customer would be:

$$\frac{5}{5 + 1.5} \times 800 \text{ ft.} = 615 \text{ ft.}$$

This leaves 185 ft. from the transformer to the larger customer.

Since this type of problem has not been placed on the chart, the next best thing is to pick out two or three cases treated on the chart which hit on either side of the conditions desired, and draw conclusions therefrom.

As far as the smaller customer is concerned, it can be assumed, in using the chart, that the conditions on the other side of the transformer are equal to his. This is equivalent to the case where the customers are 2 × 615 or 1230 ft. apart. Group 1 on the chart indicates that No. 6 copper secondary could be used for the smaller customer. Group 2 indicates that separate transformers should be hung, not because of regulation, but because of overall economy.

As far as the larger customer is concerned, it can be assumed also in using the chart that the conditions on the other side of the transformer are similar to his. This is equivalent to the case where the customers are 2 × 185 or 370 ft. apart. Group 7 on the chart indicates that No. 2 secondary could be used for the larger customer.

Although one indication points toward the use of two transformers, two indications favor the use of only one transformer. The best probable procedure, according to the assumptions made, would be to use one transformer, place it approximately 185 ft. from the larger customer and build No. 2 and No. 6 secondaries to the larger and smaller customers respectively. However, this conclusion was based on assumptions which included the logical location of the transformer provided the secondary wire sizes were the same to each customer. Such is not the case with the final decision, and the difference in conductivity of the two sizes of wire must be taken into account.

In the new problem the size and length of service drops alter the results by virtue of the effect upon voltage regulation, but do not affect the balance of the economy involved. If it is eventually found that these customers should be served on one transformer, the logical location for the transformer to give the same voltage regulation to each is such that the distances to the customers, including service drop, are inversely proportional to the respective demands, when consideration is also given to the fact that No. 2 wire has about 2.55 times the capacity of No. 6 wire. Therefore, the distance from the transformer to the smaller customer would be:

$$\frac{5 \times 800 + 5 \times 300 - 1.5 \times 2.55 \times 300}{1.5 \times 2.55 + 5}$$

which equals 495 ft. This leaves 305 ft. to the larger customer.

As far as the smaller customer is concerned, it can be assumed, in using the chart that the conditions on the other side of the transformer are equal to his. This is equivalent to the case where the customers are 2 × 495 or 990 ft. apart. Group I on the chart indicates that the No. 6 copper secondary could be used for the small customer. Group 3 indicates the same result.

As far as the larger customer is concerned, it can be assumed also in using the chart that the conditions on the other side of the transformer are similar to his. This is equivalent to the case where the customers are 2 × 305 or 610 ft. apart. Group 7 on the chart indicates that No. 2 secondary could be used for the larger customer.

All three indications point toward the use of one transformer. The best probable procedure, therefore, would be to use one transformer, place it approximately 305 ft. from the larger customer and string No. 2 and No. 6 secondaries to the larger and smaller customers respectively.

PROBLEM No. 3

Assume that it is desired to obtain from this chart information as to how far a three-wire, 115/230 volt secondary can be run from an urban transformer to a customer. Assume the customer's load is such that, if he were being served on a separate transformer, a 3 kv-a., 2300 volt would be required, and assume that his consumption is 300 kw-hr. per month. He falls in Group 6.

According to the agreed division of voltage drop between primary, secondary and service, the following restrictions are read from the chart. In each case we assume that the customer's cutout is 2 spans from the highway, and that the same sized wire is used throughout from the transformer to the cutout.

Distance in feet on highway in addition to the 2 spans of service drop	Size of Wire	Factor determining upper limit of distance
0 to 250 ft.	No. 6	Regulation
250 to 500 ft.	No. 4	Regulation
500 to 760 ft.	No. 2	Economy
Beyond 760 ft.	A separate transformer	

PATROL AND INSPECTION OF TRANSMISSION LINES

The Maintenance Methods and Procedures Subcommittee of the Overhead Systems Committee was appointed to determine the practice of member companies concerning their maintenance methods and procedures, as applied to overhead lines and apparatus.

The subcommittee has been recently engaged in the consideration of the procedures and methods applied in patrolling and inspecting transmission lines.

This Serial Report is based on a résumé of the 105 *replies to a questionnaire sent to member companies in this country and Canada to determine their practice in the patrol and inspection of transmission lines.*

An analysis of the returns by Geographic Divisions is shown in Table I. Table II is an analysis of the returns by systems.

SUMMARY

The information returned by the member companies shows their almost unanimous opinion is that periodic patrolling is worth while from the standpoints of continuity of service, increased revenue and public safety. Any one of these factors alone appears to be sufficient cause for periodic patrolling.

In direct answer to the question, "Do you feel that patrolling of transmission lines is justified?" 104 replied in the affirmative. The other company reports that patrolling is justified only after indications of trouble. One of the 104 companies which said patrolling was justified does not patrol. This is probably due to the limited mileage and special conditions of the system.

The reason given by 95 of the companies for patrolling is that conditions which might cause a line failure and interruption to service are detected and repaired before the damage is done. From the economic standpoint ten companies report an actual increase in revenue as a result of periodic inspection, while seven companies assert that inspecting increases public safety and, therefore, public good will.

While there seems to be a nearly unanimous opinion in favor of patrolling, there are some differences concerning details.

The frequency and manner of patrolling apparently, from the answers returned, depends somewhat on how rigid an inspection is maintained. Other factors which influence these are the size of the system, the voltage and importance of the line, as well as its general condition. The equipment carried and the instructions to patrolmen varies with the work included at the time of patrolling, and whether it is a periodic or an emergency patrol.

DETAILED INFORMATION FROM THE QUESTIONNAIRE

Thirty companies patrol in crews of two or more, while 80 patrol individually. A few companies use both methods, depending on which is the more convenient and economical at the time. It is of interest to note the following:

63 companies report no other work when patrolling.
25 do minor repair work on the lines. (In general repair work is done by those who patrol in crews).
7 repair their own telephone lines.
6 include substation inspection.
2 check readings of the substation meters.
1 tests the street lights.
1 reads meters in secluded districts.
1 estimates the cost of labor and material necessary to repair defects.

TABLE I

ANALYSIS OF RETURNED QUESTIONNAIRES GEOGRAPHICALLY

Geographic Division	Number of Companies Reporting	Number of Systems	Number of Miles of Transmission Lines by System Voltage						Total of Each Division
			11–15	15–30	30–60	60–100	100–150	150–	
1. Canada	3	8	130.90	....	228.00	528.00	396.7	270	1,555.60
2. New England	19	40	760.79	279.99	632.21	676.75	30.00	....	2,379.74
3. Eastern and Middle Atlantic	24	71	1,837.46	3,121.97	2,136.85	3,449.12	1,873.12	227	12,645.52
4. South Eastern, South Western and East Central	22	60	2,378.07	876.86	4,776.46	2,700.14	3,763.17	....	14,494.70
5. Great Lakes, North Central, Middle West	17	58	3,065.17	1,423.16	4,941.10	2,241.77	2,229.39	....	13,900.59
6. Pacific Coast, North West Rocky Mountain	20	59	12,546.83	1,492.20	3,676.50	4,480.94	1,911.50	976	25,083.87
	105	296	20,719.22	7,194.18	16,391.12	14,076.72	10,203.88	1,473	70,060.02

Publication No. 289-42, Serial Report, Overhead Systems Committee.

TABLE II

ANALYSIS OF RETURNED QUESTIONNAIRES BY TRANSMISSION SYSTEMS

Transmission Line Voltage, Kv.	Systems Reported	Mileage
11–15	75	20,719.22 mi.
15–30	54	7,194.18
30–60	64	16,391.12
60–100	57	14,076.72
100–150	41	10,203.88
150–	5	1,473.00
	296	70,060.02 mi. Total

Time Interval Between Patrols

Table III indicates the "Time Interval of Patrolling by Voltages." A number of the companies will appear more than once in this table as they have more than one time schedule.

TABLE III

TIME INTERVAL BETWEEN PATROLLING BY VOLTAGES

Time Interval	Kilovolts					
	11–15	15–30	30–60	60–100	100–150	150–
1 day	1	....	....	....	.....	.....
2 days	1	....	....	....	.....	.....
3 days	2	....	2	1	.....	.....
4 days	....	2	....	....	.....	1
1 week	11	12	13	14	11	3
10 days	2	3	2	1	2	.....
2 weeks	2	9	15	10	9	1
3 weeks	1	2	....	1	1	.....
1 month	17	15	21	19	13	1
2 months	2	3	4	4	1	.....
3 months	....	1	1	1	.....	.....
6 months	2	2	....	....	1	.....
1 year	....	....	....	1	.....	.....

Two of the companies patrol only after indication of trouble on the line, such as breaker operation. Several patrol after every storm as well as periodically, whether there is indication of trouble or not. In a few cases on parts of systems, the period is varied or adjusted so that patrolling takes place after storms only.

Patrolmen Living Along Lines

There are five companies whose patrolmen live along the lines. Only one of these forwards any detailed information on the subject. An extract from this company's instructions follows:

> In general patrolmen will live in quarters made available by the company. Telephone service will be provided at each of the living quarters.
>
> All patrolmen are required to be on duty during working hours on all days other than Sundays and holidays. Absent time allowances, vacations, etc., will be allowed in accordance with the rules and regulations of the company. All absences from duty must receive the sanction of the superintendent and be carried out with due notification to and with the knowledge of the work despatcher.
>
> On alternate evening the patrolmen will be expected to hold themselves available for call.
>
> Each patrolman will be required to patrol the entire section assigned to him once every week. Patrolmen will be required to climb and make a detailed inspection of each tower at least once every month.
>
> In climbing towers two patrolmen will work together, climbing alternate towers independently. This regulation is put into effect in case of an accident to one man, there will be another man in the immediate vicinity available to render assistance. Where possible, patrolmen on adjacent sections will assist each other in the inspection, under the direction of the work despatcher. Where this is unpracticable another man from the maintenance gang will assist.
>
> In all cases of unusual weather conditions, such as snow storms, ice storms, thunder storms, wind storms, extremely hot or cold weather, hurricanes, earthquakes, etc., all previous arrangements and schedules for release are automatically cancelled.
>
> The patrolmen are required, as soon as such conditions become evident, to immediately report over the nearest telephone to the work despatcher or supervisor. From that time on until conditions are relieved, patrolmen will, at all times, keep the work despatcher informed as to their location or destination.
>
> During the time the patrolman is making his inspection he will be expected to take care of any small jobs requiring attention which do not require any special tools—such as tightening up loose bolts, temporarily fixing fences, putting in bars, etc.
>
> In case of finding any major defects on the line—such as broken strands in the conductors, shattered or burnt insulators, burnt guard rings or hardware, burnt conductor, presence of kites or other foreign obstacles on the wires—he shall immediately call and report to the work despatcher.

Transportation

An analysis of the method of transportation is given in Table IV.

TABLE IV

System Voltage (Kv.)	Foot	Horseback	Automobile	Trolley, Train and Speeder	
11–15	5,531.22	54.5	3,146.6	30	Total mileage reported in answer to this question.
15–30	4,902.94	44.0	2,780.9	21	
30–60	8,733.82	1,283.0	2,926.0	692	
60–100	8,461.92	259.3	3,146.6	?	
100–150	7,131.18	365.0	124.0	?	
150–	393.0	124.0	751.0	?	
	35,154.1 mi.	2,129.8 mi.	12,875.2 mi.	743	*50,902.1

---

*This does not show the total system mileage reported because of insufficient information but is accurate enough to give an idea of the general practice of the country.

Table V shows the miles in the different systems that follow private rights-of-way, highways and streets. Nearly all lines on rights-of-ways are patrolled on foot. Thirty per cent of those on streets or highways are patrolled this way as well.

Special Equipment

Of the 105 companies reporting

57 use field glasses on patrol,
8 use pole butt testers,
5* use hot line tools,
4 use telephone test sets,
4* use insulator testing equipment,
2 use radio trouble finders.

---

*These companies patrol in crews.

Two companies state definitely that their patrolmen do not use field glasses. In response to a letter from the committee, one company says:

> Some years ago the patrolmen were supplied quite generally with field glasses for use in patrolling and inspecting lines. However, the experience obtained during such procedure convinced us that proper patrols were not being made, but that the men were taking the easiest method—using field glasses to inspect their lines. Generally, glasses are valuable in locating trouble. Occasionally, by the use of the glass, the man will pass up trouble, thereby increasing the length of the outage; also the expense to find and repair the trouble.
>
> After considerable experience where the glasses were used, all equipment of this sort was called in and instructions issued that patrols must be made directly under the line. Since this procedure has been established, the operating record of the transmission lines has improved quite materially, less failures have resulted and there have been very few cases of trouble which have been passed. For the above reasons we feel that the use of field glasses by our patrolmen is not practical.

TABLE V

System Voltage (Kv.)	Private Right of Ways	Highways and Streets	Total
11–15	6,136.94	13,373.12	19,510.06
15–30	3,471.68	3,346.32	6,818.00
30–60	12,215.02	3,846.49	16,061.51
60–100	8,256.38	4,183.44	12,439.82
100–150	7,679.76	1,997.63	9,677.39
150–	1,370.00	103.00	1,473.00
	59.3%	40.7%	65,979.78

Another company answers as follows:

> No special equipment is used. I have tried field glasses on various occasions, particularly for spotting burns or defects in the cables, but have always found that the bare eye will detect such defects much easier than can be done with the help of field glasses. The reason for this seems to be that the background is always the sky, and no matter if the sky is clear or cloudy, the cable seems to blend with the background so that it practically disappears when looking through the glasses.

One company reports using a camera, another having the patrolmen carry snake bite treatment, another a slack puller, and a fourth wading pants. The transportation equipment generally used is of the lighter type of car, in most cases Fords, Dodges, Chevrolets, etc.

MEMBER COMPANY PRACTICE

The following has been extracted from letters written by two companies when answering the questionnaire, which are of more than ordinary interest.

APPALACHIAN ELECTRIC POWER COMPANY

> In the past the various lines have been patrolled on foot, once or twice a year, or as often as the local manager deemed desirable. If a line was giving more or less trouble, it accordingly received more patrolling.
>
> We are this year inaugurating a new system of general inspection patrol to be made spring and fall, just after the lightning season, and the results obtained from this patrol will determine just about how often it will be necessary to make general inspections over our entire system in the future.
>
> This general inspection patrol is copied after the system that I have been using for a final inspection of all of our transmission lines during and at the end of construction, before they are turned over to the operating department. I have been keeping a regular form of inspection report for several years, which is now being made the basis of our general patrol report, of which I am inclosing several blank copies.
>
> This inspection crew is made up of three, four or five men, who work together under a chief inspector. They climb every structure and make a detailed examination as close to the conductors as possible. They examine all bolts on their way down the structure, tightening any that might be loose, and report any condition that they find is not normal. We note on this report various specific points that must be covered during the inspection, so that they will not be overlooked. Under the question of clearance, they measure the actual clearance if the line is not alive, and where lines are alive they note "good" or "poor," as the case might be. All of our structures are numbered, and a separate sheet is made out for each individual structure. A copy of this report is sent to the general superintendent, and a copy furnished to the system operator and to the operating district managers. If the report indicates that repairs are necessary, the district manager arranges, at the present time, to make the necessary repairs when the lines can be taken out of service, after which a re-inspection is made and additional reports filed with the respective parties.
>
> We keep in our office a record of all of these reports, by structure number, so that if anything happened on any particular structure, we could tell how often and when it had been inspected.

EASTERN CONNECTICUT POWER COMPANY

> Originally we had regular patrolmen patrolling our transmission lines and found the work both expensive and unsatisfactory, due to repeated misses or overlooking of defective conditions. Under this scheme the patrolling of the line was of doubtful value and very unsatisfactory.
>
> We have now adopted a scheme of having the patrolling done by a crew of four, taken out of the regular line department. These men, being the ones who would naturally have to repair defective lines after trouble has occurred, which might well be at very inconvenient times and under very bad weather conditions, have a very definite interest in seeing that the patrol is as thorough as possible.
>
> The method of operation is for a crew of four men with a light truck (usually a Reo Speed Wagon) to start out until they reach the nearest point on the transmission line to be patrolled. This crew of four is composed of two climbers and two groundmen, who are also competent chauffeurs. At the start of the transmission line, two men, a climber and groundman, start to patrol the line. The other two men take the truck to a designated highway crossing, leave the truck and start to patrol along the line in the same direction that the original two started. When the first two come to the crossing where the truck is, they take the truck and drive to another point further along the line, and the procedure is repeated. In this way we are able to patrol a line in a very economical manner with men who are very definitely interested in seeing that the patrol is most thorough, and the results have been very satisfactory.
>
> It is our practice to patrol the 66-kv. lines at least once a month at all seasons of the year with this method, and the lower voltage lines with the same frequency in the summer months; but during the winter months, if the weather conditions have been mild, we sometimes extend the time to eight weeks. Regardless of this systematic patrol if, at any time, the lines go out either during a thunder storm or any other time, unless the cause of the interruption is definitely known, an additional patrol is made; and, in addition, during the severe lightning season patrols will be made even though the line in question had no interruption during the preceding storm.
>
> We have found this method of handling the work both economical and very satisfactory. Our experience with regular patrolmen who do no other type of work was extremely unsatisfactory, both in the expense of the work and in the reliability.

INSTRUCTIONS

Several companies inclosed supplements in answer to the request for additional information. An attempt has been made to pick out the more representative types of instructions for patrolmen, and, it is hoped that these, together with some representative report forms that have been selected, will present a general idea of what the patrolmen are instructed to do and observe. The selections from the sets of instructions received follow.

KANSAS GAS & ELECTRIC COMPANY

Most men make the mistake of regarding patrolling as a simple, easy job which anyone can do, provided he can walk. A good patrolman must have the same characteristics which insure success in other work, i.e., he must concentrate on the task at hand, must know just what is expected of him and must not only be able to do it but to tell others how it was done. In other words, he must make complete reports correctly portraying conditions.

Patrolmen frequently come in contact with the public. At such times a patrolman should remember that he *is* the company in the eyes of persons he meets and talks to. He should be uniformly courteous and should make every effort to avoid damage to growing crops by reason of his patrolling. By closing all gates he opens, preventing stock from straying, he will build good will for himself and the company.

A patrolman should make the acquaintance of residents along the lines he patrols. He should tell them why patrolling is necessary and something of the importance of uninterrupted service on the lines. Many persons with this knowledge will take the trouble to report wires down or other line trouble when they see or hear of it.

What to Report

All patrolmen at various times are confronted with the question, "Shall I report this?" or "Is this serious enough to report?" A brief review of the reasons for having patrolmen will forever settle this recurring question. There are few cases in which a patrolman can make actual repairs. It necessarily follows that the primary function of a patrolman is to *see* everything and report what he sees. Therefore, a good slogan is: When in doubt make a report.

Patrolmen will report *all* irregularities on both power and telephone lines and stations. Loose tie wires, nuts, clamps, broken insulators, poles and cross-arms; poles out of line, brush into or near lines, etc. Special attention should be given the latter, as service depends on keeping both power and telephone lines clear.

Following are listed a few of the conditions which should occasion a report. You will think of many others as you cover the line.

1. Broken or cracked insulators
2. Poles broken off
3. Poles leaning out of line at the top, 2 ft. or more
4. Broken strands in conductors
5. Broken ground wires
6. Ground wire loose from support
7. Tie wires broken or burned
8. Cross-arm split or rotted
9. Nuts off or loose on any poles
10. Broken or slack guys
11. Trees or tree limbs in such positions that they may touch or blow into the line wires or telephone wires. Any trees which, if they broke off at the ground line, would fall into the wires are considered danger timber and should be reported
12. Trees under the line with clearance of less than 4 ft.
13. Trees clearing the telephone line less than 2 ft. underneath or 4 ft. to one side
14. Broken guy insulators
15. Broken telephone insulators
16. Woodpecker holes that impair the strength of the pole. If you are unable to tell the extent of such holes, report this fact and a special inspection will be arranged for.

You will report all dangerous conditions each time that you cover the line until the condition is corrected, unless special permission is granted by the general foreman to cease reporting individual troubles.

If lines are not in need of repairs, the reports should so state. Reports requiring immediate attention telephone to the despatcher. Less important reports will be noted on the patrolman's daily report (Form No. 1276) which will be mailed to the patrol headquarters daily. Reports telephoned to the despatcher will be noted on the daily report with the time of telephoning, person receiving the report, etc.

Patrolmen will report in the morning the route they expect to cover, will call in over private line at each phone station, and will report as soon as they have covered the section of line assigned for the day.

Patrolmen walking lines on which no company telephones are available will report on public telephone and maintain a reporting schedule where possible, as follows:

Morning, mid-morning, noon, mid-afternoon and night.

The Neosho-Midian line is an exception to this rule. When patrolling this line reports will be made to the nearest despatcher (Wichita or Neosho) morning and night. No other reports will be made unless trouble requiring immediate action is involved.

Patrolmen will report promptly the approach of a storm and will give the telephone number at which they can be called during the progress of the storm. If the storm is general in character or progresses along the line the patrolman should again report to headquarters before he resumes patrolling. This instruction applies to all lines.

Repetition of Reports

The question frequently arises whether to report a condition once or to report the same condition on each inspection trip until it is corrected. A report once having been made, should be repeated on the subsequent trips until the repair work is done or until the patrolman has been authorized to cease making the report. Such permission will be for the case at hand only, and should not be construed to apply to other reports.

General Instructions for Emergency Patrolling

The importance of efficient organization for emergency patrolling is shown by the fact that locating trouble on lines often takes longer than repairing the break after it is located. Since communication with patrolmen is lost when they start, it is of great importance that each man understands what to do in emergencies. The following general instructions should be followed. They will be supplemented by special instructions to cover extraordinary features of the case at hand.

1. Stay away from the line. You do not have clearance on it, and it may be energized or tried out at any time.
2. Walk from your starting point in the direction specified until you find the trouble or meet the man walking toward you.
3. Report to system operator (special instructions may require report to someone else) at half hourly intervals if you can do so without getting so far away from the line as to risk not seeing another patrolman. If you are on a cross-country line and do not pass telephones, make a big effort to telephone your headquarters at least once each hour.
4. When you locate the trouble go to the nearest telephone and report, making sure that you give exact location and as nearly as possible the extent of the damage. If you are not given specific instructions at this time, return to the breakdown and guard the public and domestic animals from accident. After you locate the trouble and report it you can usually do a lot, even if you are alone, to speed the repairs.

When you talk to the system operator, therefore, get clearance on the line, ***provided you are not ordered to leave the location,*** and do all you can. The system operator will ordinarily have the line opened and will be ready to issue clearance on it by the time the location of the trouble is reported to him. If you are in doubt as to what you alone can do to repair the damage while waiting for help, do not hesitate to ask for detailed instructions from headquarters.

5. If it becomes necessary for you to leave the line while patrolling to telephone, leave a note attached to a conspicuous part of the nearest pole or tower, telling where you are and what time you left the line. This will prevent any possibility of another patrolman passing during your absences. Hold order tags are handy for this purpose, and a supply will be kept at crew headquarters for your convenience.
6. If you meet your man or reach the end of the line without finding the trouble, report to the system operator from the nearest telephone and ask for further instructions.
7. Remember that trouble apparently on a line may actually be on substations connected to the line. This is a strong possibility when unattended substations are involved. Be sure, therefore, that you inspect any substation on your section of the line, whether it be at the point from which you start patrolling, end patrolling, or along the line. Exceptions to this will be given as special instructions when necessary.

THE CONNECTICUT LIGHT & POWER COMPANY

Condition of poles, towers, fixtures, guys, anchors, pins, conductors, insulators, lightning arresters, grounds, line transformers and accessory equipment as well as clearances from trees and other obstacles shall be noted. Transmission patrolmen shall pay particular attention to locating cracked or broken insulators, indications of flashover and such trees and limbs as are likely to come in contact with or dangerously close to wires during high winds or when heavily loaded with ice.

At substations, condition of transformers, grounds on transformers and framework, leads, bushings, switches, buses, potheads, cables and accessory equipment, also transformer oil levels and temperatures shall be noted. Attention should be paid to see that buildings furnish proper protection to indoor equipment. Necessity for safeguards, danger or caution signs to warn unauthorized persons of hazards shall be noted.

In the discharge of their duties patrolmen shall not place themselves in hazardous positions, and they shall exercise care not to break or cut down fences or in any way injure crops or property through or over which they must pass.

METROPOLITAN EDISON COMPANY

Make a report of line, or section of line patrolled on transmission line inspection sheet furnished for that purpose.

Report all trouble, or dangerous conditions, by pole or tower number, and the number of line. Give exact location as near as possible.

Always patrol lines directly under the line. (Under no circumstances shall any patrolman go off the right of way to go around a creek or any other obstacle, without coming back to the line as near as possible to the point of leaving.)

Always stop on the *far* and *near* side of all poles, towers and structures and give all equipment a very careful inspection. This is very important on dead-end construction, as some towers have 216 insulators as part of the equipment that *must* be inspected.

Report All Broken Insulators

When a broken insulator is found, make a thorough examination of the ground around the pole or structure, as well as the equipment, and try to determine the cause.

In most cases of broken insulators that have caused line trouble, or have been broken by a power arc, the pieces found on the ground will have the glazing blistered. Insulators broken by stones, or causes other than power arc, will be broken clean.

Examine the Pieces of Insulators Found on the Ground

Report all foreign objects, on any part of conductors, poles, structures or equipment, kite strings, small pieces of wire, limbs hanging over conductors, corn husk, small limbs, paper or any foreign object hanging over the insulators. Loose bark on poles that is likely to swing into line.

Report truss pins leaning, loose tie wires, cross-arms that are loose and standing away from pole, crooked cross-arms, loose through bolts and lag screws, poles leaning out of line, poles and towers that require back-filling, caused by washout or earth settling around base of towers, or butt of poles, loose bolts and tower members, tower members that are bent and out of position.

Report slack guy wires, rusted and broken guys, broken guy strain insulators, trees that are close to, or in danger of blowing into lines.

Report high weeds in structures, switches that are not closed properly, or poorly adjusted, broken switch castings, and switches that are not locked.

A very careful inspection *must* be made at all structures for loose connections and loose lugs.

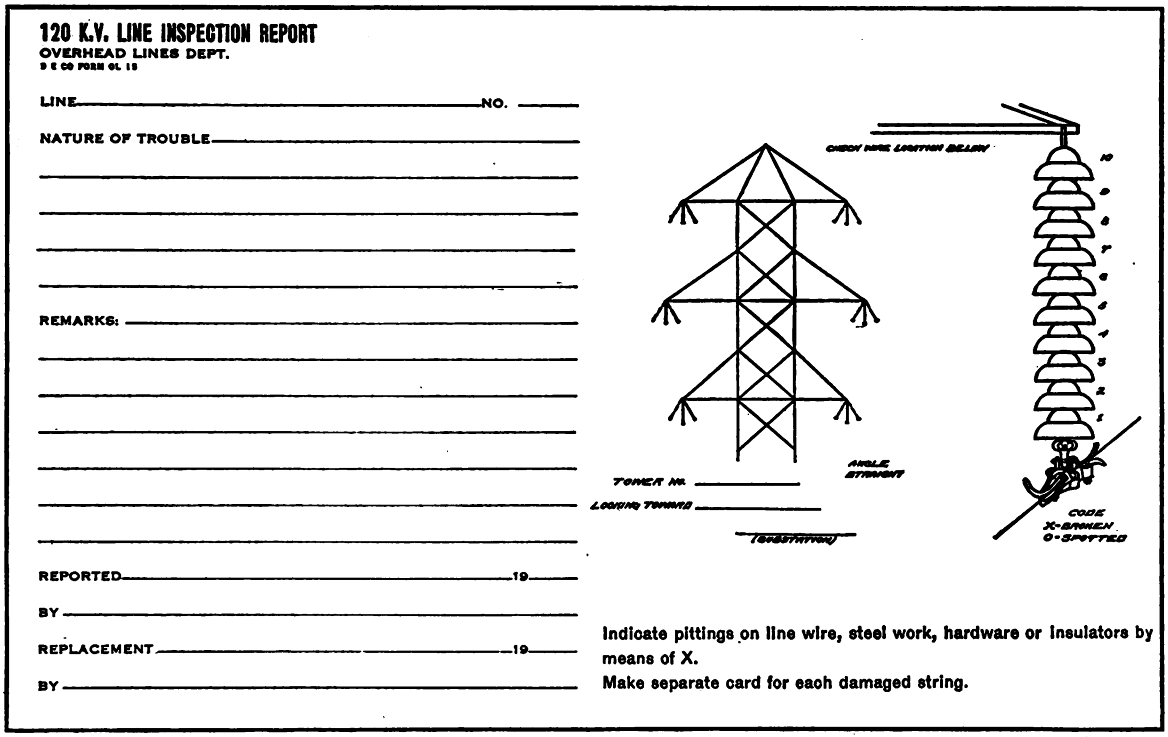
On several occasions our regular line patrolman has avoided a very serious interruption by finding solder on the ground under switching structures that came out of an overheated lug.

Report all danger signs that have been destroyed or removed from poles, tower and structures.

In no case shall any patrolman hesitate to report any condition that he thinks will cause trouble. The same will be given a very careful investigation.

INSPECTION REPORT FORMS

Fig. 1-6 inclusive are specimen field report forms used by several of the reporting companies.



120 K.V. LINE INSPECTION REPORT

OVERHEAD LINES DEPT.

D E CO FORM OL 13

LINE________________________NO. ______

NATURE OF TROUBLE________________________

REMARKS: ________________________

REPORTED________________________19______

BY ________________________

REPLACEMENT________________________19______

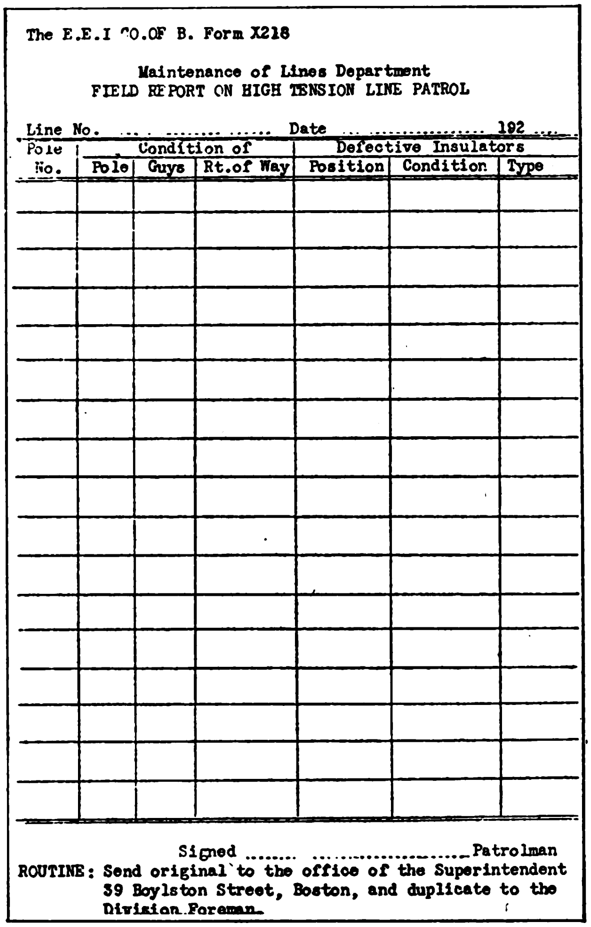
BY ________________________

CHECK WIRE LOCATION BELOW
10
9
8
7
6
5
4
3
2
1
ANGLE
STRAIGHT
TOWER NO. ______
LOOKING TOWARD ______
(SUBSTATION)
CODE
X-BROKEN
O-SPOTTED

Indicate pittings on line wire, steel work, hardware or insulators by means of X.

Make separate card for each damaged string.

FIG. 1—120-KV. LINE INSPECTION REPORT—DETROIT EDISON CO.



The E.E.I CO.OF B. Form X218

Maintenance of Lines Department

FIELD REPORT ON HIGH TENSION LINE PATROL

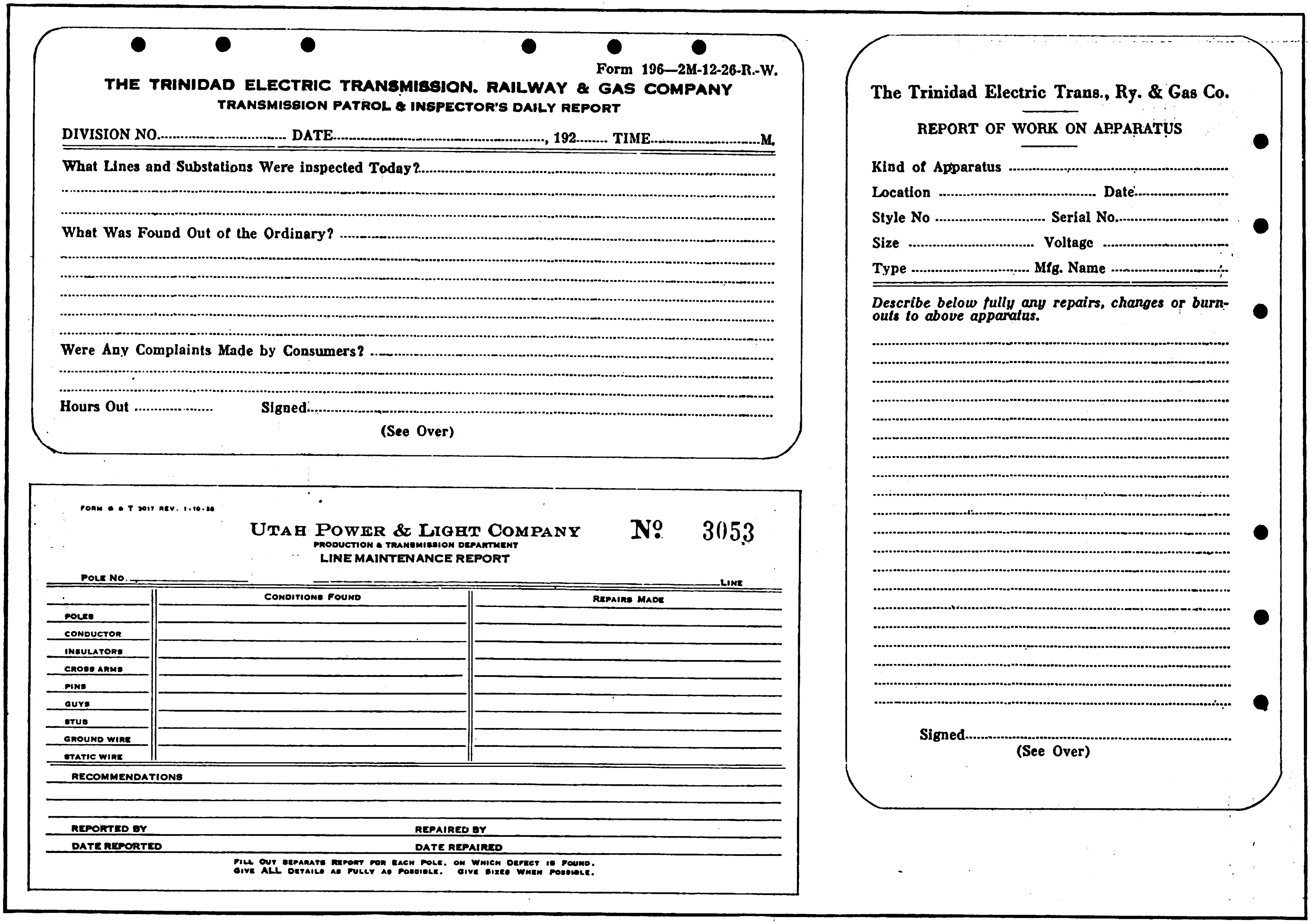
Line No. ... . Date ... . 192 ....

Pole No.	Condition of			Defective Insulators		
	Pole	Guys	Rt.of Way	Position	Condition	Type

Signed ....Patrolman

ROUTINE: Send original to the office of the Superintendent 39 Boylston Street, Boston, and duplicate to the Division Foreman.

FIG. 2—FIELD REPORT FORM ON HIGH TENSION LINE PATROL—EDISON ELECTRIC ILLUMINATING CO. OF BOSTON.



Form 196—2M-12-26-R.-W.

THE TRINIDAD ELECTRIC TRANSMISSION. RAILWAY & GAS COMPANY
TRANSMISSION PATROL & INSPECTOR'S DAILY REPORT

DIVISION NO.................. DATE.................................., 192....... TIME......................M.

What Lines and Substations Were inspected Today?..........

What Was Found Out of the Ordinary? ....

Were Any Complaints Made by Consumers? ....

Hours Out .... Signed..........

(See Over)

FORM P & T 3017 REV. 1-10-26

UTAH POWER & LIGHT COMPANY
PRODUCTION & TRANSMISSION DEPARTMENT
LINE MAINTENANCE REPORT

No. 3053

POLE NO. ____________ ____________ LINE

	CONDITIONS FOUND	REPAIRS MADE
POLES		
CONDUCTOR		
INSULATORS		
CROSS ARMS		
PINS		
GUYS		
STUB		
GROUND WIRE		
STATIC WIRE		

RECOMMENDATIONS

REPORTED BY ____________ REPAIRED BY ____________

DATE REPORTED ____________ DATE REPAIRED ____________

FILL OUT SEPARATE REPORT FOR EACH POLE, ON WHICH DEFECT IS FOUND.
GIVE ALL DETAILS AS FULLY AS POSSIBLE. GIVE SIZES WHEN POSSIBLE.

The Trinidad Electric Trans., Ry. & Gas Co.

REPORT OF WORK ON APPARATUS

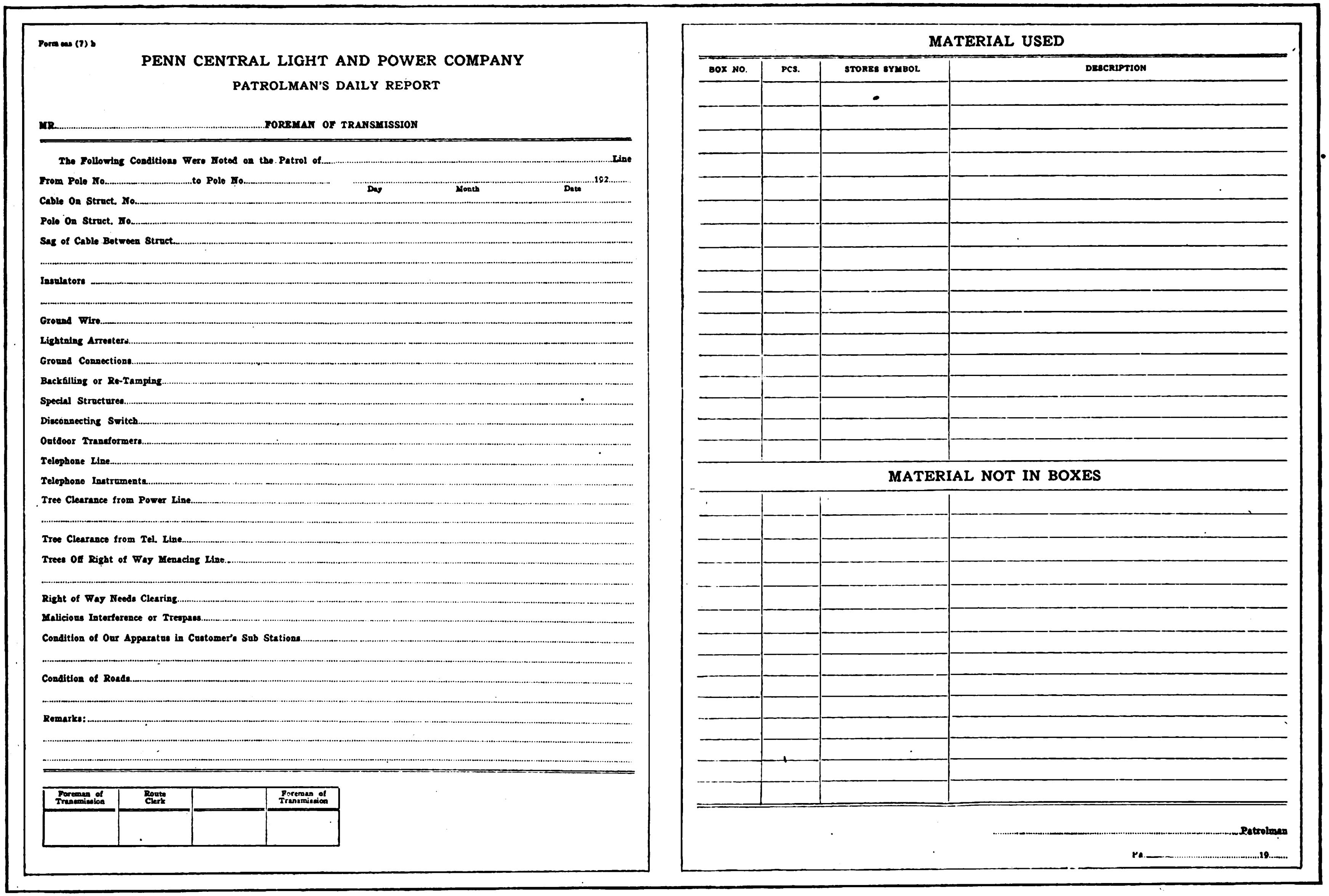
Kind of Apparatus ....
Location .... Date..........
Style No .... Serial No..........
Size .... Voltage ....
Type .... Mfg. Name ....

Describe below fully any repairs, changes or burn-outs to above apparatus.

Signed..........

(See Over)

FIG. 3—REPORT FORMS—THE TRINIDAD ELECTRIC TRANSMISSION, RAILWAY & GAS CO. AND UTAH POWER & LIGHT CO.



Form eas (7) b

PENN CENTRAL LIGHT AND POWER COMPANY

PATROLMAN'S DAILY REPORT

MR..FOREMAN OF TRANSMISSION

The Following Conditions Were Noted on the Patrol of..Line

From Pole No..............................to Pole No..............................Day..........Month..........Date..........192.........

Cable On Struct. No...

Pole On Struct. No...

Sag of Cable Between Struct...

....

Insulators ....

....

Ground Wire...

Lightning Arresters...

Ground Connections...

Backfilling or Re-Tamping...

Special Structures...

Disconnecting Switch...

Outdoor Transformers...

Telephone Line...

Telephone Instruments...

Tree Clearance from Power Line...

....

Tree Clearance from Tel. Line...

Trees Off Right of Way Menacing Line...

....

Right of Way Needs Clearing...

Malicious Interference or Trespass...

Condition of Our Apparatus in Customer's Sub Stations...

....

Condition of Roads...

....

Remarks:...

....

....

Foreman of Transmission	Route Clerk		Foreman of Transmission

MATERIAL USED

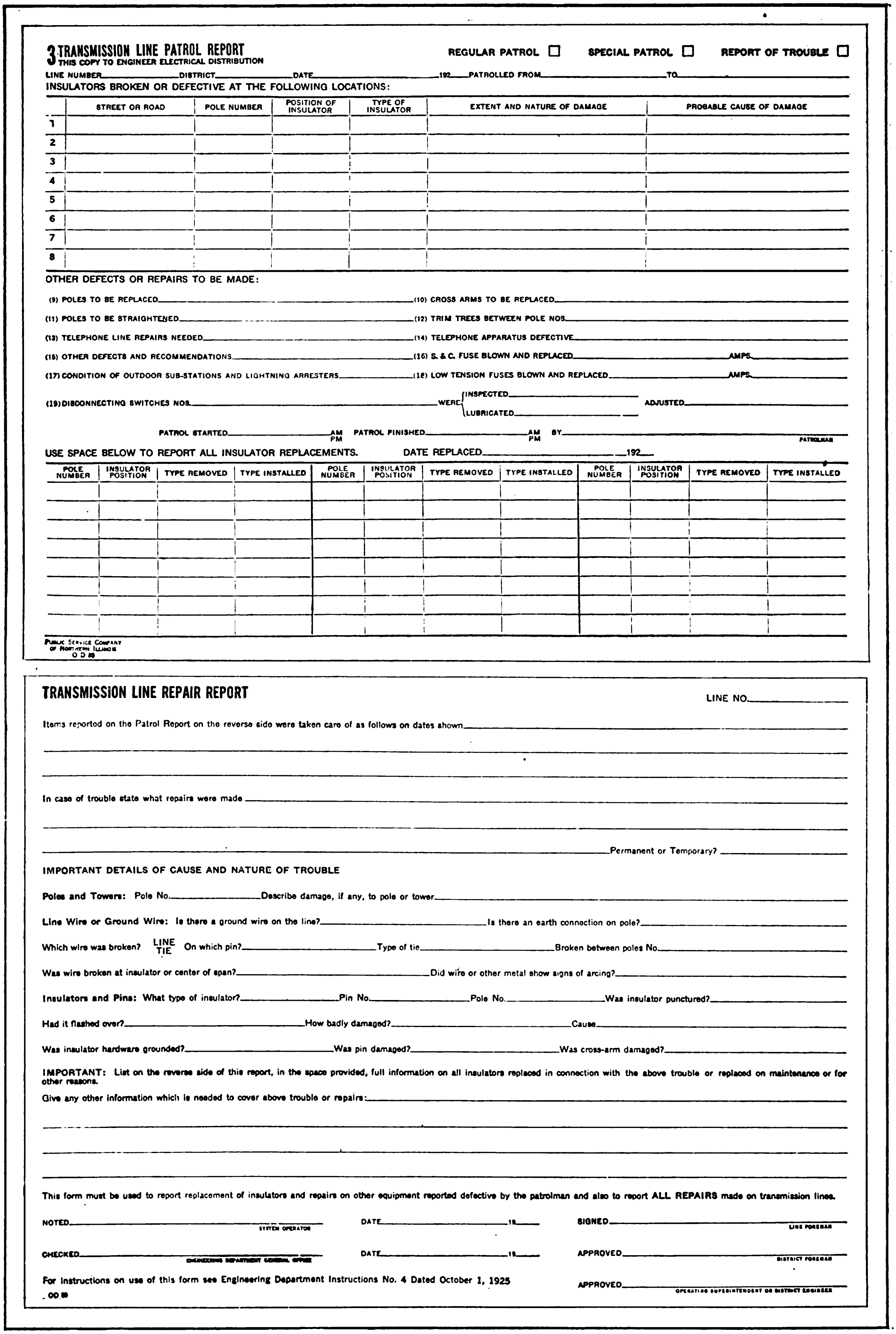
BOX NO.	PCS.	STORES SYMBOL	DESCRIPTION

MATERIAL NOT IN BOXES

....Patrolman

Pa..............................19.........

FIG. 4—PATROLMAN'S DAILY REPORT FORM—PENN CENTRAL LIGHT & POWER CO.



3 TRANSMISSION LINE PATROL REPORT
THIS COPY TO ENGINEER ELECTRICAL DISTRIBUTION

REGULAR PATROL ☐ SPECIAL PATROL ☐ REPORT OF TROUBLE ☐

LINE NUMBER____ DISTRICT____ DATE____192__ PATROLLED FROM____ TO____

INSULATORS BROKEN OR DEFECTIVE AT THE FOLLOWING LOCATIONS:

	STREET OR ROAD	POLE NUMBER	POSITION OF INSULATOR	TYPE OF INSULATOR	EXTENT AND NATURE OF DAMAGE	PROBABLE CAUSE OF DAMAGE
1						
2						
3						
4						
5						
6						
7						
8						

OTHER DEFECTS OR REPAIRS TO BE MADE:

(9) POLES TO BE REPLACED____ (10) CROSS ARMS TO BE REPLACED____

(11) POLES TO BE STRAIGHTENED____ (12) TRIM TREES BETWEEN POLE NOS.____

(13) TELEPHONE LINE REPAIRS NEEDED____ (14) TELEPHONE APPARATUS DEFECTIVE____

(15) OTHER DEFECTS AND RECOMMENDATIONS____ (16) S. & C. FUSE BLOWN AND REPLACED____AMPS.____

(17) CONDITION OF OUTDOOR SUB-STATIONS AND LIGHTNING ARRESTERS____ (18) LOW TENSION FUSES BLOWN AND REPLACED____AMPS.____

(19) DISCONNECTING SWITCHES NOS.____ WERE { INSPECTED____ LUBRICATED____ } ADJUSTED____

PATROL STARTED____AM PM PATROL FINISHED____AM PM BY____ PATROLMAN

USE SPACE BELOW TO REPORT ALL INSULATOR REPLACEMENTS. DATE REPLACED____192__

POLE NUMBER	INSULATOR POSITION	TYPE REMOVED	TYPE INSTALLED	POLE NUMBER	INSULATOR POSITION	TYPE REMOVED	TYPE INSTALLED	POLE NUMBER	INSULATOR POSITION	TYPE REMOVED	TYPE INSTALLED

PUBLIC SERVICE COMPANY
OF NORTHERN ILLINOIS
O D 89

TRANSMISSION LINE REPAIR REPORT LINE NO.____

Items reported on the Patrol Report on the reverse side were taken care of as follows on dates shown____

In case of trouble state what repairs were made____

Permanent or Temporary?____

IMPORTANT DETAILS OF CAUSE AND NATURE OF TROUBLE

Poles and Towers: Pole No.____ Describe damage, if any, to pole or tower____

Line Wire or Ground Wire: Is there a ground wire on the line?____ Is there an earth connection on pole?____

Which wire was broken? LINE TIE On which pin?____ Type of tie____ Broken between poles No.____

Was wire broken at insulator or center of span?____ Did wire or other metal show signs of arcing?____

Insulators and Pins: What type of insulator?____ Pin No.____ Pole No.____ Was insulator punctured?____

Had it flashed over?____ How badly damaged?____ Cause____

Was insulator hardware grounded?____ Was pin damaged?____ Was cross-arm damaged?____

IMPORTANT: List on the reverse side of this report, in the space provided, full information on all insulators replaced in connection with the above trouble or replaced on maintenance or for other reasons.

Give any other information which is needed to cover above trouble or repairs:____

This form must be used to report replacement of insulators and repairs on other equipment reported defective by the patrolman and also to report **ALL REPAIRS** made on transmission lines.

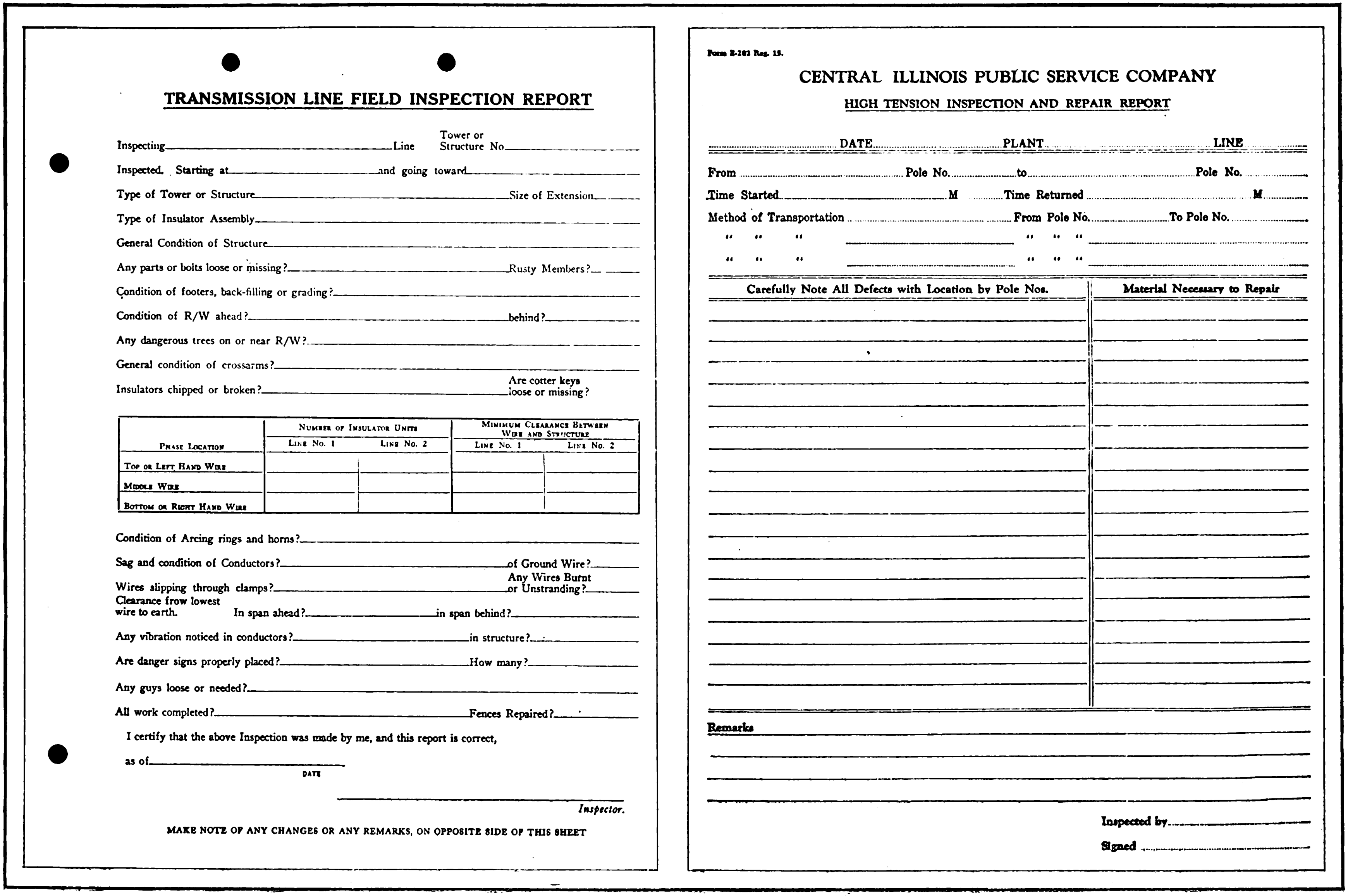
NOTED____ SYSTEM OPERATOR DATE____19__ SIGNED____ LINE FOREMAN

CHECKED____ ENGINEERING DEPARTMENT GENERAL OFFICE DATE____19__ APPROVED____ DISTRICT FOREMAN

For Instructions on use of this form see Engineering Department Instructions No. 4 Dated October 1, 1925 APPROVED____ OPERATING SUPERINTENDENT OR DISTRICT ENGINEER

OD 89

FIG. 5—TRANSMISSION LINE PATROL AND REPAIR REPORT FORMS—PUBLIC SERVICE CO. OF NORTHERN ILLINOIS.



TRANSMISSION LINE FIELD INSPECTION REPORT

Inspecting__________Line Tower or Structure No.__________
Inspected. Starting at__________and going toward__________
Type of Tower or Structure__________Size of Extension__________
Type of Insulator Assembly__________
General Condition of Structure__________
Any parts or bolts loose or missing?__________Rusty Members?__________
Condition of footers, back-filling or grading?__________
Condition of R/W ahead?__________behind?__________
Any dangerous trees on or near R/W?__________
General condition of crossarms?__________
Insulators chipped or broken?__________Are cotter keys loose or missing?

Phase Location	Number of Insulator Units		Minimum Clearance Between Wire and Structure	
	Line No. 1	Line No. 2	Line No. 1	Line No. 2
Top or Left Hand Wire				
Middle Wire				
Bottom or Right Hand Wire				

Condition of Arcing rings and horns?__________
Sag and condition of Conductors?__________of Ground Wire?__________
Wires slipping through clamps?__________Any Wires Burnt or Unstranding?__________
Clearance frow lowest wire to earth. In span ahead?__________in span behind?__________
Any vibration noticed in conductors?__________in structure?__________
Are danger signs properly placed?__________How many?__________
Any guys loose or needed?__________
All work completed?__________Fences Repaired?__________

I certify that the above Inspection was made by me, and this report is correct,

as of__________
DATE

____
Inspector.

MAKE NOTE OF ANY CHANGES OR ANY REMARKS, ON OPPOSITE SIDE OF THIS SHEET

Form E-203 Reg. 15.

CENTRAL ILLINOIS PUBLIC SERVICE COMPANY

HIGH TENSION INSPECTION AND REPAIR REPORT

..........DATE..........PLANT..........LINE..........
From..........Pole No..........to..........Pole No..........
Time Started..........M..........Time Returned..........M..........
Method of Transportation..........From Pole No..........To Pole No..........
" " "__________" " "__________
" " "__________" " "__________

Carefully Note All Defects with Location by Pole Nos.	Material Necessary to Repair

Remarks__________

Inspected by..........
Signed..........

FIG. 6—(*Left*) TRANSMISSION LINE FIELD INSPECTION REPORT FORM. (*Right*) HIGH TENSION INSPECTION AND REPAIR REPORT FORM—CENTRAL ILLINOIS PUBLIC SERVICE CO.

TYPES OF DISTRIBUTION SYSTEMS, AND METHODS OF EFFECTING CHANGEOVER

Introduction

In the first report of the Electrical Problems of Distribution Subcommittee (Publication No. 267-15), it was stated that the design of distribution systems involved two problems; the first being the development of a system that will serve the connected loads with a high degree of reliability. Very closely related to the first problem is the second one, which is that of economy. A third point to be considered is that of future growth. The design must be so planned that it will be the economical system or will readily grow into such a system under future conditions of load density and reliability requirements.

These points are repeated for emphasis, as it is felt that these are the three guiding principles to be followed in designing any system. The economics should not be slighted and should be the guiding principle in all distribution system design.

A fourth point which in the past has received only slight consideration for residential service, but is becoming more and more important, is that of designing a distribution system so that maintenance and construction can be accomplished with a minimum outage to customers' service. This feature is particularly important in extending an existing system or planning a conversion or revamping of an old one, since a system once installed in accordance with a particular design cannot be altered without a serious number of service outages and considerable expense.

The importance of reducing to an absolute minimum the number of service outages will be readily recognized in view of the number of electrical appliances now being used in the average residence. The increase in the number of oil burning furnaces, electric ranges, electric clocks, washing machines and such equipment makes continuity of service a necessity. Indeed, it is principally through the sale of such equipment that residential consumption of electricity can be increased. Since the continued sale of such equipment depends to a great degree upon the satisfaction obtained in its use, the sale of load building apparatus must not be jeopardized by frequent outages with the resulting discomfort or inconvenience, but should be encouraged by continuous service.

In the first report (Publication No. 267-15) general features of distribution practices were outlined, together with tables showing their relative usage. In this report the study has been restricted to the subject of the design of the individual feeder layout for one general type of system, namely, the 4000 volt, three-phase, four-wire system. It is felt that a general analysis of the various types of feeder layout and the advantages and disadvantages of the various classifications, particularly as to where their application is economical, will be of value. The application of the various types to actual systems is also discussed.

In the second part of this report various methods of changing over to a 4000 volt, three-phase, four-wire system from two-phase and three-phase 2300 volt systems are discussed. As the data in the first report indicated that a number of companies were considering such a changeover, the collection of data regarding the experience and methods followed by other companies in effecting similar changes was justified.

In conducting a changeover of this type the problem becomes partly one of economy. Undoubtedly, in planning a change, various methods of effecting it will be considered, the problem resolving itself into one of choosing the one that will be the most economical and at the same time will not result in a prohibitive number of service outages.

PART I

TYPES OF DISTRIBUTION SYSTEMS

SCOPE

It is the purpose of this report to discuss the various classifications of distribution systems in general, as to their operating advantages, and to present in detail standard types of distribution system connections, especially those used on 4000 volt Star Systems, thus establishing a much needed nomenclature.

The committee has made a survey of 95 companies, studying the distribution systems of 48 of these companies operating a 4000 volt Star System, and has tabulated the following information on the practices and experiences of these companies.

Many companies have reported operation at several different voltages at the present time, due to a transition period, but are gradually eliminating the lower voltages and adopting one or more of the higher voltages as a standard. The reasons set forth by these companies for their change in distribution voltages have been summarized and embodied in this report.

CLASSIFICATION OF VARIOUS SYSTEMS IN USE

The distribution systems of 95 operating companies in the United States and Canada have been classified in Table I as to the range of voltages in use.

Publication No. 289-46, Serial Report, Overhead Systems Committee.

TABLE I

PRIMARY DISTRIBUTION VOLTAGES IN USE BY COMPANIES REPORTING

			% of Companies
	2200 to 2400 volt only		21.0
Star	2200 to 2400/3810 to 4136 volt only		10.0
Star	4000 with 2200 to 2400 volt, 3-phase systems	9.5	
Star	4000 with 2200 to 2400, 2-phase systems	1.5	
Star	4000 with 2200 to 2400, 3-phase and 2-phase systems	4.2	
Star	4000 with 2200 to 2400, 3-phase and 1-phase systems	5.3	
		—	20.5
Star	4000 with 4400 to 7200 volt	3.3	
Star	4000 with 4400 to 13,200 volt	4.2	
Star	4000 with 11,000 to 13,200 volt	1.5	
		—	9.0
Star	4000 with lower and higher voltages		11.5
	2200 to 2400 volt with 4400 to 6900 volt		21.0
	2200 to 2400 volt with 4400 to 13,200 volt		2.7
	2200 to 2400 volt with 11,000 to 13,200 volt		4.3
			100.0

A study of Table I shows that 10 per cent of the companies are operating solely a 4000 volt Star System, and that 20 per cent are still operating in addition some 2200 to 2400 volt circuits. While the major part of their systems is 4000 volts Star, it is reasonable to assume that a total of 30 per cent will be operating solely 4000 volt Star Systems as soon as changeovers are completed.

In addition to these companies, 9 per cent are operating 4000 volt Star for concentrated load areas, and are using higher voltages for isolated towns and rural lines. To carry our conclusion still further, it may be safe to assume that 11 per cent of the systems operating 4000 volt Star Systems with some load still at 2200 to 2400 volts with higher voltages for rural services will, in the near future, eliminate the lower voltage circuits and operate at 4000 volt Star with a higher voltage for isolated loads. Therefore, at the present time the trend shows that a total of 51 per cent of the companies are using 4000 volt Star for a large portion of their distribution load. Of the remainder, approximately 24 per cent have indicated a tendency to go directly from 2200/2400 Delta Systems to a higher Delta voltage for their concentrated and rural load. This leaves 21 per cent who so far have taken no steps to increase their distribution voltages and 4 per cent who still operate a 2200/2400 volt Delta System with 11,000/13,200 volt Delta for concentrated load and rural service. As load densities increase so that higher voltages will be necessary, it is possible that a large number of these companies will change over their lower voltage Delta Systems to 4000 volt Star Systems.

A comparison of systems of all voltages and a tabulation showing the percentage of companies using each system was included in the serial report "Electrical Problems of Distribution" (Publication No. 267-15).

A company operating a 2300 volt system, whether single-phase, two-phase, or three-phase Delta, may change over to a 4000 volt Star System with the least expense and derive the benefit of greater capacity supplying larger areas from one substation with combined light and power load. Where rural service is considered, the practice indicates the use of a transmission voltage of 11,000 to 13,200 volts, or, if the distances are not too great, the adoption of one of the Delta Systems from 4600 to 7200 volts for this use (so that a higher voltage Star System may be used in the future). Therefore, it may be advisable to maintain two voltages and to have two stocks of transformers for supplying the distribution load on both systems.

For residential service, business districts of low load density, rural and small towns covering limited territory, 2300/4000 volts finds a definite application. A higher voltage Delta System for concentrated business sections, rural service and small towns in scattered territory, may be economical and desirable.

TYPES OF CONNECTIONS

Outline of Types

In general, all types of distribution circuits may be divided into three classes. Each class may have several subdivisions as given in Table II. Each company has coined a name for its particular type of circuit, so that it is very difficult to hold the subdivisions of these general classes to a minimum. In this report an effort has been made to include all the major differences of the various types of circuits without covering a multitude of those which have only certain peculiar features differentiating them from the general types. The outline in Table II classifies the various types.

TABLE II

TYPES OF PRIMARY AND SECONDARY DISTRIBUTION SYSTEM CONNECTIONS

1. *Primary System*
   a. Radial
      1. Main
      2. Feeder and Main
      3. Segregated Phase
      4. Duplicate Service
      5. Parent Feeder
   b. Loop
      1. General Distribution
      2. Bulk Load Distribution
   c. Network
2. *Secondary System*
   a. Radial
   b. Network
      1. Isolated.
      2. Interconnected.

It will be noted that in describing any particular type of distribution system it will be described first in respect to the type of primary system and, second, to the type of secondary system. This is essential to a clear understanding of the particular system, since the primary system may be one of several types entirely different from the type of secondary system. Thus, a radial secondary system may be supplied by a radial, loop or network type of primary. The same may be said of a secondary network. Therefore, the dual classification is recommended.

Primary Systems

(a) Radial

The radial type of distribution circuits, in some form, is in most common use today, and by means of diagrams some of the different types into which this general group of circuits has been divided will be described. The various classifications of the radial systems are simply modifications necessitated by local conditions.

(1) Main

The most common type, or radial main, as shown in Fig. 1, is used where a feeder is installed from a substation into a given area and takes care of all of the load in that district. The feeder itself will run as near to the center of load as is practicable, and a feeding point established which may be used as a basis of regulation. From this feeding point, radial mains are run in all directions with laterals to pick up the load. In general three-phase mains are run through the heavily loaded areas with single-phase taps to pick up isolated single-phase loads.

An adaptation of the radial main system is what is popularly termed the tree or herring-bone type of feeder. This is similar to the radial and main feeder except that the feeder portion supplies the system of mains at that portion of the feeder area nearest the substation instead of at the center of the load. Its application is principally in small towns and rural districts. Undoubtedly, it is the result of extending a single line along a road or isolated street to serve customers along that particular thoroughfare. As territory on both sides of the line develops, side taps and extensions along intersecting roads result in it being expanded into a feeder supplying a sizeable area. The schematic connections may be represented as shown in Fig. 1 if it is assumed that the feeder is connected at one end instead of the center of the feeder area. This type of feeder is adaptable only to areas of light load density, as the regulation and losses are greater.

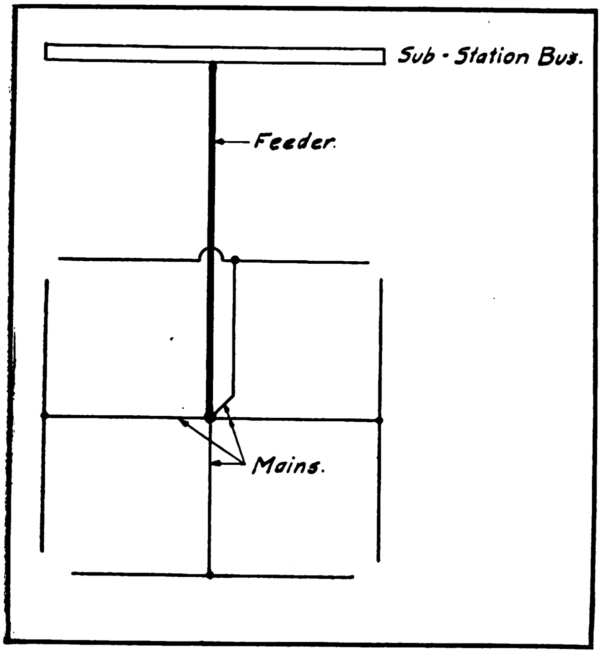


FIG. 1—RADIAL, MAIN PRIMARY FEEDER.

(2) Feeder and Main

The type known as the feeder and main, as shown in Fig. 2, consists of a heavy copper four-wire main, extending through a district or possibly between substation areas, and divided up into feeder lengths. Each feeder length is sectionalized and connected by a feeder to an adjacent substation. Laterals are installed from the main into adjacent load areas. This is merely a modification of standard radial system where geographical conditions require narrow feeder areas or where high load densities exist in a narrow area.

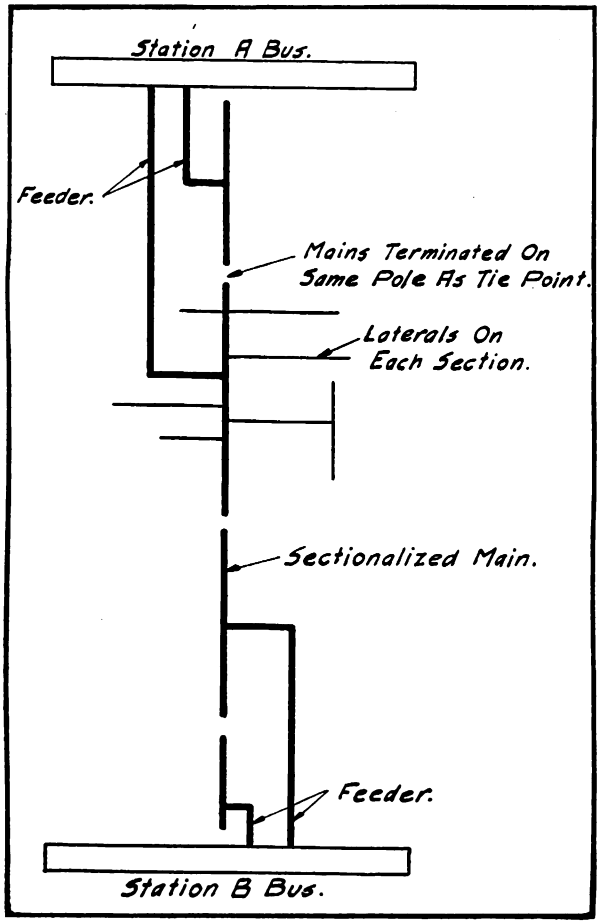

Station A Bus.
Feeder.
Mains Terminated On Same Pole As Tie Point.
Laterals On Each Section.
Sectionalized Main.
Feeder.
Station B Bus.

FIG. 2—FEEDER AND MAIN PRIMARY FEEDER.

(3) Segregated Phase

The segregated phase system, Fig. 3, is a slight modification of the radial main in which single phase mains are run in three directions from the feeding point, and each phase handles all the load in a definite phase area instead of carrying the three phases into each district.

(4) Duplicate Service

A duplicate service scheme as shown in Fig. 4 is really a direct application of the radial main to an important load area, such as a business district, where continuity of service is paramount. In this system the radial main circuits are interlaced so that all customers or distribution banks may be served by two separate circuits; preferably circuits from two different stations. The scheme is not in common use as a distribution circuit.

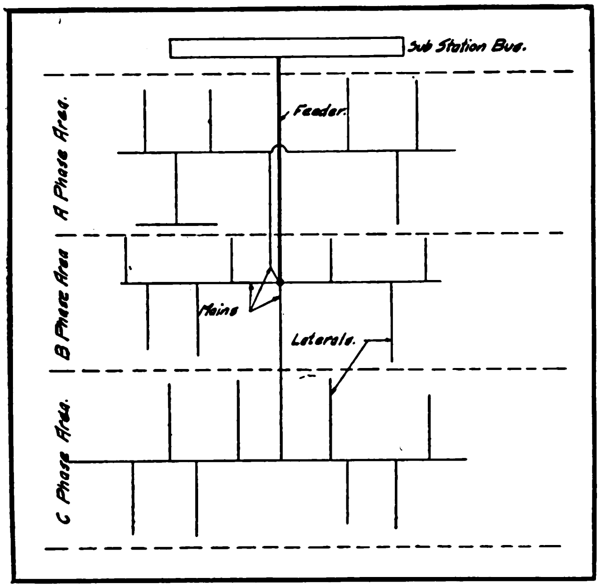

Sub Station Bus.
Feeder.
Mains
Laterals.
A Phase Area.
B Phase Area
C Phase Area.

FIG. 3—SEGREGATED PHASE PRIMARY FEEDER.

(b) Loop

The second general class of circuits known as the Loop System is very common for transmission service, but recently has been more frequently used in distribution systems. In general, all types of loop circuits are the same, although two different applications are in use.

First, as shown in Fig. 5, the large customers' feed consists of a feeder extending from one substation out through a territory and either back to the same substation or to one adjacent, with large customers connected in series and with protection equipment on both sides of each customer's service. In case of trouble on the feeders the switches nearest the fault will open, but no banks will be out of service.

Second, the distribution loop, as illustrated in Fig. 6, is very similar to the large customers' feed, but the feeder is equipped with automatic sectionalizing

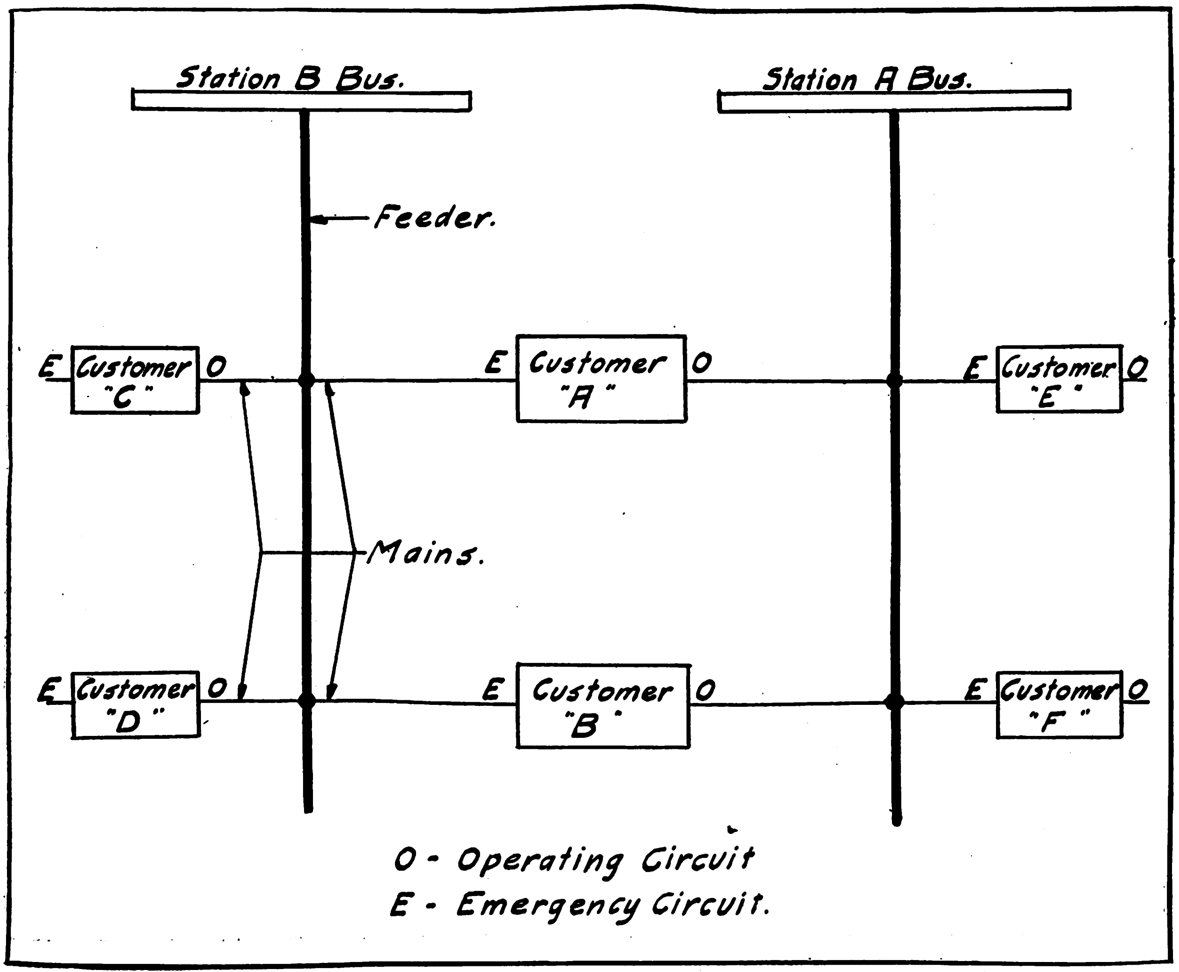

Station B Bus.
Station A Bus.
Feeder.
E Customer "C" O
E Customer "A" O
E Customer "E" O
Mains.
E Customer "D" O
E Customer "B" O
E Customer "F" O
O - Operating Circuit
E - Emergency Circuit.

FIG. 4—DUPLICATE SERVICE PRIMARY FEEDER SYSTEM.

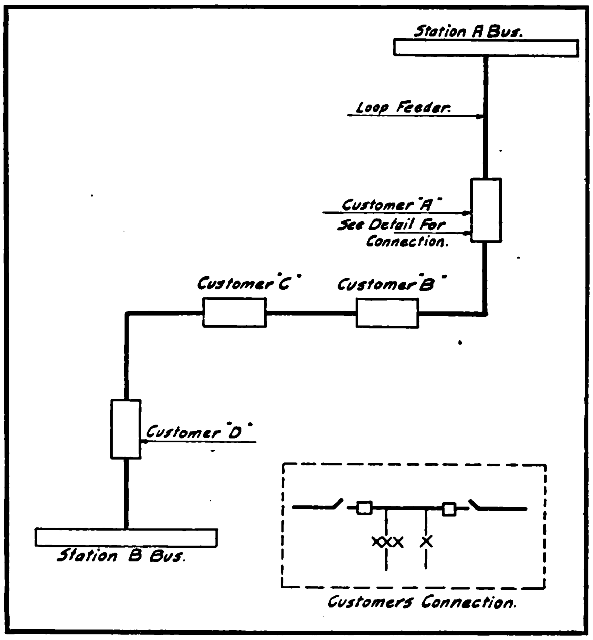

Station A Bus.
Loop Feeder.
Customer "A"
See Detail For Connection.
Customer "C"
Customer "B"
Customer "D"
Station B Bus.
XXX X
Customers Connection.

FIG. 5—LARGE CUSTOMERS' LOOP FEED PRIMARY SYSTEM.

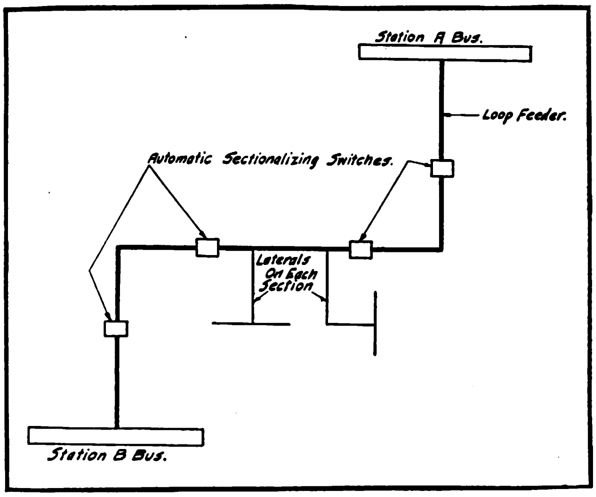

Station A Bus.
Loop Feeder.
Automatic Sectionalizing Switches.
Laterals On Each Section
Station B Bus.

FIG. 6—GENERAL DISTRIBUTION LOOP PRIMARY SYSTEM.

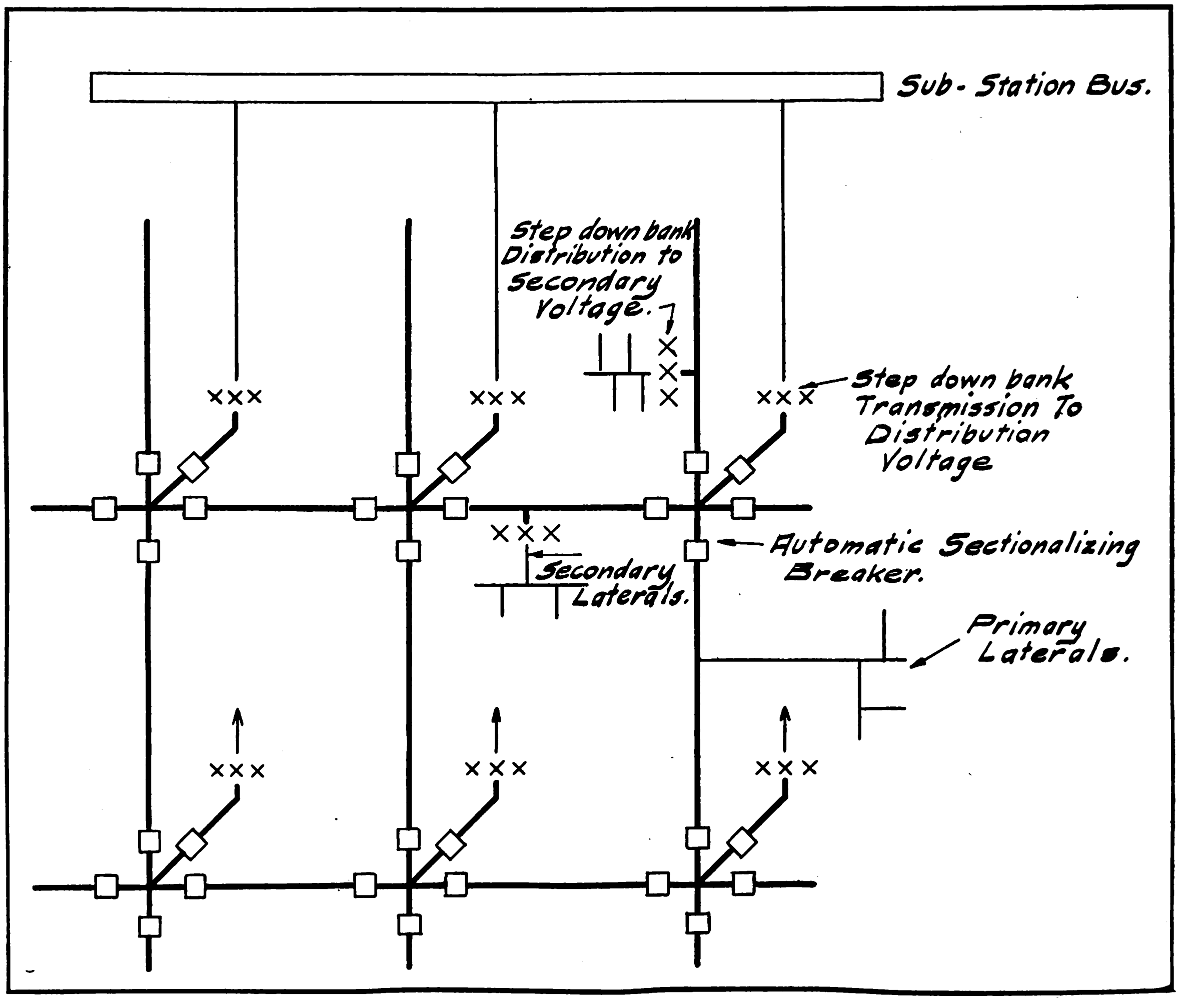

Sub-Station Bus.
Step down bank Distribution to Secondary Voltage.
Step down bank Transmission To Distribution Voltage
XXX
Automatic Sectionalizing Breaker.
Secondary Laterals.
Primary Laterals.

FIG. 7—PRIMARY NETWORK.

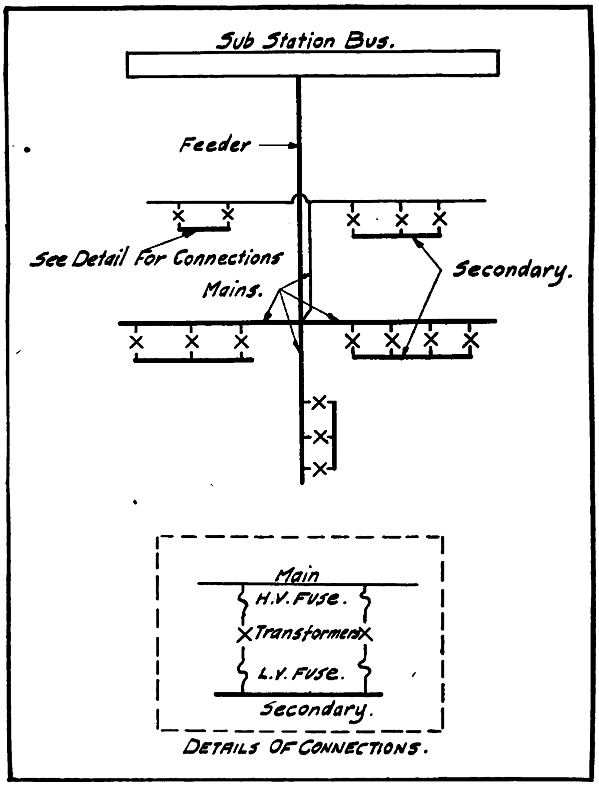


FIG. 8—RADIAL PRIMARY SECONDARY NETWORK.

switches to cut out a bad section in case of trouble, leaving the rest of the feeder in service. The feeder sections between such sectionalizing switches may have banks connected directly to them or laterals which reach out into adjacent territory and supply load. The loop is relayed with time delay relays or pilot wire protection so that the two switches nearest the trouble will open, leaving only that section out of service.

(c) Network

A primary network has been proposed and is being used in at least one city which will be capable of indefinite expansion as far as area and load are concerned. Fig. 7 illustrates this type of circuit. This system consists of a number of radial transmission circuits extending from a generating or substation bus to the load, with one stepdown bank connected directly to each circuit. The secondary of this stepdown bank, presumably at 4000 volts, would be connected to a bus through an automatic oil switch, from which lines would extend in four directions, each line tying into a similar bus some distance away. These tie lines from which laterals would be installed are protected by an automatic oil switch at each end. Distribution transformers with their respective radial secondaries would be connected to these ties and laterals and thus serve the area.

Secondary Systems

(a) **Radial**

The radial secondary system is so widespread in its use and so familiar to distribution engineers that it need neither be described nor discussed. It will suffice to say that a radial secondary system consists of a number of isolated secondaries, each supplied by one transformer or transformer bank.

(b) **Network**

The secondary network type of distribution has gained recognition very rapidly in the last few years, and while in most cases it is confined to underground installations, it will be discussed here as one of the types under consideration.

A radial primary, secondary network, as illustrated in Fig. 8, can be used quite extensively in overhead territories and has proved very successful. It consists of banking several sets of transformer banks common to the same primary and secondary with protection on both the primary and secondary sides. This insures service on the secondary, although one transformer on the network may have failed. Surplus capacity on the secondary must, of course, be installed to take care of the failure of one bank on each network. Periodic load check on each bank and inspection of the primary and secondary fuses must be made to make sure that all banks are in service.

The multiple primary feed network, Fig. 9, is most applicable in districts of high load density. In this case all transformers are tied solidly to a primary feeder of the radial type and in turn tied to a common secondary bus through automatic low voltage network protectors. This type of system has been covered in detail in other papers, and no attempt will be made to discuss it beyond its comparison with other types of distribution circuits.

The loop primary feed network system, as shown in Fig. 10, is a very recent combination of two important types of distribution circuits, and it therefore may be considered as a separate class of circuit. This system consists of several distribution loop circuits operating between two substations or from one substation bus with automatic sectionalizing switches between each transformer installation. Transformers are connected directly to these loop feeders and through secondary fuses supply a common secondary bus. This type of circuit eliminates the necessity of installing as great an amount of surplus transformer capacity as is needed in the multiple primary network, but requires a much greater surplus of feeder capacity. In case of a primary feeder failure, only one bank on that feeder is out of service due to the selectivity of the automatic sectionalizing switches.

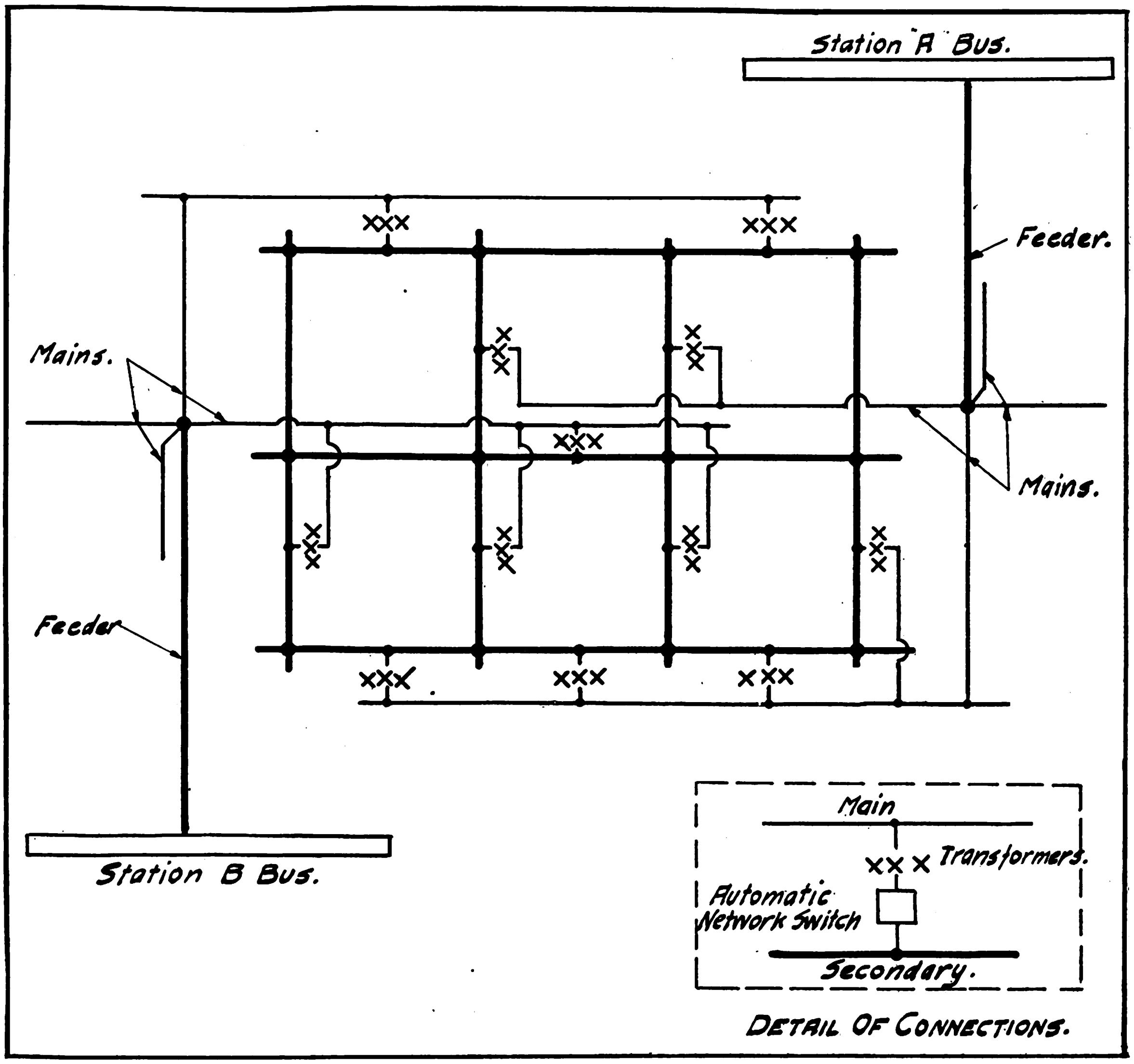

Station "A" Bus.
Feeder.
Mains.
Mains.
Feeder
Station B Bus.
Main
Transformers.
Automatic Network Switch
Secondary.
DETAIL OF CONNECTIONS.

FIG. 9—SECONDARY NETWORK WITH MULTIPLE RADIAL PRIMARY FEED.

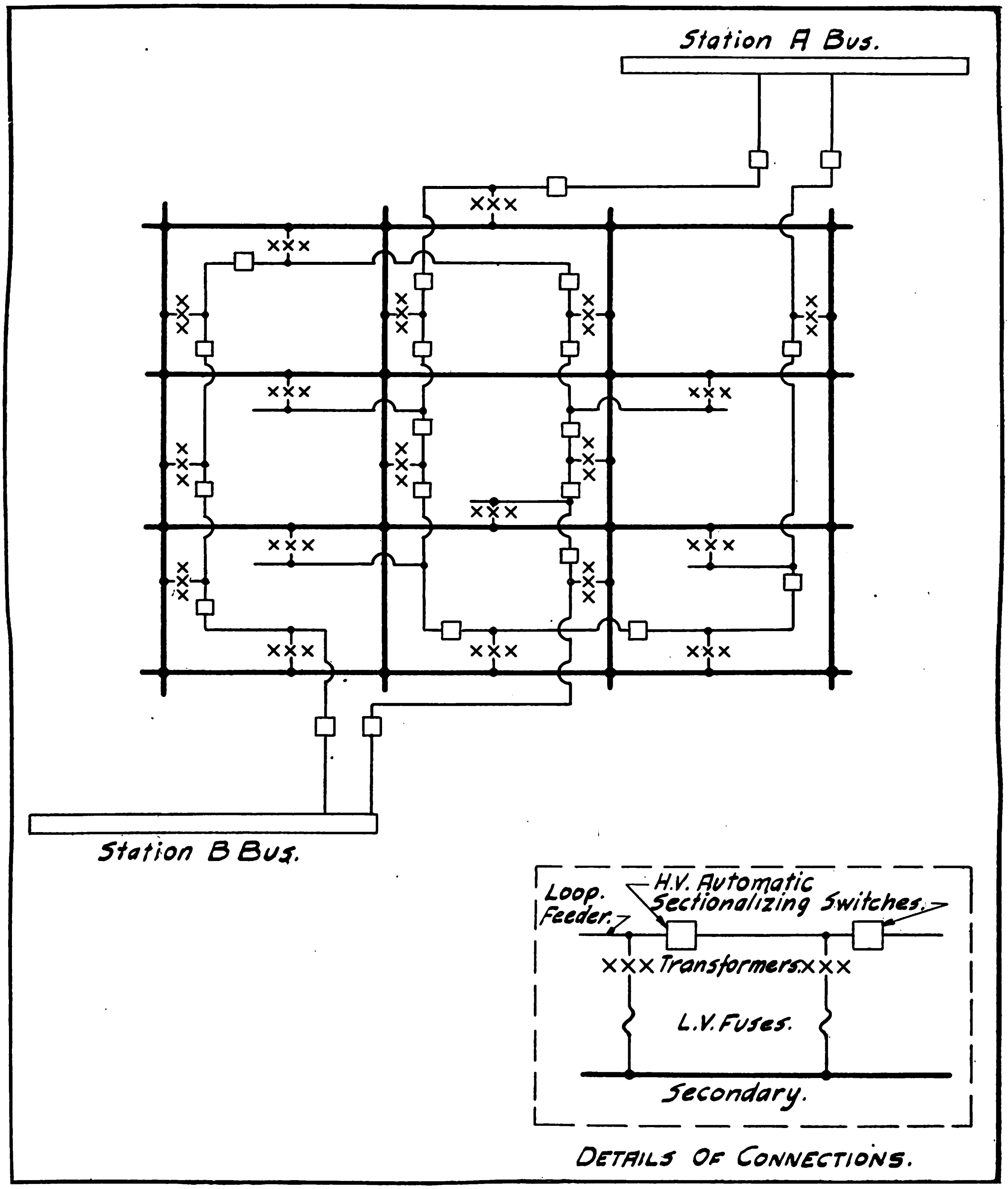

Station A Bus.
Station B Bus.
Loop. Feeder.
H.V. Automatic Sectionalizing Switches.
Transformers.
L.V. Fuses.
Secondary.
DETAILS OF CONNECTIONS.

FIG. 10—SECONDARY NETWORK WITH LOOP PRIMARY FEED.

APPLICATION OF VARIOUS TYPES OF SYSTEMS

In territories of medium low density the radial main system offers a very desirable type of circuit to give good regulation and permit the use of three-phase equipment over a large territory. Load may be balanced between phases on this type of circuit and thus utilize the full capacity of the feeder itself. The radial main system may not be economical in territories of very low load density covering a large area. Interconnection with adjacent feeders is usually maintained so that the portion of the feeder between the substation and feeder points may be cut out and service maintained by connecting the mains to adjacent feeders.

In changing from a single-phase, 2300 volt system to a 4000 volt Star system, the segregated phase type of circuits may be adopted with a minimum amount of copper. This type of circuit should be most economical for districts with low load density covering a considerable territory. Independent voltage regulation at the feeding point may be maintained on all phases. It is difficult to balance the phases on this type of circuit and it does not permit the use of three-phase equipment except when adjacent to the feeding point. An extensive rearrangement is necessary in order to take care of added load without excessive voltage drop or unbalancing of the phases. In order to take three-phase load, considerable revamping is necessary in adding additional copper. Neutral loss is increased but copper cost in mains is reduced.

The duplicate service scheme offers a very reliable service with a minimum outage to service such as business districts, hospitals and the like. It permits taking feeders out of service without serious interruption to the customer, and also permits regulating the load on each feeder. This type of circuit necessitates the installation of two oil switches or sets of fuses at each installation, and these require constant maintenance. An excessive amount of copper is required in order to cover a large area with this type of service, and it is only justified in concentrated business districts where continuity of service is an important factor. It is the opinion of many engineers that this scheme has no paramount advantages for supplying business areas if the successful operation of a multiple primary feed secondary network is possible.

The feeder and main system offers the best type of circuit for narrow districts of medium load density with laterals reaching out to adjacent lower density load areas. The phases may be readily balanced and extensions added with the least amount of new construction. During low load periods the feeder may be taken out of service and the main tied to the adjacent main section without excessive voltage drop. This permits maintenance of the feeder and all switches at the station without an interruption of service. This type of circuit has no advantage in large territories of very low load density due to the heavy copper main necessary between substation areas. This may be used where a narrow business area has developed requiring additional feeders due to increased load densities.

The loop system offers a very reliable source of supply to large customers, with the minimum amount of copper, but with the installation of two oil switches at each customer's installation. This system when used to supply general distribution may require the installation of automatic sectionalizing switches at frequent intervals so that only a small amount of load will be dropped in case of the failure of one section of the feeder. The general advantages and disadvantages of both types of loop circuits are similar. The loop is a very reliable source of energy for combination power and light loads at a uniform voltage. Division of the load may be controlled from either end of the loop, and one end of the circuit may be taken out of service without affecting the service of the loop. The loop system necessitates the installation of two oil switches at the substation to carry the load of one circuit and also the installation of sectionalizing switches, either automatic or non-automatic.

The radial network in territories where a few adjacent banks supply important loads will insure the load against an outage due to transformer failure but not due to primary feeder failure. This system permits paralleling several banks of transformers covering adjacent blocks on the same secondary, provided primary and secondary fuses are installed to supply and to protect the service against the failure of one transformer. In such cases the secondary fuses should not be placed for overload protection, but for failure of the transformer itself.

The multiple primary feed is especially adaptable to concentrated business areas where continuity of service is of major importance by the proper interlacing of primary feeders supplying the low voltage secondary. Any primary feeder may be out of service without materially affecting the loading of the remaining transformers or the voltage on the secondary. It also permits the combination of light and power on the same secondary. Suitable automatic low voltage network protectors are on the market which give very satisfactory operation. The expenditure necessary to set up such a network is not justified unless high load densities exist which will render a network economical. Additional transformer capacity must be installed to take care of the possibility of one feeder being out at any time without causing excessive voltage drops between remaining banks.

The loop primary feed network employs the combined features of the loop and the network as given above, and is more adaptable to territories of lesser load density where continuity of service is an important factor. Such an installation does not necessitate as great an amount of spare transformer capacity, since only a small section of a feeder may be out of service due to primary feeder failure.

The proposed primary network will permit a very reliable source of supply for moderately loaded areas

The scheme is very flexible and is so arranged that trouble on any section will affect only a small area. This type of circuit would be very effective in residential areas of medium load density where the type of service rendered by the secondary network is desirable but where the load does not warrant its adoption. Consideration must be given the type of oil switches to be used so that they do not prove to be a hazard. As the voltage drops are small, due to the close spacing of small substations, unregulated feeders may be used. They may also be used for districts having light load densities. As load density increases more small substations may be added. Substations are small and simple, consisting only of a transformer bank and five oil switches. This system may be used where it is ultimately intended to change over to a multiple primary feed secondary network.

ADAPTABILITY OF VARIOUS SYSTEMS TO FUTURE GROWTH

In order to take care of increased load beyond the feeder capacity, both the radial main and segregated phase type often require considerable rearrangement and construction. New feeder areas must be set up and load cut over from existing feeders to form a new feeder area. In the segregated phase scheme, especially, considerable difficulty may be experienced in relieving the load on existing feeders and still maintain a balanced phase condition. A new switch position at a substation must be provided and a feeder installed from this substation to the center of load of the new feeder area. With a radial main system new feeders may be created readily if a more or less continuous network of primary mains exists with junction boxes at each intersection point. The procedure in establishing a new feeder is to install the new feeder to the junction box at the new feeder joint and open the boxes at the boundary of the new feeder area. With an overhead system, the procedure is simpler by virtue of the fact that lines may more readily be worked on when alive.

Where the duplicate service scheme is used, new feeders must be installed to take care of a desired load when additional capacity is needed. In general, a rearrangement similar to the radial main scheme is required. Arrangement must be made, however, to extend an existing feeder into the territory for the emergency service.

The feeder and main type is the simplest of all the radial feeder systems to readapt for increased load. The main may be cut or redivided and a new feeder switch position in the substation connected to the new main section without any further expense or rearrangement.

The general distribution and large customer feed loop system may be loaded to the limit of that which can be carried from one end without excessive voltage drop, giving due consideration to existing loads. Beyond this point, if new load is added, a separate loop must be installed from two new feeder positions at the substation.

The radial network may be extended up to the limit of the feeder, at which time it must be sectionalized and new feeders added. In this type of system it would be preferable to have several small networks instead of grouping all transformers on one feeder onto a common secondary due to the limitation of present day fuses. Growth of load may be provided for in the same manner as for the radial main system.

The multiple primary feed network is very flexible and new feeders may be interlaced with the existing feeders to take care of increased loads. Each bank on the new feeder is tied to the existing secondary grid or an extension, if in new territory.

TYPICAL INSTALLATIONS

Operating circuit maps were requested from a number of companies having 4000 volt distribution systems and maps were received by the committee which illustrated in detail the important features of several of the typical circuits. These maps have been revised to be applicable to a typical area, and, as reproduced here, illustrate in a comparable manner applications of the various types of systems.

Radial Main

Fig. 11 shows a simple radial circuit supplying single-phase and three-phase load.

Segregated Phase

Fig. 12 shows an example of a segregated phase feeder. This circuit consists of a feeder and three-phase mains, tied into adjacent feeder areas for emergency connections. Single-phase laterals are run from the mains so that definite areas as marked are designated for each phase. In this type of circuit, three-phase laterals may be extended to pick up power loads, although all lighting is connected according to specified phase areas. Each phase is regulated for its own feeding point.

Duplicate Service

Fig. 13 illustrates an application of duplicate service to large customers. These circuits are interlaced throughout an outlying business district supplying duplicate service to important buildings. While these circuits are not solely duplicate service feeders, they illustrate the method of interlacing feeders for this type of service.

Feeder and Main

Fig. 14 shows the use of a feeder and main system. A sectionalized main extends through the two boroughs, each section being supplied by a feeder from one of the substations. The laterals and transformer connections for the entire area were left off so as not to make the map unreadable. A section of one lateral is shown to illustrate the transformer layout. This main eventually will be extended into adjacent substation areas forming a possible main bus tie between substations. The main sections and the feeders are connected by means of pole top disconnecting switches to its respective main sections.

Loop

Fig. 15 shows a typical loop layout between several substations. These circuits supply large customers' installations as well as large banks for low voltage distribution. Due to the short distance between installations pilot wire protection is used in most installations.

Radial Network

No maps illustrating an overhead system radial network were received, and while the circuit shown in Fig. 16 is not entirely adaptable to overhead use, it will illustrate the possible use of the radial network system. The solid lines represent a primary feeder with its tie points. Large transformers are connected by fuses between the primary and the secondary. The secondary, which is shown in dotted lines, also has emergency ties to adjacent secondaries. This map shows a more extensive secondary network than would be feasible in an overhead area due to the additional hazards of trees and storms. Radial networks vary in extent from the simple one having two transformers whose secondaries are tied, to a very complete interconnection.

Multiple Primary Network

Fig. 17 shows the primary layout of a multiple primary feed secondary network. The primaries consist of 4000 volt or higher voltage feeders interlaced to supply transformer installations, so that no adjacent banks are connected to the same feeders. Each bank of transformers is 300 kv-a. and they supply concentrated loads in buildings in which the banks are installed, and also smaller loads connected to street secondary mains. If one feeder fails it automatically disconnects itself from the network by means of the automatic network switches and the entire load is carried by the remaining feeders. This installation is entirely underground and is used only to illustrate this type of circuit.

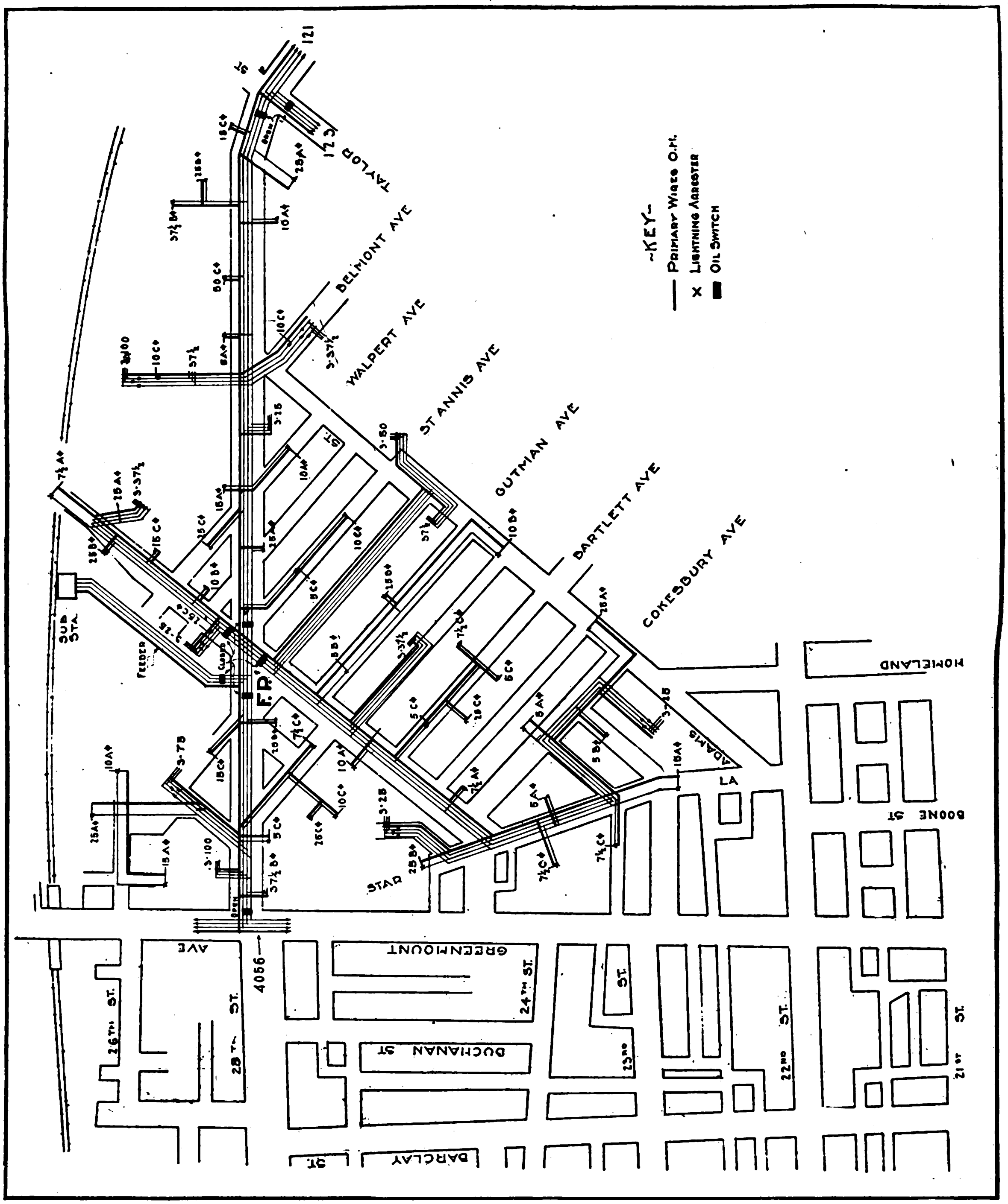

~KEY~
— PRIMARY WIRES O.H.
× LIGHTNING ARRESTER
■ OIL SWITCH
121
123
TAYLOR
BELMONT AVE
WALPERT AVE
ST ANNIS AVE
GUTMAN AVE
BARTLETT AVE
COKESBURY AVE
HOMELAND
ADAMS
LA
BOONE ST
STAR
SUB STA.
FEEDER
F.R.
4056
GREENMOUNT AVE
24TH ST.
26TH ST.
28TH ST.
BUCHANAN ST
23RD ST.
22ND ST.
21ST ST.
BARCLAY ST

FIG. 11—EXAMPLE OF RADIAL MAIN PRIMARY FEEDER LAYOUT.

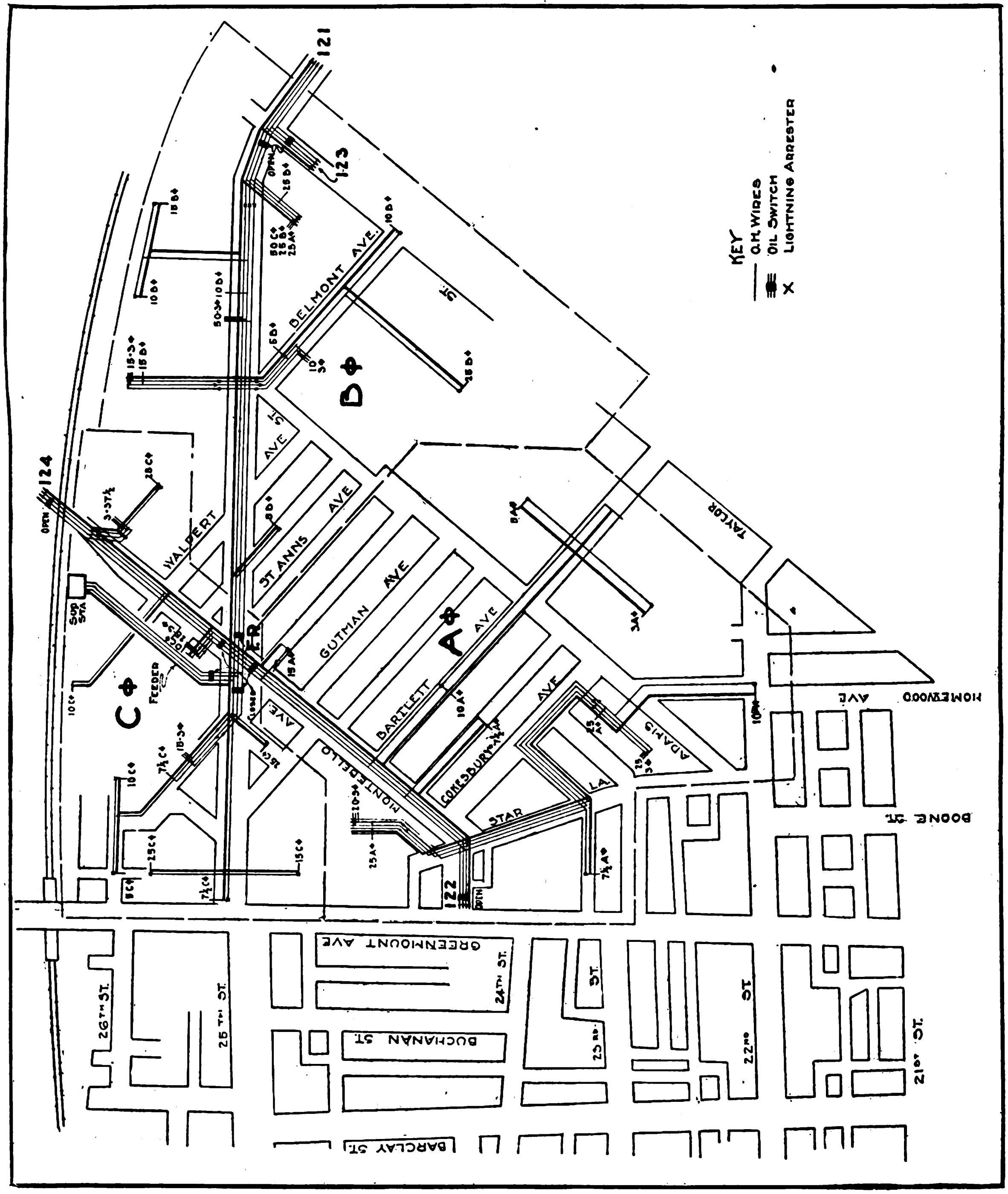

121
123
124
122
OPEN
BELMONT AVE.
ST.
D Φ
WALBERT
ST ANNS AVE
GUTMAN AVE
A Φ
BARTLETT AVE
AVE
ST.
TAYLOR
HOMEWOOD AVE
ADAMS
STAR LA.
COKESBURY AVE
MONTEBELLO AVE
C Φ
FEEDER
SUB STA.
FR
GREENMOUNT AVE
24TH ST.
BUCHANAN ST
BARCLAY ST.
26TH ST.
25TH ST.
23RD ST.
22ND ST.
21ST ST.
BOONE ST.
KEY
O.H. WIRES
OIL SWITCH
LIGHTNING ARRESTER

FIG. 12—EXAMPLE OF RADIAL SEGREGATED PHASE PRIMARY SYSTEM WITH SOME THREE-PHASE SERVICES.

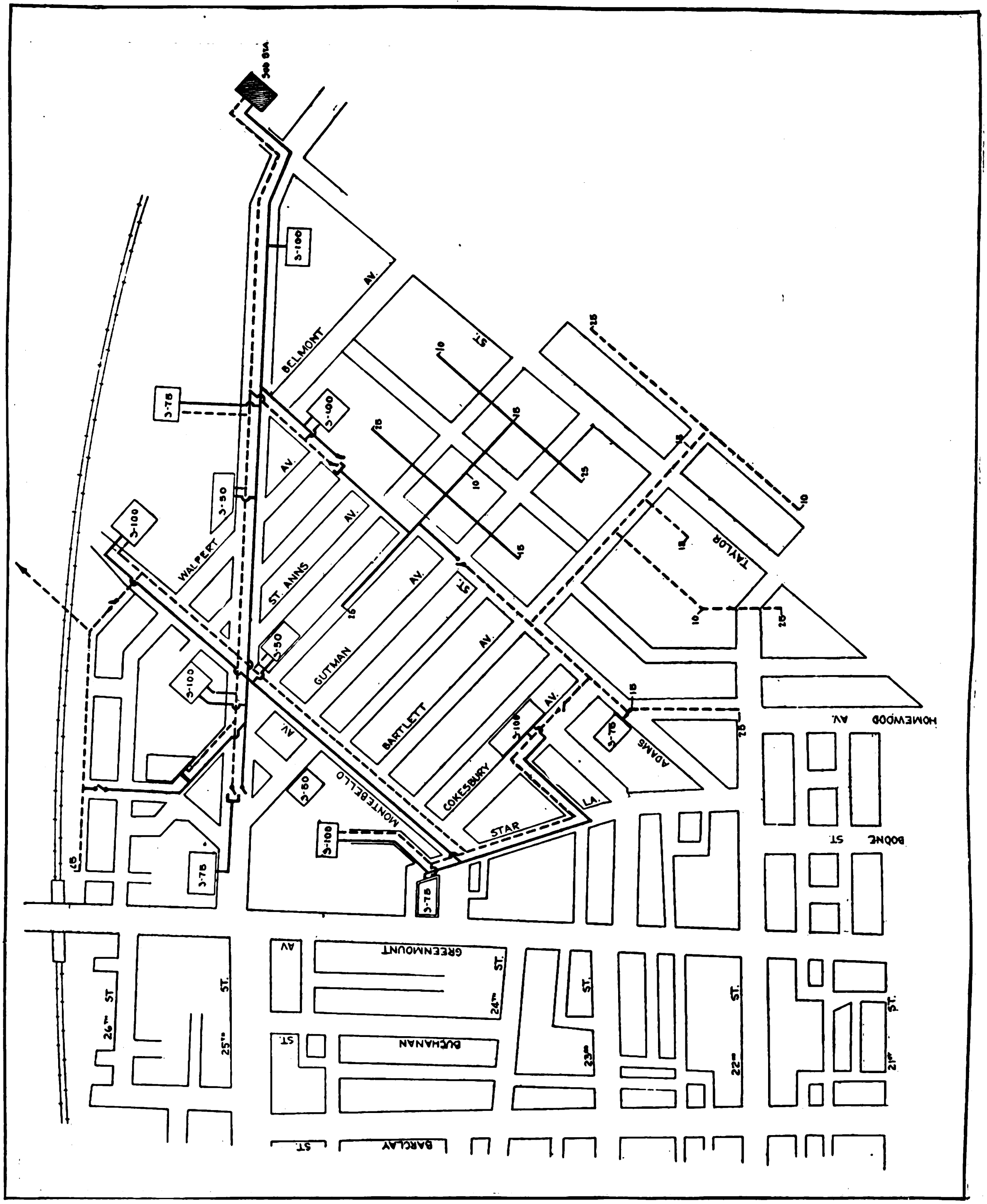

SUB STA.
BELMONT AV.
WALPERT
ST. ANNS AV.
GUTMAN AV.
BARTLETT AV.
COKESBURY AV.
STAR LA.
MONTEBELLO AV.
ADAMS ST.
TAYLOR
HOMEWOOD AV.
BOONE ST.
GREENMOUNT AV.
BUCHANAN ST.
BARCLAY ST.
26TH ST.
25TH ST.
24TH ST.
23RD ST.
22ND ST.
21ST ST.
3-100
3-75
3-50
10
15
25

FIG. 13—Example of Primary System Rendering Duplicate Service to Large Customers.

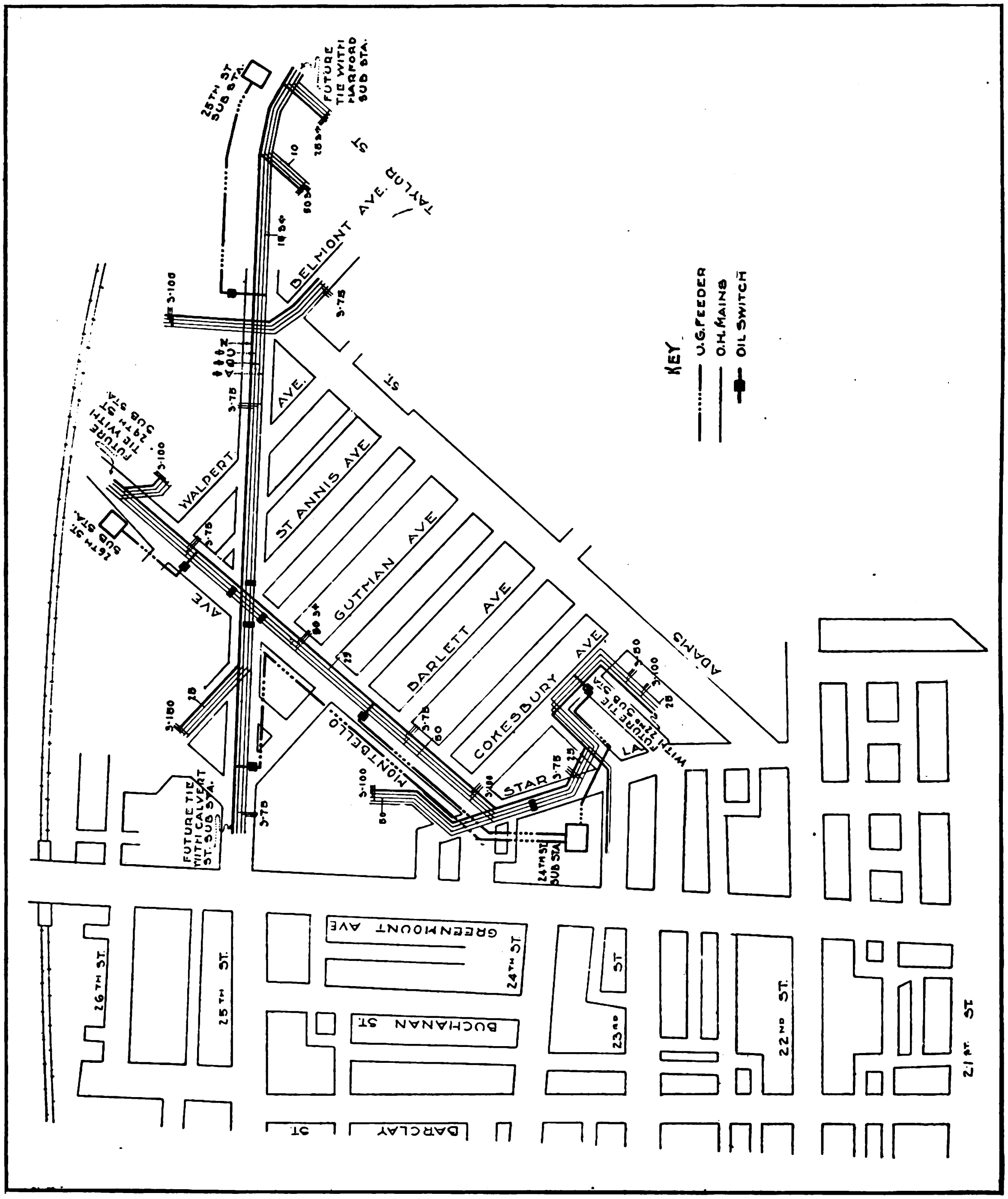

25TH ST SUB STA.
FUTURE TIE WITH HARFORD SUB STA.
BELMONT AVE.
TAYLOR ST
ST
WALDERT
FUTURE TIE WITH 26TH ST SUB STA.
26TH ST. SUB STA.
AVE
AVE.
ST ANNIS AVE
GUTMAN AVE
BARLETT AVE
COKESBURY AVE
STAR
LA
FUTURE TIE WITH 22ND ST. SUB STA.
ADAMS
MONTBELLO
24TH ST SUB STA
FUTURE TIE WITH CALVERT ST. SUB STA.
GREENMOUNT AVE
24TH ST
BUCHANAN ST
25TH ST
26TH ST
23RD ST
22ND ST
21ST ST
BARCLAY ST
KEY
U.G. FEEDER
O.H. MAINS
OIL SWITCH
3-100
3-75
3-150
10
25
50

FIG. 14—EXAMPLE OF FEEDER AND MAIN PRIMARY FEEDER SYSTEM.

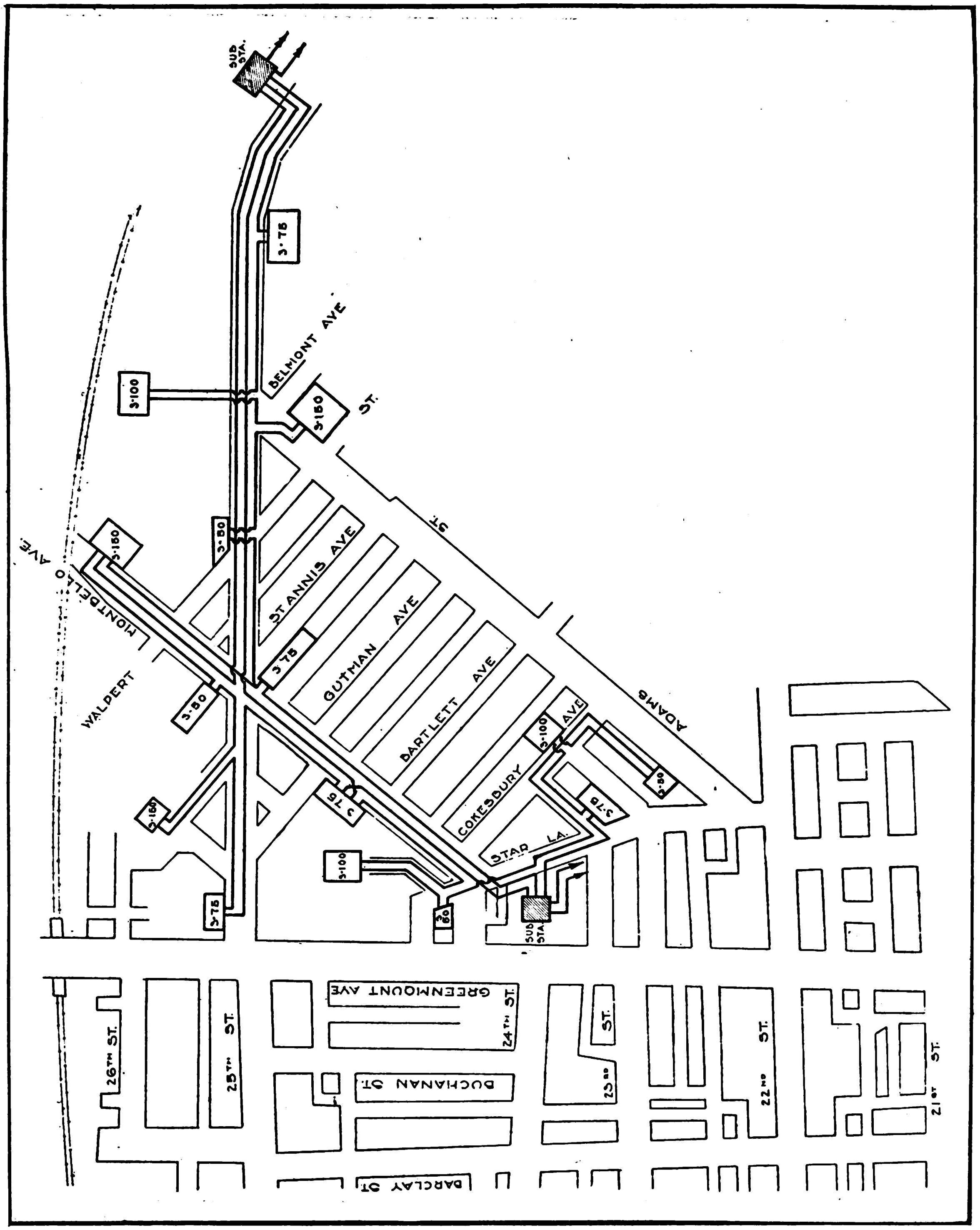

SUB STA.
3·75
BELMONT AVE
3·100
3·150
ST.
ST
ST ANNIS AVE
3·80
3·150
MONTBELLO AVE
3·75
GUTMAN AVE
BARTLETT AVE
ADAMS
WALDERT
3·80
3·150
3·75
COKESBURY AVE
3·100
3·80
3·75
STAR LA.
3·100
3·80
3·75
SUB STA.
GREENMOUNT AVE
24TH ST.
BUCHANAN ST.
BARCLAY ST
26TH ST.
25TH ST.
ST.
23RD
22ND ST.
21ST ST.

FIG. 15—EXAMPLE OF LOOP PRIMARY FEEDER.

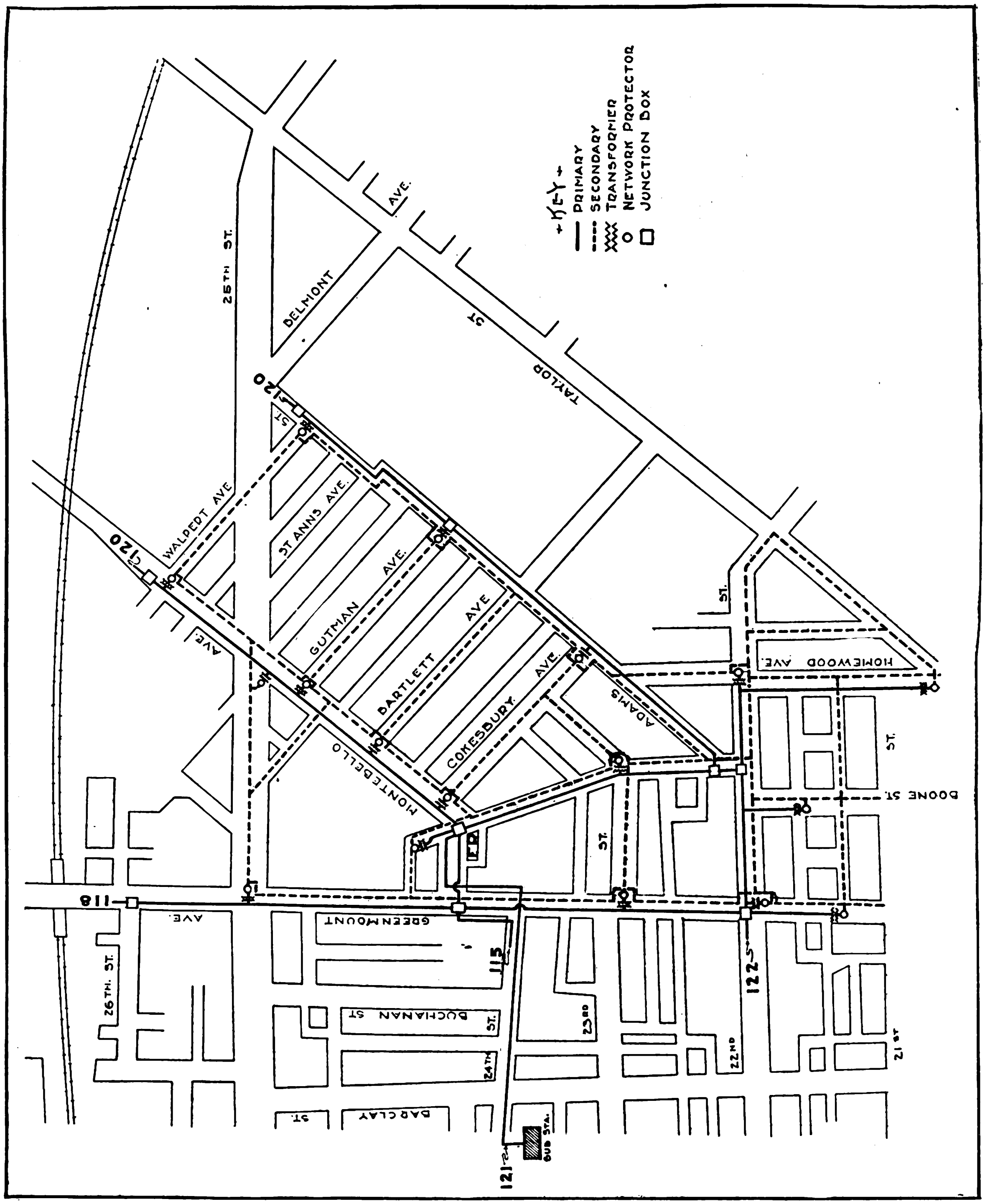

KEY
PRIMARY
SECONDARY
TRANSFORMER
NETWORK PROTECTOR
JUNCTION BOX
25TH ST.
26TH ST.
DELMONT
AVE.
TAYLOR
ST.
WALPERT AVE
ST ANNS AVE.
GUTMAN AVE.
BARTLETT AVE.
COKESBURY AVE.
ADAMS ST.
HOMEWOOD AVE.
BOONE ST.
MONTEBELLO AVE.
GREENMOUNT AVE.
BUCHANAN ST.
BARCLAY ST.
24TH ST.
23RD
22ND
21 ST
120
120
118
115
121
122
SUB STA.

FIG. 16—Example of Radial Primary Secondary Network.

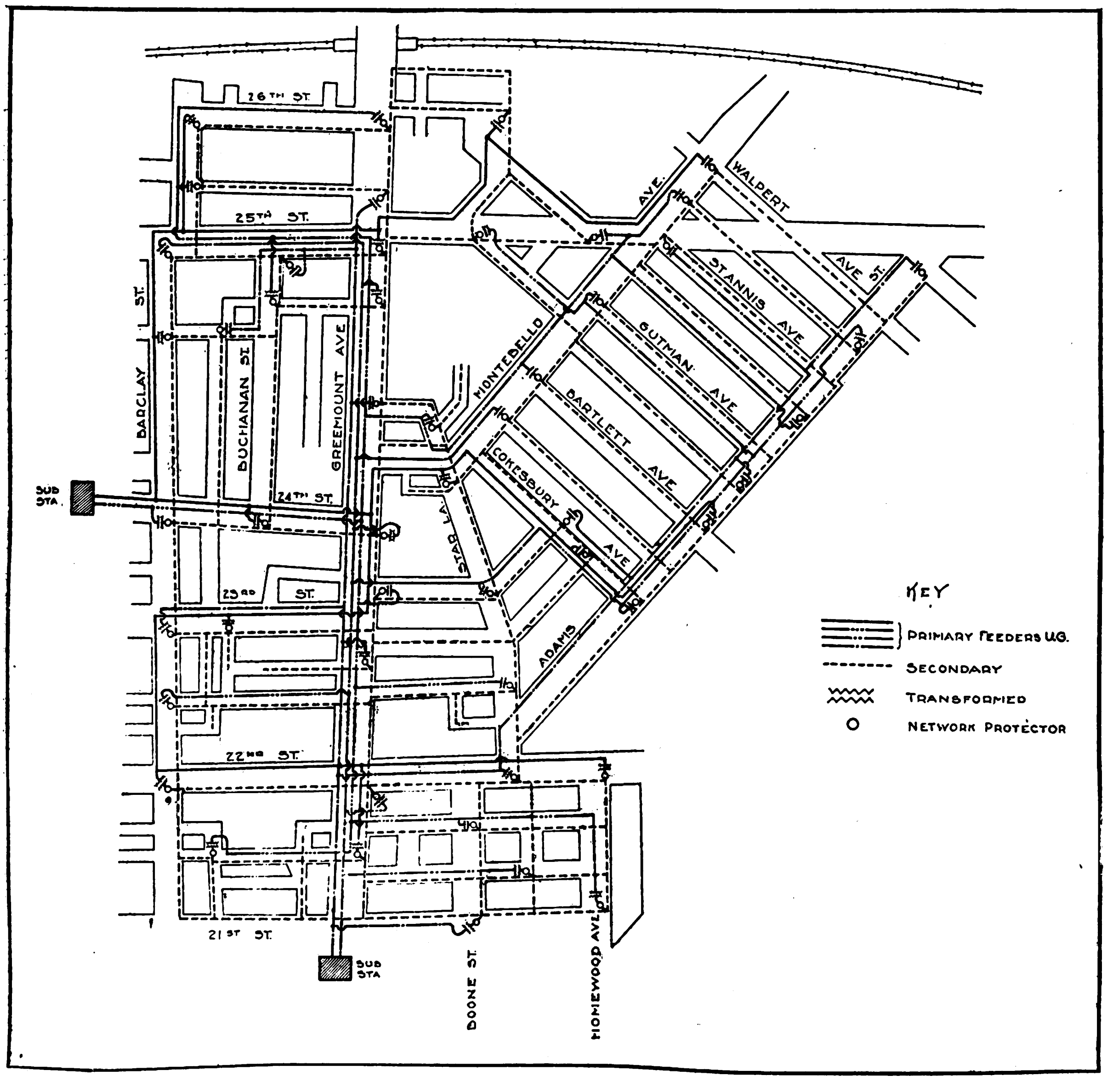

26TH ST.
25TH ST.
BARCLAY ST.
BUCHANAN ST.
GREEMOUNT AVE
24TH ST.
23RD ST.
22ND ST.
21ST ST.
SUB STA.
SUB STA
WALPERT
AVE.
ST ANNIS AVE
AVE ST.
GUTMAN AVE
BARTLETT AVE
MONTEBELLO
COKESBURY AVE
STAR LA.
ADAMS
DOONE ST.
HOMEWOOD AVE
KEY
PRIMARY FEEDERS U.G.
SECONDARY
TRANSFORMED
NETWORK PROTECTOR

FIG. 17—EXAMPLE OF PRIMARY LAYOUT OF MULTIPLE RADIAL PRIMARY FEED, SECONDARY NETWORK.

PART II

METHODS OF CHANGING OVER TO 4000 VOLT SYSTEMS

SCOPE

The greatly increased consumption of electrical energy has rendered the 2200 volt distribution systems of many utilities inadequate to economically meet the ever-growing demand. The present tendency among many utility engineers appears to be toward distribution at 4000 volts, 3-phase, 4-wire Star, utilizing to a great extent the existing equipment of the 2200 volt system now in use. Where increased capacity and improved regulation are required at minimum cost, this change, if adequate, is obviously the most practical method.

A number of utilities have made the change with apparent satisfaction, and others are contemplating similar changes. This subcommittee has endeavored to learn from the companies that have changed the advantages and disadvantages that have developed and the methods used in changing their distribution systems. From answers received, it appears that the 4-wire, 3-phase Star systems have many advantages over the 3-wire, 2200 volt systems, the greatest of which is that transmission effected at 3800 or 4000 volts nearly doubles the range of distribution. An important point to be considered in systems having long single phase branches is that a 4000 volt, 4-wire system retains 2200 volts in these branches; whereas, a straight doubling of voltage overcomes this deficiency. In the 4000 volt, 4-wire system the neutral wire runs near earth potential and is usually grounded at the generating station or substation. It is necessary, therefore, that more attention be paid to the insulation from ground of phase wires and connected apparatus such as fuses, than in the 2200 volt system, since a ground on any phase wire causes a short circuit. Linemen also must exercise greater care when working on lines.

It is very difficult in a report of this character to go greatly into detail, due to the fact that details concerning a voltage changeover must, necessarily, vary considerably in every case. Each company will have its own individual problem which will, no doubt, differ appreciably from the problem facing any other company, considering a similar voltage change. Therefore, the details of voltage changeovers cannot be set forth at any great length without first making a number of hypothetical assumptions as to existing conditions. Such assumptions are not justifiable except to provide a mere example. Since such an example could hardly fit the actual requirements of any company, it could be of use only in pointing the way to general conclusions and methods applicable in every case. It would seem better to formulate and state at once such conclusions and general methods as have been gathered from the questionnaire replies received from various companies.

If the system is 3-phase, all parts of the circuit must be changed at the same time. This necessitates reconnection of transformers, regulators, switching apparatus, etc., at the substation. As there are usually two buses, one of these is set aside for the new connections and a neutral bus is added. The circuits are then changed from the old bus to the new one as the work progresses. When a new substation is built the work is greatly simplified in that the station can be arranged for the new system, new circuits are run out to where the old ones are to be picked up, and terminated in disconnecting switches or disconnecting potheads, as the case may be.

So far as conductor spacing is concerned, considerably higher than 2200 volts may be safely carried on lines at single pin spacing of 14 in. without violation of safety codes, although many companies have found it advisable to increase the horizontal spacing with the new voltage. If wider clearances than those in present use should be necessary or advisable, considerable rebuilding of the overhead lines may be involved. Distribution transformers need not be replaced in changing to a 4000 volt, 4-wire system from a 2300 volt Delta system. This effects a large saving.

The determination of the exact amount of equipment to be replaced or the amount of rebuilding necessary or advisable can only be made after a thorough survey of any case in question. It will, however, depend to a large extent upon whether or not the higher voltage has been foreseen and apparatus purchased with the future change in mind. If a great deal of replacement is necessary, it may be better under certain circumstances to build a new system and change over to it. In many instances such a procedure would probably result in less outage than in the case where the old distribution system is changed over to a higher voltage. This would be particularly true where a considerable replacement of service equipment is necessary. In most cases, however, the existing equipment, or a large percentage of it, is suitable for operation at 4000 volts, and it is generally best to use it, and change the existing system to the higher voltage. The exact costs of changing are rather difficult to determine, and general figures can be of little value.

So far as the effect of the type of distribution system in use on the method of changeover is concerned, it does not seem that the general procedure as given below would be varied to a great extent in any case. Where the radial main type of distribution is used, interruptions to power customers could be considerably lessened, where necessary, due to the possibility of duplicate feed with a temporary bank of transformers or portable substation, while reconnecting the primary of the main bank. Even though temporary banks were not used, a smaller number of crews would be needed to make the changeover with the same length of service interruption. The latter fact would probably be true also with the loop system, dependent on the length between sectionalizing switches and the number of services on a section. The length of neutral required with a loop would be a maximum. Where the segregated phase system is used to a large extent, the installation of the neutral is simplified, since it need only run to the feeding center.

The methods of changeover applicable in most cases are given below:

CHANGING 2300 VOLT, 3-PHASE, 3-WIRE TO A 2300/4000 VOLT 4-WIRE SYSTEM

A complete field survey should be made prior to the change; a set of construction maps made showing all connections, all branches and transformer connections, and instructions made up, including detailed prints of all changes necessary. Each Division, that is, the Station, the Underground and the Overhead Departments' work should be outlined and coordinated into a set of instructions, including the work to be done and the time for doing it, and the gangs organized in such a manner that each department would have its part of the work completed without any conflict with the others. Temporary work and all permanent construction work that can be completed prior to the actual cutover should be done. Circuits are usually changed over on Sundays in order to inconvenience power customers as little as possible. On the Saturday preceding the change each power customer having polyphase current should be visited, the rotation of his motors marked and arrangements made for getting into his premises to make tests the following day.

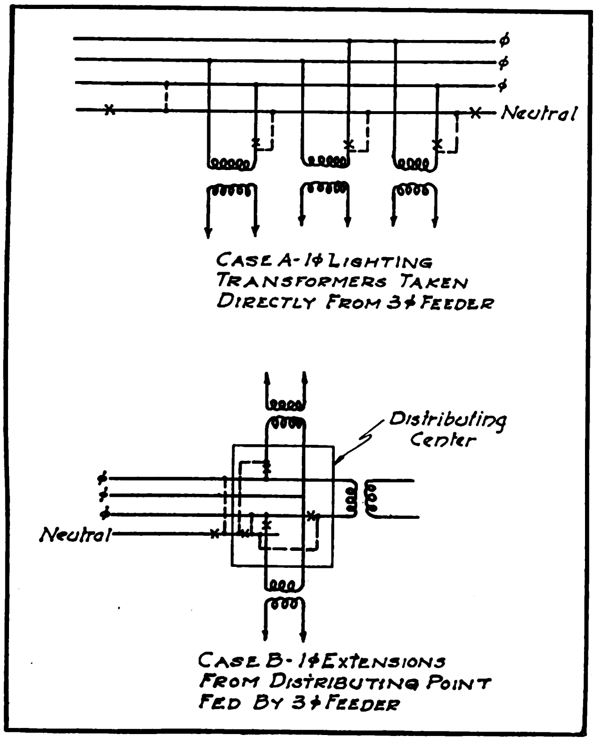

ϕ
ϕ
ϕ
Neutral
Case A-1ϕ Lighting Transformers Taken Directly From 3ϕ Feeder
Distributing Center
ϕ
ϕ
ϕ
Neutral
Case B-1ϕ Extensions From Distributing Point Fed By 3ϕ Feeder

FIG. 18—METHOD OF TEMPORARILY CONNECTING NEUTRAL IN CHANGING OVER TO THREE-PHASE, FOUR-WIRE SYSTEM.

The outside work consists of installing a neutral wire parallel to the other three wires for connection to all the single-phase lighting transformers on the circuit. It is usual to have the neutral wire disconnected from the station and cut open in at least three places corresponding to the phase distribution of the completed circuit. Then connect portions of this neutral by jumpers to the existing circuit, and connect all the single-phase transformers to it until ready to make the change, when the jumpers are cut off and the neutral wire connected through and to the station bus, as is shown in Fig. 18. At the time the feeder is shut off, or shortly before, if possible, a crew is put to work opening cutouts on three-phase transformer banks. As soon as this is completed, service can be restored to the single-phase load with minimum interruption. In cases where transformer banks have been operated open delta, the necessary third transformer for the 4-wire arrangement, if used, should be installed previous to the new connection so that it is only necessary for the gangs of men to go over the circuit and change the connections for 4-wire operation as in Fig. 19.

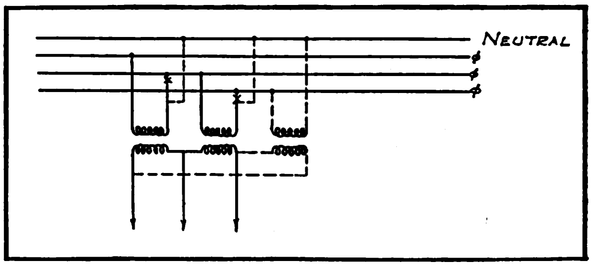


FIG. 19—METHOD OF CHANGING OVER 2300 VOLT OPEN DELTA BANK TO 4000 VOLT STAR DELTA.

The possibility of reversal of phase rotation is, of course, present in making these changes and a form of 2-phase or 3-phase motor, as the case may be, or a phase rotation indicator should be used for checking to see that the original direction of rotation is not reversed. Serious damage to machinery may be caused by failure to observe proper precautions in this respect, since few installations are equipped with reverse phase relays.

CHANGING 2300 VOLT, 2-PHASE, 4-WIRE TO 2300/4000 VOLT, 3-PHASE, 4-WIRE

In order to balance the load on the new system a survey of each circuit should be made; the transformers reassigned to the three phases; temporary cutouts installed, and connections run for the transformers which are to be connected to the new B and C phases, Fig. 20. Each circuit may be divided into sections and sectionalizing switches installed on the phase wires. Separate orders are made up for each section and a line crew assigned to that portion of the circuit if the above practice is followed. At the time scheduled for the changeover, crews proceed to the location of the disconnecting switches controlling the section for which they are responsible, and upon word from the man in charge the circuit is cut from the old to the new bus and phase A immediately energized. With this arrangement it is possible to care for the lighting customers whom an interruption would seriously inconvenience, by arranging for their supply from phase A. Each crew then proceeds to pull the disconnecting switches on phases B and C, and then the transformer fuses on these two phases. Where single phase lines branch off the circuit, disconnecting switches may be installed previously, so that it is but necessary to cut the old line taps at these switches. When all of the main disconnecting switches have been pulled, phases B and C are energized, and as each crew finishes clearing its section and reports back at its starting point, it tests phases B and C at the disconnecting switch. If found clear, the switches are then thrown in. As soon as these phases are made alive, fuses are installed in the new cutouts, thereby connecting the transformers to their proper phase.

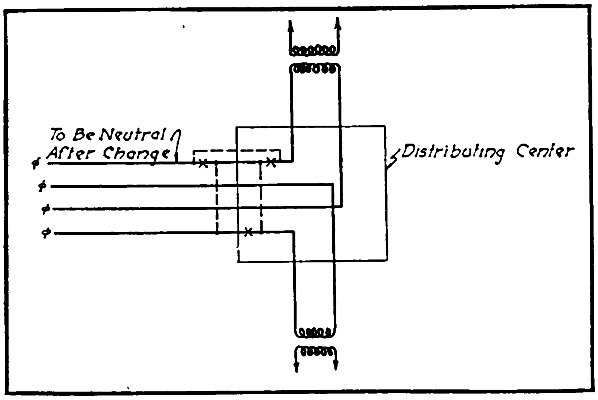


FIG. 20—TEMPORARY CONNECTIONS FOR FUTURE NEUTRAL ON TWO-PHASE, FOUR-WIRE CHANGE TO THREE-PHASE, FOUR-WIRE.

An interruption of from six to eighteen hours is generally required to change over large power customers. In some cases this long interruption would cause great inconvenience to the customer, and in these special cases a duplicate installation is usually made previous to the discontinuance of the 2-phase primary feed, and the job is handled as mentioned previously in connection with single phase.

One large utility reports that the majority of its power customers' motors were reconnected for 3-phase before the circuits were changed and these customers were supplied by using transformers having 86.6 per cent taps on the secondary and giving them a Scott Connection during the time between changes.

SPECIAL TRANSFORMERS AND CONNECTIONS

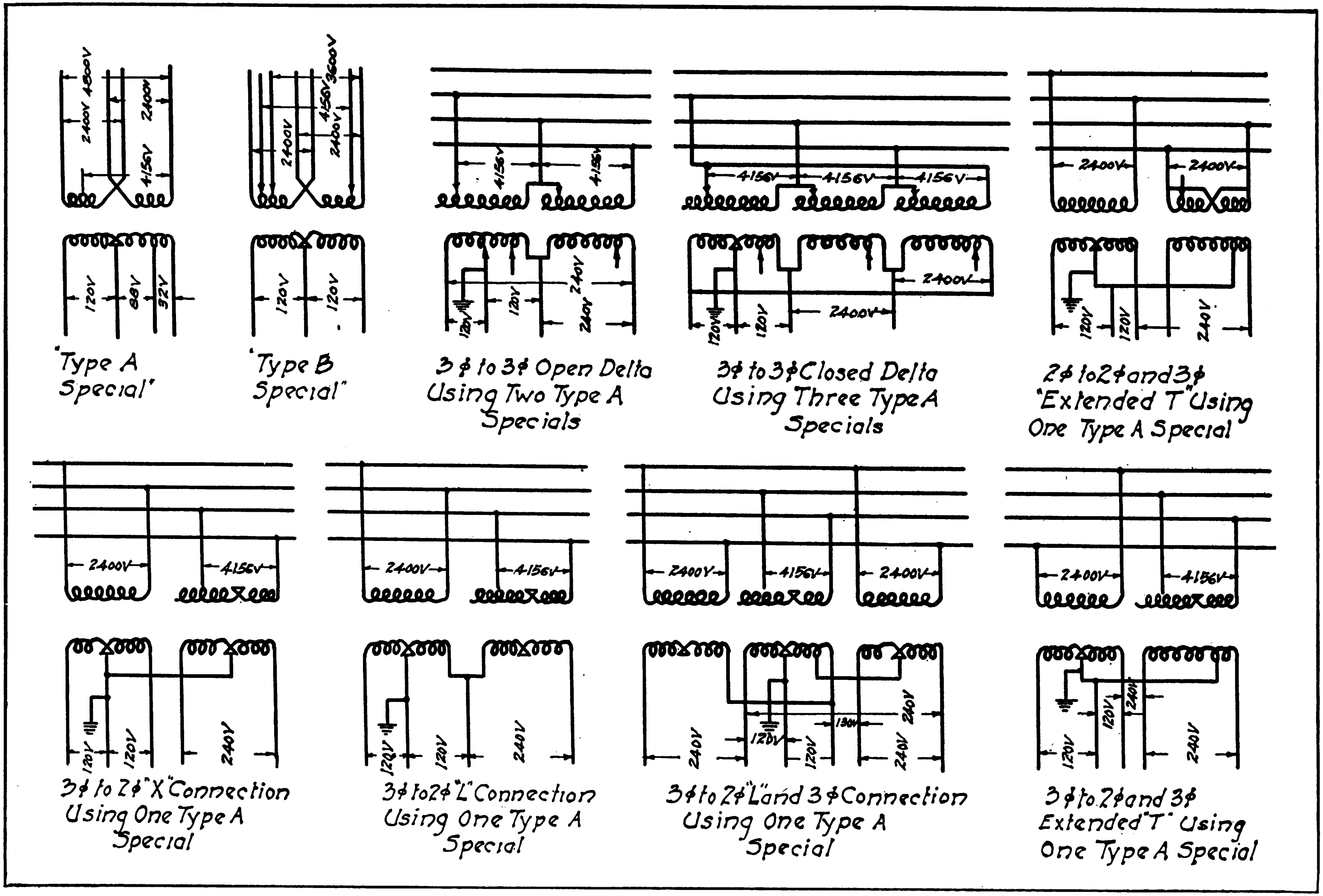
In changing over from 2-phase to 3-phase Star distribution there are many 3-phase loads to be supplied from 2-phase primaries and 2-phase loads to be supplied from 3-phase primaries. These transformations cannot be made with the standard transformers. Two special designs of transformers are available for this purpose. One of these is shown in Fig. 21 and is referred to as Type B Special. This transformer has a double primary winding with three taps, the voltages of which are indicated in Fig. 21. The secondary consists of a single winding with a tap at the mid-point. The other design, referred to as the Type A Special, is also shown in Fig. 21. It is similar to the Type B Special, but differs in having a Scott (87 per cent) tap in the secondary winding and only one tap (87 per cent) on the primary. The rating is based on the Scott voltage (4156 volts), instead of the full voltage (4800 volts), so that, by using the full voltage, 13 per cent more than its rating may be delivered without overloading the transformer.

Both of these special transformers were designed to transform from 2400/4156 primary voltage to 120/240 volt secondary. They can be used also on 2200/3810 volt or 2300/4000 volt primary systems. Fig. 21 shows the voltages of the leads of both transformers and some special connections using the Type A Special.

GENERAL COMMENTS

When contemplating the changing of a system to 4000 volts, 4-wire, a great deal depends upon the amount of careful study and preparation which has been made of the subject prior to the changeover. To facilitate the general progress of the work and to avoid interruptions, it is a good plan to supply each line crew with a set of construction standards in blueprint or book form of a convenient size, in order that they may familiarize themselves with the various types of construction to be used. The National Electric Light Association Suggested Specification will be found useful as a guide for this, but detailed plans, specifications and bills of material should be provided for the kind of construction to be followed under actual conditions and suited to the particular kind of system under construction.

It is strongly urged that utilities considering this change take into account that any false economy, neglecting to properly prepare their lines for the change, will cost them dearly in customers dissatisfied by impaired service, since service can be maintained only when the lines are in good condition. The possibility of tree grounds must be eliminated either by trimming, using higher poles or tree wire; any defective insulators, lightning arresters or junction boxes must be replaced, slack must be pulled from conductors, and in some instances conductor spacing must be increased. It is well to pay particular attention to arranging conductors in fixed relative positions throughout the system. Interruption of customers' services should be worked out with care since good will is always an important item. The actual handling of details will depend to a large extent upon the location, size of the company and type of service to be interrupted, together with the length of interruption necessary. In some sections advertisement in newspapers of proposed changeovers and the time work will be started and completed may be all that is necessary. In some cases private interviews may be the only solution to obtaining an interruption; and in others, usually


2400V
4800V
4156V
2400V
120V
88V
32V
3600V
120V
240V
130V

"Type A Special"

"Type B Special"

3ϕ to 3ϕ Open Delta Using Two Type A Specials

3ϕ to 3ϕ Closed Delta Using Three Type A Specials

2ϕ to 2ϕ and 3ϕ "Extended T" Using One Type A Special

3ϕ to 2ϕ "X" Connection Using One Type A Special

3ϕ to 2ϕ "L" Connection Using One Type A Special

3ϕ to 2ϕ "L" and 3ϕ Connection Using One Type A Special

3ϕ to 2ϕ and 3ϕ Extended "T" Using One Type A Special

FIG. 21—Special Transformers and Connections Used in Change-Over of the Primary System from Two-Phase to Three-Phase.

large customers where the necessary interruption would cause great inconvenience, no interruption can be allowed and duplicate temporary service must be run in and connected before cutting over. A small company may use the first two methods; but a large company will generally use all with the possible exception of the newspapers, and in these cases interruptions are usually scheduled by telephone or personal interview. Still another method is to send printed notices by a messenger to the customer affected. This last method has been used to advantage by a number of companies.

SUGGESTED SPECIFICATIONS FOR OVERHEAD LINE MATERIALS, AND METHODS OF CONSTRUCTION FOR LOW AND MEDIUM VOLTAGE LINES

The Subcommittee on Overhead Line Materials and Methods of Construction for Low and Medium Voltage Lines was appointed:

1. *To ascertain the extent of the use of the suggested specifications for overhead construction materials prepared by a subcommittee and published by the Overhead Systems Committee in the Report in 1924, Publication No. 24-15. The material in that publication has been revised and appears in the Overhead Systems Reference Book, published by the National Electric Light Association in 1927.*
2. *To prepare, along the lines followed by the previous subcommittee, such new suggested specifications as were proposed by the member companies and manufacturers, which were thought to be warranted for publication.*
3. *To present construction drawings, showing the use of materials covered by the new proposed specifications, and photographs of transformer pole and cable pole installations, illustrating typical practice in various parts of this country.*
4. *To gather such information, in connection with the use of materials, as may be of interest to the member companies.*

PART I

USE OF SPECIFICATIONS SUGGESTED IN 1924

For this purpose the subcommittee mailed to 60 member companies a questionnaire asking whether each individual specification, published in 1924, was used by that company.

Number of questionnaires sent out....... 60
Number of questionnaires answered...... 45
Percentage of questionnaires answered... 75%
Total number of replies possible, 58 items by 45 replies, or...................... 2,610
Total number of replies received......... 2,581
Percentage of replies received........... 99%
Number of replies, affirmative....1400 or 54%
Number of replies, negative......1181 or 46%
95% of the specifications are used by over 20% of companies.
74% of the specifications are used by over 40% of companies.
50% of the specifications are used by over 60% of companies.
17% of the specifications are used by over 80% of companies.

The diagram, Fig. 1, explains graphically, the extent of the use of these N. E. L. A. suggested specifications.

The specification "D" numbers, plotted as abscissæ, are enumerated in the index to specifications immediately following. From letters received by the subcommittee from member companies, and the comments made by manufacturers, the N. E. L. A. specifications are receiving greater attention each year, and it is hoped that, where differences are minor, they will be adhered to in place of using special materials. It is to the common advantage, economically, of both users and manufacturers, to use those materials which are favored by a great number of companies.

***Index to Suggested Specifications (1924 Report)**

D 5-24......Creosoted Yellow Pine Poles (material)
D 100-24....Untreated Wood Cross Arms (material)
D 107-22....Cross Arm Gage
D 110-22....4-pin Cross Arm (low voltage)
D 111-22....6-pin Cross Arm (low voltage)
D 112-22....8-pin Cross Arm (low voltage)
D 120-22....6-pin Alley Arm (low voltage)
D 130-22....2-pin Cross Arm (medium voltage)
D 131-22....4-pin Cross Arm (medium voltage)
D 150-23....Wood Insulator Pins (material)
D 160-22....Wood Pin
D 180-24....Ground Wire Molding (material)
D 190-24....Ground Wire Molding
D 200-22....Steel (material)
D 209-22....Bolts and Nuts (general)
D 210-22....Hot Galvanizing
D 220-22....Flat Cross Arm Brace
D 225-22....Alley Arm Brace
D 227-22....26-in. Vertical Brace
D 228-22....50-in. Vertical Brace
D 230-24....Angle Cross Arm Brace
D 231-23....6 ft. Angle Cross Arm Brace
D 235-22....⅜ in. Carriage Bolt

Publication No. 289-45, Serial Report, Overhead Systems Committee.

*All these specifications, except D5-24, were reprinted in the 1927 Overhead Systems Reference Book.

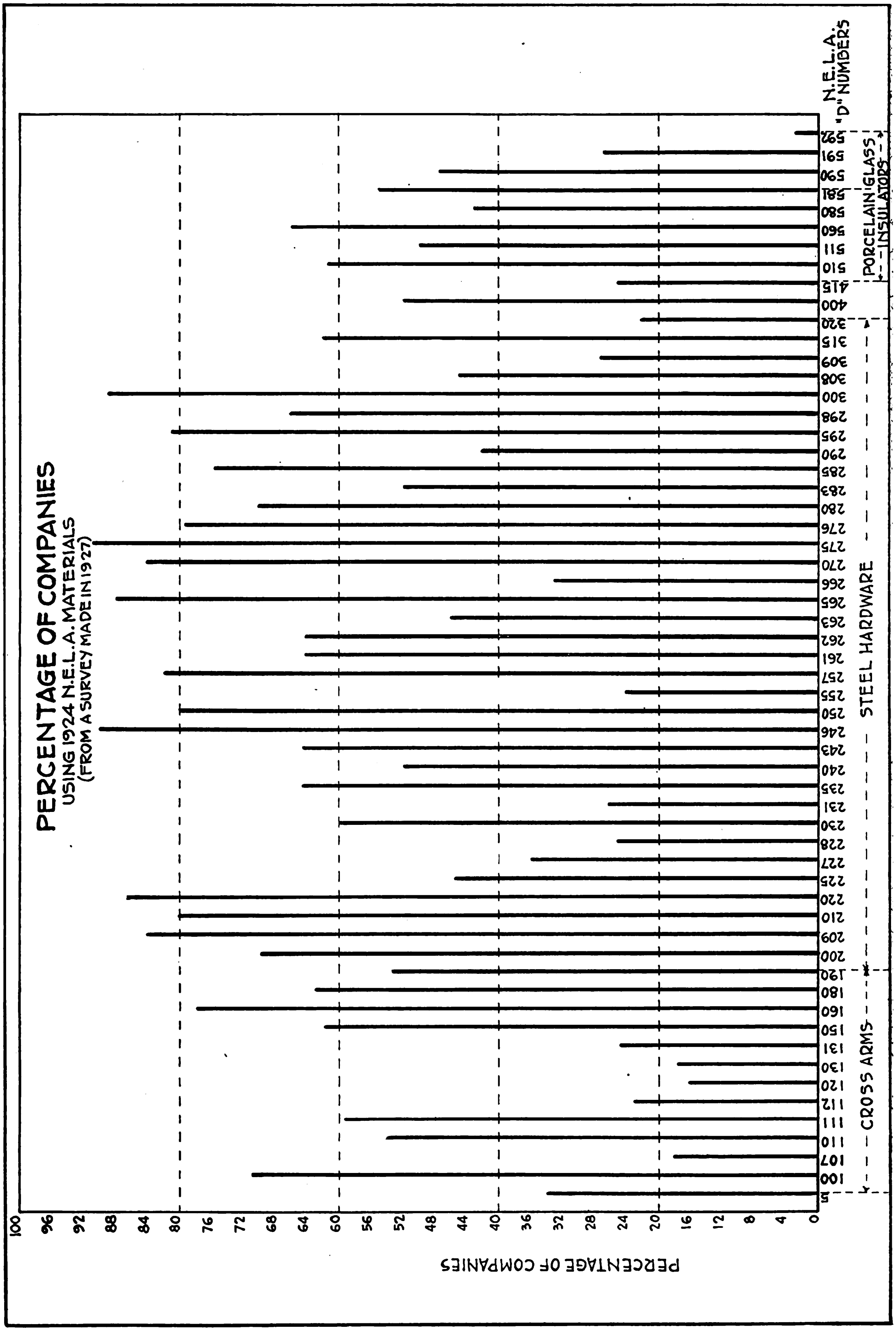

PERCENTAGE OF COMPANIES
USING 1924 N.E.L.A. MATERIALS
(FROM A SURVEY MADE IN 1927)
PERCENTAGE OF COMPANIES
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
64
68
72
76
80
84
88
92
96
100
N.E.L.A. "D" NUMBERS
5
100
107
110
111
112
120
130
131
150
160
180
190
200
209
210
220
225
227
228
230
231
235
240
243
246
250
255
257
261
262
263
265
266
270
275
276
280
283
285
290
295
298
300
308
309
315
320
400
415
510
511
560
580
581
590
591
592
CROSS ARMS
STEEL HARDWARE
PORCELAIN
GLASS
INSULATORS

FIG. 1.

D 240-22....⅜ in. Machine Bolt
D 243-22....½ in. Machine Bolt
D 246-22....⅝ in. Machine Bolt
D 250-22....⅝ in. Double Arm Bolt
D 255-22....½ in. Eye Bolt
D 257-23....⅝ in. Eye Bolt
D 261-24....⅝ in. Anchor Rod
D 262-24....¾ in. Anchor Rod
D 263-23....1 in. Anchor Rod
D 265-22....½ in. Lag Screw
D 266-22....⅝ in. Lag Screw
D 270-22....Round Washer
D 275-24....Square Washer
D 276-24....Anchor Rod Washer
D 280-22....Pole Step
D 283-22....Pole Guard
D 285-23....Guy Clamp
D 290-22....Guy Clip
D 295-24....Guy Hook
D 298-22....Guy Plate
D 300-22....Thimble
D 308-22....Eye Nut
D 309-23....Clevis
D 315-22....Staple
D 320-24....Spool Strap
D 400-22....Malleable Castings (material)
D 415-22....Driving Point
D 510-23....Side Groove Pin Insulator (porcelain)
D 511-23....Top Groove Pin Insulator (porcelain)
D 560-23....Guy Strain Insulator
D 580-23....Spool Insulator (small type)
D 581-23....Spool Insulator (large type)
D 590-23....Side Groove Pin Insulator (glass)
D 591-23....Top Groove Pin Insulator (glass)
D 592-23....Service Pin Insulator (glass)

PART II

PROPOSED NEW SUGGESTED SPECIFICATIONS

Certain of these suggested specifications have been added as revisions to those previously published.

1⅜-in. Pin and Insulator Threads

Following the report of original investigation made by L. J. Corbett of the Pacific Coast Section, N. E. L. A., the Committee has endeavored to make a uniform recommendation for the standardization of 1⅜ in. insulator threads and 1⅜ in. wood, steel, lead, and wire pin threads, bearing in mind that these threads should be correlated with the present standards for 1 in. pin and insulator thread. As the number of threads per inch are exactly the same for 1 in. and 1⅜ in. insulators, there appears to be no reason why they should not be identical. Due, however, to manufacturing processes, certain modifications had to be made in the metal pin threads.

Indexing of Suggested Specifications

The letter "D," representing the first unit of the index number, applies to material used in overhead line construction. The second unit in the index is a number, up to 1000, which signifies the specific type of overhead material referred to, the designating numbers being as follows:

Nos. 1 to 49 are assigned to poles.

Nos. 50 to 99 are assigned to preservatives and preservative treatment.

Nos. 100 to 149 are assigned to wood cross arms.

Nos. 150 to 199 are assigned to wood pins.

Nos. 200 to 399 are assigned to steel braces, bolts and similar equipment.

Nos. 400 to 499 are assigned to malleable and gray castings.

Nos. 500 to 599 are assigned to insulators.

Nos. 600 to 699 are assigned to wire and covering for wire.

Nos. 700 to 799 are assigned to transformers.

Nos. 800 to 899 are assigned to lightning arresters, cutouts, switches and similar equipment.

Nos. 900 to 999 are assigned to miscellaneous equipment not covered by the previous subdivisions.

The third unit of the designating number consists of two digits, representing the year in which the specification is proposed, and in case of revision the only change in the designating symbol will be the change in this unit of the index.

The fourth unit of the index consists of the letter "T," which shall be retained as long as the suggested specification is on trial, but will be dropped from the index symbol as soon as its use has become general.

Variations

The dimensions shown in the following suggested specifications are qualified by an allowable variation designated upon the drawings by small letters. These variations are deemed sufficient to allow for necessary deviation incident to present manufacturing practice or to slight differences in design. The amount of variation allowed is, as far as possible, consistent with the allowable accuracy of manufacture. Smaller variations are provided for thickness of plates or cross section of bars and rods that can be adhered to for the rougher operations of manufacture such as lengths cut by shears or locations of holes made by punches.

It is not intended that the manufacturer may avail himself of the allowable variation to reduce the amount of material furnished.

It is not proposed that the variations shall be accumulative either plus or minus, but shall refer only to the dimensions to which they are appended. Every dimension stated in the suggested specifications includes the allowable variation, as it is manifestly unfair to either the manufacturer or the consumer to be compelled to depend upon the individual judgment of the inspectors upon even relatively unimportant dimensions.

The small letters "a" to "k" in the accompanying key designate the amount of variation, and where the letter "x" appears, no variation is allowed. Where two letters are shown, the first letter designates the amount of variation *over* the dimension and the second letter designates the amount of variation *under* the dimension shown.

EXAMPLE

2¼"c —denotes an allowable variation of 1/16 in. over or under 2¼ in.

2¼"gc—denotes an allowable variation of ⅜ in. over 2¼ in., and 1/16 in. under 2¼ in.

2¼"dx—denotes an allowable variation of ⅛ in. over 2¼ in., but no variation under 2¼ in.

KEY TO ALLOWABLE VARIATIONS

Symbol	*Over*	*Under*
x	None	None
a	1/64 in.	1/64 in.
b	1/32 in.	1/32 in.
c	1/16 in.	1/16 in.
d	⅛ in.	⅛ in.
e	3/16 in.	3/16 in.
f	¼ in.	¼ in.
g	⅜ in.	⅜ in.
h	½ in.	½ in.
j	¾ in.	¾ in.
k	1 in.	1 in.

Review of Materials

D 70 and D 75—POLE PAINT. These suggested specifications are published for the guidance of those who still use paint, though numerous companies prefer the use of stain, which permits the evaporation of moisture and has some preservative qualities.

D 109—2-PIN CROSS ARM. This cross arm is extensively used for rural lines, when only two wires are to be installed. For assembly, see Fig. 57.

D 125—2-PIN CROSS ARM. Where a triangular arrangement of wires is desired this arm, together with pole top pipe pin D 355 or ridge pin support D 362, can be used. For assembly, see Fig. 58.

D 220—FLAT CROSS ARM BRACE. Dimensions of the 20 in. brace to be used with arm D 109, have been added on this drawing, first published in 1922.

D 225—ALLEY ARM BRACE. Dimensions of the 7 ft. brace have been added on this drawing, first printed in 1922.

D 230—ANGLE CROSS ARM BRACE. A 37 in. brace was added, to go with the arm D 125. Also, the dimension B for the 48 in. brace was changed to 18 in.

D 264—¼ IN. LAG SCREW. These lag screws are extensively used with service brackets.

D 264.1—⅜ IN. LAG SCREW. These lag screws may be used for mounting secondary racks.

D 270—ROUND WASHER. Two additional sizes for ⅝ in. and ¾ in. machine bolts were inserted on this drawing, first published in 1922.

D 282—GUY WIRE PROTECTOR. Two well-known types are shown. For assembly see Fig. 59.

D 299—MOLDING GUY PLATE. This plate is to be used with 1 in. molding, D 190-24. For assembly see Fig. 60.

D 322—PRESSED STEEL SPLIT CLEVIS and D 324—DROP FORGED ONE PIECE CLEVIS. Both types of clevises are for use with guy strain insulators. For assembly, see Fig. 62.

D 330—¼ IN. EXPANSION BOLT. This size is used for mounting service brackets, D 910.

D 332—½ IN. EXPANSION BOLT. This size can be used for installation of secondary racks, D 920, also for mounting eyelets and insulator clevises on walls.

D 340—1 IN. STEEL PIN. Three types of 1 in. steel pin, for use on low voltage lines, are shown. The threads for these pins should be checked with the gage, D 997.

D 350—STEEL PIN. For the present only drop forged type is shown, though there are other pins, such as hollow malleable iron type, well suited for the same purpose. An endeavor is made to limit the height to 14 in. by 2 in. steps.

D 355—POLE TOP PIPE PIN and D 362—RIDGE PIN SUPPORT. Pole top pipe pin is preferred by many to the ridge pin support. For assembly, see Fig. 58.

D 430—8 IN. ANCHOR PLATE and D 431—12 IN. ANCHOR PLATE. Cone anchors are still very popular, being efficient and low in cost. For assembly, see Fig. 61.

D 570—MULTIFIN GUY STRAIN INSULATOR. This drawing completes the series of guy strain insulators D 560-23. The large size is very adaptable for dead ending of large conductors.

D 650—GALVANIZED STEEL STRAND and D 660—COPPER COVERED STEEL STRAND. The tables of breaking strength agree with the values given in the Overhead Systems Reference Book.

D 900—WIREHOLDER. This wireholder has a large hole suitable for use of duplex service wires.

D 910—SERVICE BRACKET. Service brackets as shown are made by a number of manufacturers and differ only in minor details. For assembly, see Fig. 63.

D 920—SECONDARY RACK. This is the first attempt to standardize on the outline of the rack and the distance between mounting holes to permit replacement.

D 950—SPLICING SLEEVE. This sleeve is recommended by Pacific Coast companies and is preferred to a sleeve having a "figure eight" cross section.

D 970—SOLDER. For the convenience of member companies, the composition of wiping solder was added in the table. This composition has been found by several companies to be better than other combinations.

D 990—1 IN. and 1⅜ IN. THREAD IN INSULATOR. This drawing represents a proposed thread in insulator. This thread has well-rounded corners, this being necessary because of the character of the materials used in making porcelain. The principle of having the groove larger than the ridge is used because it is believed that this condition is necessary on account of defects resulting from uneven pitch, glaze unevenly filling up the corners and presence of chips and dust in the groove. The bottom of the pinhole is made with a liberal radius providing the necessary clearance to the top of the pin. This condition is necessary to take care of some pins found on the market. Attention is called to the fact that no allowable variations have been provided on this drawing, the thread fit to be checked with insulator gage D 995.

D 991—1 IN. and 1⅜ IN. WOOD PIN THREAD. This drawing shows a standard wood pin thread, such as is used by most companies, and is believed to be satisfactory. The permissible variation from the nominal size of diameter of the first thread is shown on this and the following drawings as being 1/64 in. "over" and nothing "under." It is believed that this condition will fit a greater number of insulators which are made somewhat oversize, and, though the pin may not enter as far as the top thread of the pinhole, it will insure a better fit than in the opposite case, when the pin is too small and the pinhole is too large.

On this drawing, as well as on the following drawings, another principle has been carried out: the pitch diameter of the pin rides on the root diameter of the porcelain. It is believed that in this manner the stress is developed at the base of the porcelain thread where it has maximum width.

D 992—1 IN. and 1⅜ IN. CAST LEAD PIN THREAD. This drawing shows the cast lead pin thread. Sufficient clearance is provided between the lead thread and the porcelain thread.

D 993—1 IN. and 1⅜ IN. WIRE PIN THREAD. This drawing shows the wire pin thread, such as is manufactured by a well-known hardware concern. The 5/64 in. radius for the wire thread was deemed necessary by the manufacturer to insure sufficient strength of this type of thread. This dimension is believed to be permissible in view of the adjustability of this type of thread.

D 994—1 IN. and 1⅜ IN. PRESSED STEEL PIN THREAD. This drawing shows the pressed steel pin thread, as made by another well-known manufacturer. This type of thread also has some adjustable features, and it has been found satisfactory by many users of this pin.

D 995—1 IN. and 1⅜ IN. INSULATOR GAGE THREAD. This drawing shows a proposed thread for an insulator gage. This thread resembles the thread of the wood pin, D 991, with the exception that the ridge is made 1/16 of an inch wide instead of 3/32 of an inch, because the gage, being made of steel, has no adjustable features. It is believed, however, that this thread will be a sufficiently rigid requirement for checking the insulator thread. The sliding rod, as shown on this drawing, must clear the top of the gage from ¼ in. to ⅝ in. This clearance should be definitely decided upon when a sample gage is made and tested on a sufficient number of good insulators.

D 996—1 IN. and 1⅜ IN. INSULATOR GAGES. This drawing shows two insulator gages. The 1 in. gage is made to resemble a wood pin because it was recently found that a wood pin would not enter an insulator, due to a shoulder in the insulator pinhole. This shoulder was provided by the manufacturer to increase the thickness of the wall at that point.

The 1⅜ in. gage is not provided with that feature because practically no wood pins are used for 1⅜ in. insulators. The general dimensions of these two gages were taken from actual gages used by one large company manufacturing porcelain insulators.

D 997—1 IN. and 1⅜ IN. INSULATOR PIN GAGES. This drawing represents pin gages. The design was illustrated in the report made by the Pacific Coast Electrical Association. Limitation shall be specified when sample gages are made and have been tried out on a sufficient number of pins.

D 70-28 T
(Tentative)

PRIMER POLE PAINT*

Scope

The paint required under this suggested specification shall be known as Primer Pole Paint, and shall be used as the primer paint. It shall be an easy flowing, good spreading, durable, ready mixed paint, having a finish of sufficient bonding power to be used with Pole Paint as the finishing paint.

General

Previous to the issuance of an order to any manufacturer, such manufacturer shall be required to submit duplicate samples to the purchaser, of not less than one quart each, of the paint representative of the material to be delivered under this suggested specification. All subsequent shipments shall be rejected if found inferior in any respect to the samples submitted, or not in accordance with this suggested specification.

Chemical Properties

The base pigments must be finely ground in properly refined, raw linseed oil, and reduced to a ready-for-use consistency with pure, raw linseed oil, approved dryer and volatile thinner.

Pigment

Pure pigments, free from grit, adulterants and all impurities, of the class necessary to produce the standard shades adopted, must be used. The combination shall include no barytes, nor other make-weight or inert material of low covering power, nor any substance soluble in water, nor aniline colors, lakes, or other organic coloring matter. It shall be finely ground, and not less than 99 per cent shall pass a 100-mesh sieve, and all shall pass an 80-mesh sieve.

Oil

The oil used must be strictly pure, well-settled and perfectly clear raw linseed oil, free from rosin, rosin oil, fish oil, mineral oil or other adulterants.

Dryer

The dryer used must be a good quality of lead or manganese dryer in the proper proportion to dry the paint within the time specified. Lead and manganese resinate dryers will be permitted.

The amount of colophony used, however, shall not exceed 1 per cent by weight of the paint.

Thinner

The thinner shall be turpentine volatile mineral spirits or a mixture thereof. The mineral spirits shall be a high grade naphtha conforming to the U. S. Federal Specifications Board, Standard Specification No. 16 for volatile mineral spirits for thinning paint. (Circular No. 98, Bureau of Standards; Technical Paper No. 323, Bureau of Mines.)

Water

Any water in excess of 2 per cent by weight shall be considered a cheapener and adulterant, and shall be sufficient cause for rejection of the entire lot without further test.

Pigment

Not less than 26 per cent nor more than 30 per cent.

Volatile Thinner

Not less than 18 per cent nor more than 22 per cent.

Raw Linseed Oil and Dryer Solids

Not less than 50 per cent.

Drying

The paint must dry, free from tack, within 12 hours and in not less than six hours under normal drying conditions.

Color

The color shall be the same in tone and shade as the standard samples or color cards submitted by the purchaser.

Packing

Unless otherwise stated on the purchase order, the paint shall be delivered in five gallon cans, bearing labels or stencils, giving the manufacturer's name and address, the kind and quantity of the contents, and the purchaser's order number.

Net weight or full measure only will be paid for. All cans shall have suitable openings (securely sealed during shipment) for the ready removal of the paint from the cans.

Inspection

Inspection and acceptance may be made either at the point of manufacture or upon delivery of the finished product. The manufacturer shall give the purchaser or his representatives such access to his works during working hours as is reasonable and necessary to determine the suitability of the material to be supplied and shall furnish all necessary apparatus, labor and other facilities for making the inspection herein called for without cost to the purchaser. The manufacturer shall eliminate all paint that he considers defective, according to this suggested specification, before offering any lot for inspection, or before shipping. Neither inspection, waiving of inspection, nor the purchaser's acceptance shall relieve the manufacturer from obligation to furnish paint in accordance with this suggested specification.

Paint not conforming with this suggested specification shall be rejected and the manufacturer shall replace such rejected paint with paint complying with this suggested specification at his own expense, or shall allow credit for such rejected paint.

---

*Several companies are satisfied with the use of Finishing Pole Paint D 75-28 T and omit the Primer Pole Paint D 70-28 T.

D 75-28 T
(Tentative)

POLE PAINT*

Scope

The paint required under this suggested specification shall be known as Pole Paint, and shall be used as the finishing paint. It shall be an easy flowing, good spreading, durable, ready mixed paint, having a sufficient hiding power to give a uniform finish with one coat of Primer Paint and one coat of Pole Paint on soft wood.

Preference will be given to paints displaying the greatest spreading rate with satisfactory hiding power.

General

Previous to the issuance of an initial order to any manufacturer, such manufacturer shall be required to submit to the purchaser duplicate samples, of not less than one quart each, of the paint representative of the material to be delivered under this suggested specification. All subsequent shipments will be rejected if found to be inferior in any respect to the samples submitted, or not in accordance with this suggested specification.

Chemical Properties

The base pigments must be finely ground in properly refined, pure, raw linseed oil and reduced to a ready-for-use consistency with pure, raw linseed oil, approved dryer and volatile thinner.

Pigment

Pure pigments free from grit, adulterants and all impurities, of the class necessary to produce the standard shades adopted, must be used. The combination shall contain no barytes, nor other make-weight or inert material of low covering power, nor any substance soluble in water, nor aniline colors, lakes or other organic coloring matter. It shall be finely ground and not less than 99 per cent shall pass a 100-mesh sieve, and all shall pass an 80-mesh sieve.

Oil

The oil used must be strictly pure, well-settled and perfectly clear raw linseed oil, free from rosin, rosin oil, fish oil, mineral oil or other adulterants.

Dryer

The dryer used must be a good quality of lead or manganese dryer in the proper proportion to dry the paint within the time specified. Lead and manganese resinate dryers will be permitted.

The amount of colophony used, however, shall not exceed 1 per cent by weight of the paint.

Thinner

The thinner shall be turpentine, volatile mineral spirits or a mixture thereof. The mineral spirits shall be a high grade naphtha conforming to the U. S. Federal Specifications Board, Standard Specification No. 16 for volatile mineral spirits for thinning paint. (Circular No. 98, Bureau of Standards; Technical Paper No. 323, Bureau of Mines.)

Water

Any water in excess of 2 per cent by weight shall be considered a cheapener and adulterant, and shall be sufficient cause for rejection of the entire lot without further test.

Drying

Pole Paint must dry, free from tack, when applied over the Primer Paint, within 24 hours, and shall produce a firm, flexible, insoluble, opaque film which shall show a high degree of resistance to change in color on exposure to weather, and shall conform to the following limits, by weight, in composition.

The Pole Paint comes in two consistencies: the one for summer use should be labeled Summer Pole Paint and the one for winter application Winter Pole Paint.

Summer Pole Paint†

Pigment

Not less than 40 per cent, nor more than 45 per cent.

Volatile Thinner

Not less than 5 per cent, nor more than 10 per cent.

Linseed Oil and Dryer Solids

Not less than 48 per cent.

Winter Pole Paint†

Pigment

Not less than 48 per cent, nor more than 53 per cent.

Volatile Thinner

Not less than 10 per cent, nor more than 15 per cent.

Linseed Oil and Dryer Solids

Not less than 35 per cent.

Color

The color shall be the same in tone and shade as the standard samples or color cards submitted by the purchaser.

Packing

Unless otherwise stated on the purchase order, the paint shall be delivered in five-gallon cans, bearing labels or stencils, giving the manufacturer's name and address, the kind and quantity of the contents, and the purchaser's order number.

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*See footnote for D 70-28 T.

†For certain regions one kind of Pole Paint may be found sufficient.

Net weight or full measure only will be paid for. All cans shall have a suitable opening (securely sealed during shipment) for the ready removal of the paint from the cans.

Inspection

Inspection and acceptance may be made either at the point of manufacture or upon delivery of the finished product. The manufacturer shall give the purchaser or his representative such access to his works during working hours as is reasonable and necessary to determine the suitability of the material to be supplied, and shall furnish all necessary apparatus, labor and other facilities for making the inspection herein called for without cost to the purchaser. The manufacturer shall eliminate all paint that he considers defective, according to this suggested specification, before offering any lot for inspection or before shipping. Neither inspection, waiving of inspection nor the purchaser's acceptance shall relieve the manufacturer from obligation to furnish paint in accordance with this suggested specification.

Paint not conforming with this suggested specification shall be rejected and the manufacturer shall replace such rejected paint with paint complying with this specification at his own expense, or shall allow credit for such rejected paint.

D 90-28 T
(Tentative)

POLE STAIN

Scope

This suggested specification covers the quality of coal tar distillate (or coal tar creosote) to be used for the preservative treatment of wood.

General

Previous to the issuance of an initial order to any manufacturer, such manufacturer shall be required to submit to the purchaser, duplicate samples of not less than one quart each, of the stain representative of the material to be delivered under this suggested specification. All subsequent shipments will be rejected if found to be inferior in any respect, to the samples submitted, or not in accordance with this suggested specification.

Chemical Properties

The coal tar distillate or coal tar creosote called for under this suggested specification is obtained by the distillation of coal at a temperature high enough to yield a tar consisting mainly of compounds of the aromatic series. It shall be without adulteration.

1. The specific gravity at 38 deg. cent. compared with water at 15.5 deg. cent. shall be not less than 1.03.

2. The oil shall be completely liquid at 32 deg. cent.

3. The matter insoluble in benzol shall be not more than 0.5 per cent.

4. The water content shall be not more than 3 per cent.

5. The distillate based on water-free oil up to 210 deg. cent. shall be not more than 5 per cent; up to 235 deg. shall be not more than 25 per cent; up to 355 deg. cent. shall be not less than 60 per cent.

6. The residue above 355 deg. cent. shall have a float test of not more than 50 seconds at 70 deg. cent. if the amount exceeds 5 per cent.

7. The coke residue shall be not more than 2 per cent.

Color

The color shall be the same in tone and shade as the standard samples or color cards submitted by the purchaser.

Packing

Unless otherwise stated on the purchase order, the stain shall be delivered in five-gallon cans, bearing labels or stencils, giving the manufacturer's name and address, the kind and quantity of the contents, and the purchaser's order number.

Net weight or full measure only will be paid for. All cans shall have a suitable opening, securely sealed during shipment, for the ready removal of the stain from the cans.

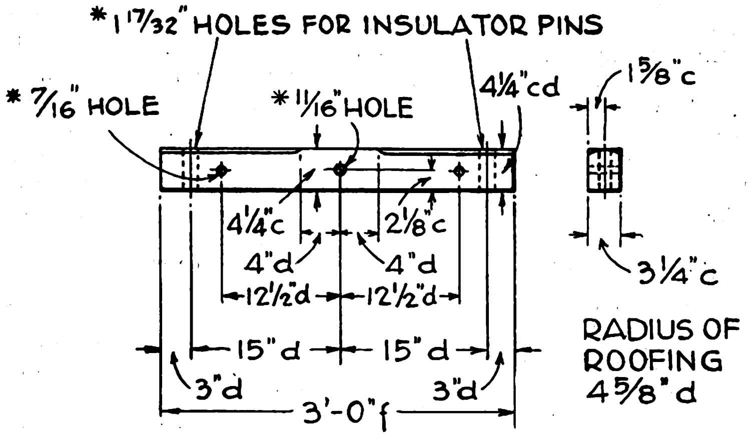
Inspection

Inspection and acceptance may be made either at the point of manufacture or upon delivery of the finished product. The manufacturer shall give the purchaser or his representative such access to his works during working hours as is reasonable and necessary to determine the suitability of the material to be supplied, and shall furnish all necessary apparatus, labor and other facilities for making the inspection herein called for without cost to the purchaser. The manufacturer shall eliminate all stain that he considers defective, according to this suggested specification, before offering any lot for inspection or before shipping. Neither inspection, waiving of inspection nor the purchaser's acceptance shall relieve the manufacturer from obligation to furnish stain in accordance with this suggested specification.

Stain not conforming with this suggested specification shall be rejected and the manufacturer shall replace such rejected stain with stain complying with this suggested specification at his own expense, or shall allow credit for such rejected stain.

D109-28T
(TENTATIVE)

2-PIN CROSS ARM
(LOW VOLTAGE)


* 1 17/32" HOLES FOR INSULATOR PINS
* 7/16" HOLE
* 11/16" HOLE
4¼"cd
1⅝"c
4¼"c
2⅛"c
4"d
4"d
12½"d
12½"d
15"d
15"d
3"d
3"d
3'-0"f
3¼"c
RADIUS OF ROOFING 4⅝"d

NOTE

* THESE DIMENSIONS TO BE CHECKED WITH CROSS ARM GAUGE.

ALLOWABLE VARIATIONS		
	OVER	UNDER
c	1/16"	1/16"
d	1/8"	1/8"
f	1/4"	1/4"
cd	1/16"	1/8"

MATERIAL:
WOOD
D100-22

FINISH:
SURFACED
4 SIDES

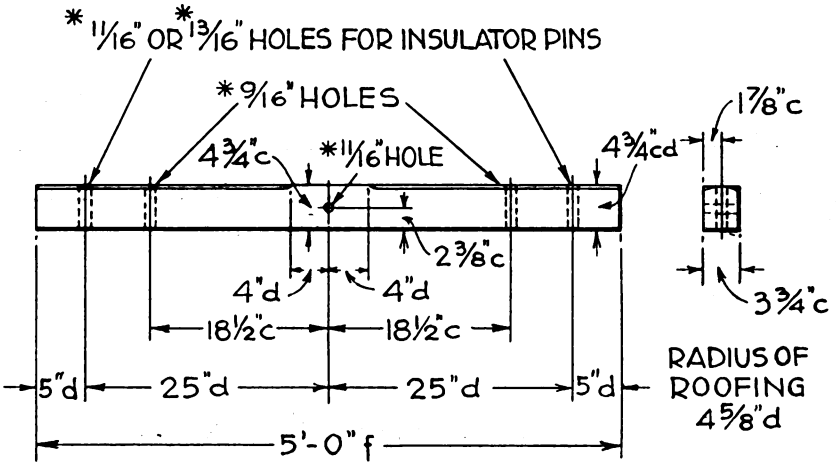
FIG. 2.

D125-28T

(TENTATIVE)

2-PIN CROSS ARM

(MEDIUM VOLTAGE)


* 11/16" OR * 13/16" HOLES FOR INSULATOR PINS
* 9/16" HOLES
4 3/4"c
* 11/16" HOLE
4 3/4"cd
1 7/8"c
2 3/8"c
4"d
4"d
3 3/4"c
18 1/2"c
18 1/2"c
5"d
25"d
25"d
5"d
RADIUS OF ROOFING 4 5/8"d
5'-0" f

NOTE

*THESE DIMENSIONS TO BE CHECKED WITH A GAUGE 1/16" SMALLER THAN THE SPECIFIED DIAMETER.

ALLOWABLE VARIATIONS		
	OVER	UNDER
c	1/16"	1/16"
d	1/8"	1/8"
f	1/4"	1/4"
cd	1/16"	1/8"

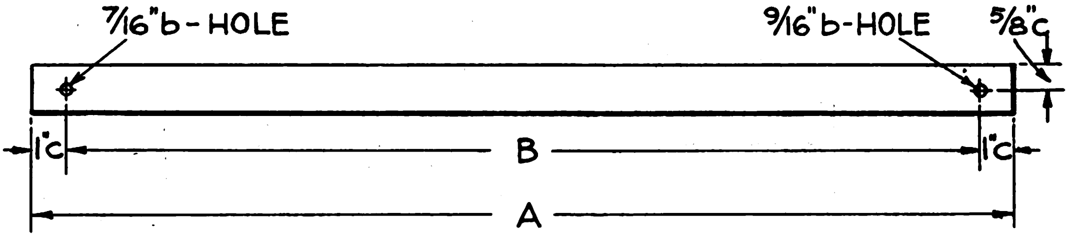
MATERIAL:
WOOD
D100-22

FINISH:
SURFACED
4 SIDES

FIG. 3.

D220-28T
(TENTATIVE)

FLAT CROSS ARM BRACE


7/16"b-HOLE
9/16"b-HOLE
5/8"c
1"c
B
1"c
A

SIZE OF FLAT: 1¼"b x ¼"a

SIZE	A	B
20 IN.	20"d	18"d
28 IN.	28"d	26"d

ALLOWABLE VARIATIONS		
	OVER	UNDER
a	1/64"	1/64"
b	1/32"	1/32"
c	1/16"	1/16"
d	1/8"	1/8"

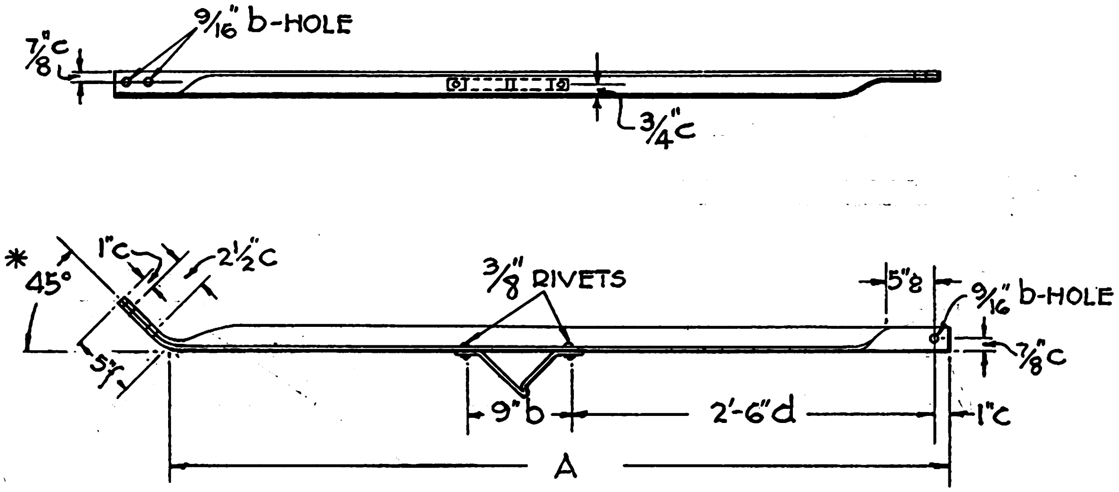
MATERIAL
STEEL
D 200-22

FINISH
HOT GALVANIZED
D 210-22

FIG. 4.

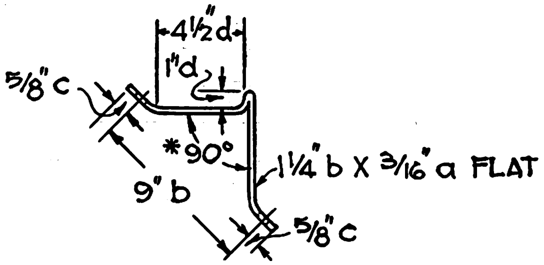
D225-28T
(TENTATIVE)

ALLEY ARM BRACE


9/16" b-HOLE
7/8"c
3/4"c
* 45°
1"c
2½"c
5"f
3/8" RIVETS
5"g
9/16" b-HOLE
7/8"c
9"b
2'-6"d
1"c
A

SIZE OF ANGLE 1¾"b x 1¾"b x 3/16"a

SIZE	A
5' FT.	5'-0"f
7 FT.	7'-0"f


4½"d
1"d
5/8"c
*90°
1¼"b X 3/16"a FLAT
9"b
5/8"c

DETAIL OF STEP
FOR BRACE.

ALLOWABLE VARIATIONS		
	OVER	UNDER
a	1/64"	1/64"
b	1/32"	1/32"
c	1/16"	1/16"
d	1/8"	1/8"
f	1/4"	1/4"
g	3/8"	3/8"
*	2°	2°

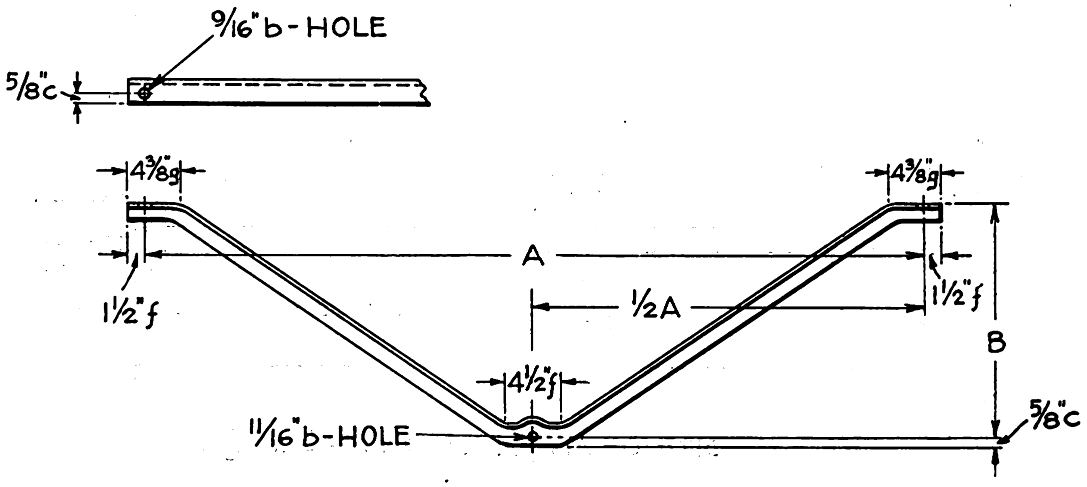
MATERIAL:
STEEL
D 200-22

FINISH:
HOT GALVANIZED
D 210-22

FIG. 5.

D230-28T
(TENTATIVE)

ANGLE CROSS ARM BRACE


9/16"b-HOLE
5/8"c
4 3/8"g
4 3/8"g
A
1 1/2"f
1/2A
1 1/2"f
B
4 1/2"f
11/16"b-HOLE
5/8"c

SIZE OF ANGLE : 1½"b x 1½"b x 3/16"a

SIZE	A	B
37 IN.	37"c	12"f
42 IN.	42"c	12"f
48 IN.	48"c	18"f
60 IN.	60"c	18"f

ALLOWABLE VARIATIONS		
	OVER	UNDER
a	1/64"	1/64"
b	1/32"	1/32"
c	1/16"	1/16"
f	1/4"	1/4"
g	3/8"	3/8"

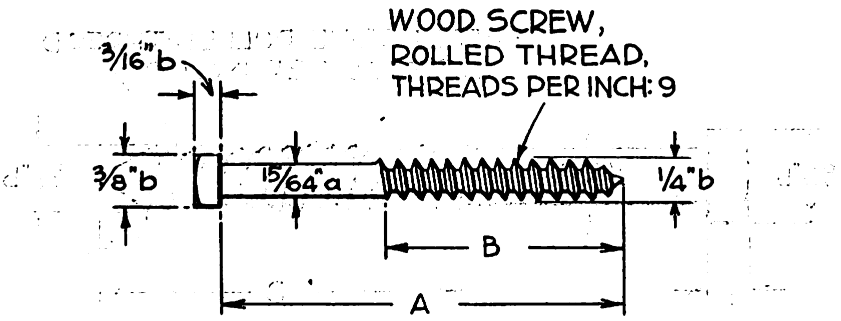
MATERIAL
STEEL
D 200-22

FINISH
HOT GALVANIZED
D 210-22

FIG. 6.

D264-28T
(TENTATIVE)

¼ IN. LAG SCREW


3/16"b
WOOD SCREW,
ROLLED THREAD,
THREADS PER INCH: 9
⅜"b
15/64"a
¼"b
B
A

A	B
1¼"d	⅞"d
2½"d	1⅜"d

ALLOWABLE VARIATIONS		
	OVER	UNDER
a	1/64"	1/64"
b	1/32"	1/32"
d	⅛"	⅛"

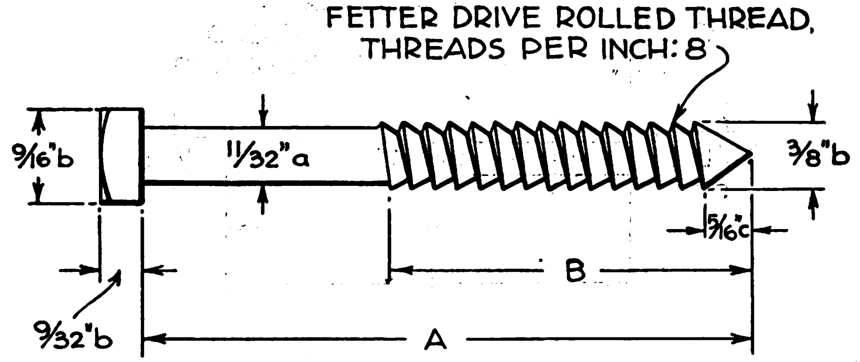
MATERIAL
STEEL
D200-22

FINISH:
HOT GALVANIZED
D210-22

FIG. 7.

D264.1-28T
(TENTATIVE)

3/8 IN. LAG SCREW


FETTER DRIVE ROLLED THREAD,
THREADS PER INCH: 8
9/16"b
11/32"a
3/8"b
5/16"c
B
9/32"b
A

A	B
4"d	2½"f
5"d	2¾"f

ALLOWABLE VARIATIONS		
	OVER	UNDER
a	1/64"	1/64"
b	1/32"	1/32"
c	1/16"	1/16"
d	1/8"	1/8"
f	1/4"	1/4"

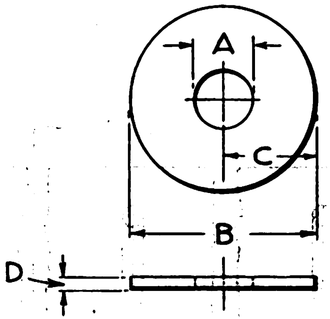
MATERIAL:
STEEL
D200-22

FINISH
HOT GALVANIZED
D210-22

FIG. 8.

D270-28T
(TENTATIVE)

ROUND WASHER



SIZE OF BOLT	A	B	C	D	
3/8" MACH.B.	7/16" b	1" c	1/2" c	5/64" a	* 14 B.W.G.
3/8" CARR.B.	1/2" b	1 1/4" c	5/8" c	5/64" a	14 "
1/2" MACH.B.	9/16" b	1 3/8" c	11/16" c	7/64" a	12 "
5/8" MACH.B.	11/16" b	1 3/4" c	7/8" c	9/64" a	10 "
3/4" MACH.B.	13/16" b	2" c	1" c	5/32" a	9 "

ALLOWABLE VARIATIONS		
	OVER	UNDER
a	1/64"	1/64"
b	1/32"	1/32"
c	1/16"	1/16"

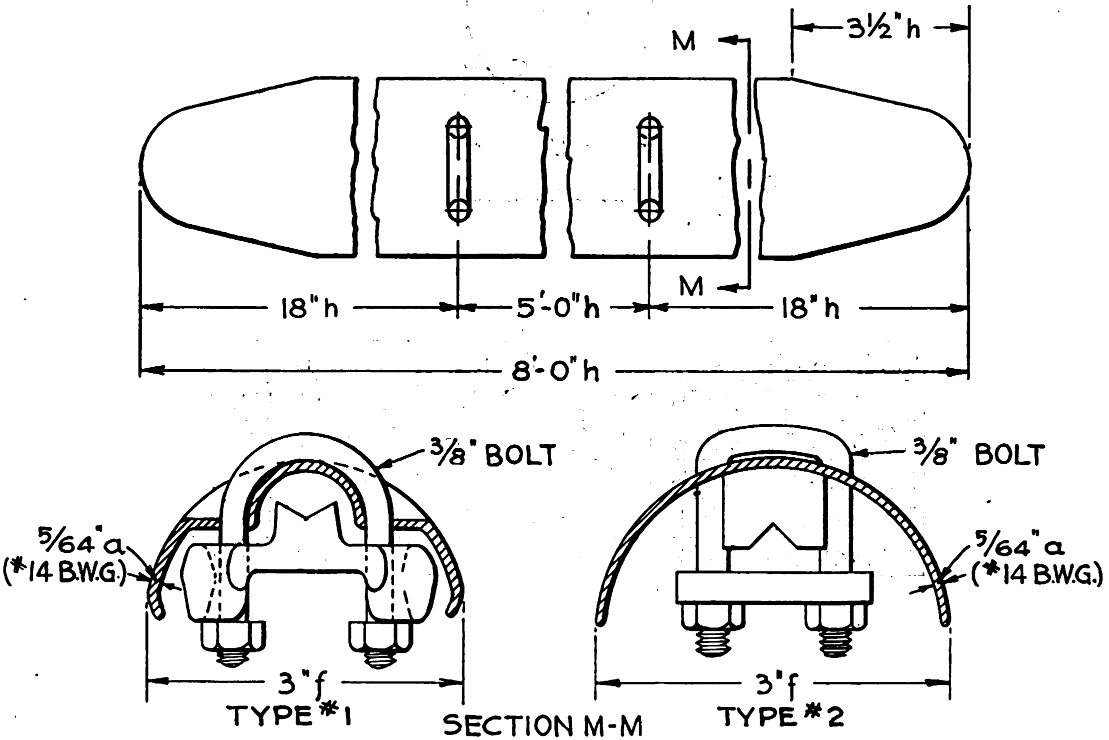
MATERIAL:
STEEL
D200-22

FINISH:
HOT GALVANIZED
D210-22

FIG. 9.

D282-28T
(TENTATIVE)

GUY WIRE PROTECTOR
(PATENTED)


M
3½"h
M
18"h
5'-0"h
18"h
8'-0"h
3/8" BOLT
5/64"a
(*14 B.W.G.)
3"f
TYPE *1
3/8" BOLT
5/64"a
(*14 B.W.G.)
3"f
TYPE *2

SECTION M-M
(ENLARGED)

ALLOWABLE VARIATIONS		
	OVER	UNDER
a	1/64"	1/64"
b	1/32"	1/32"
f	1/4"	1/4"
h	1/2"	1/2"

NOTE
PROTECTOR MUST BE GALVANIZED AFTER FABRICATION.

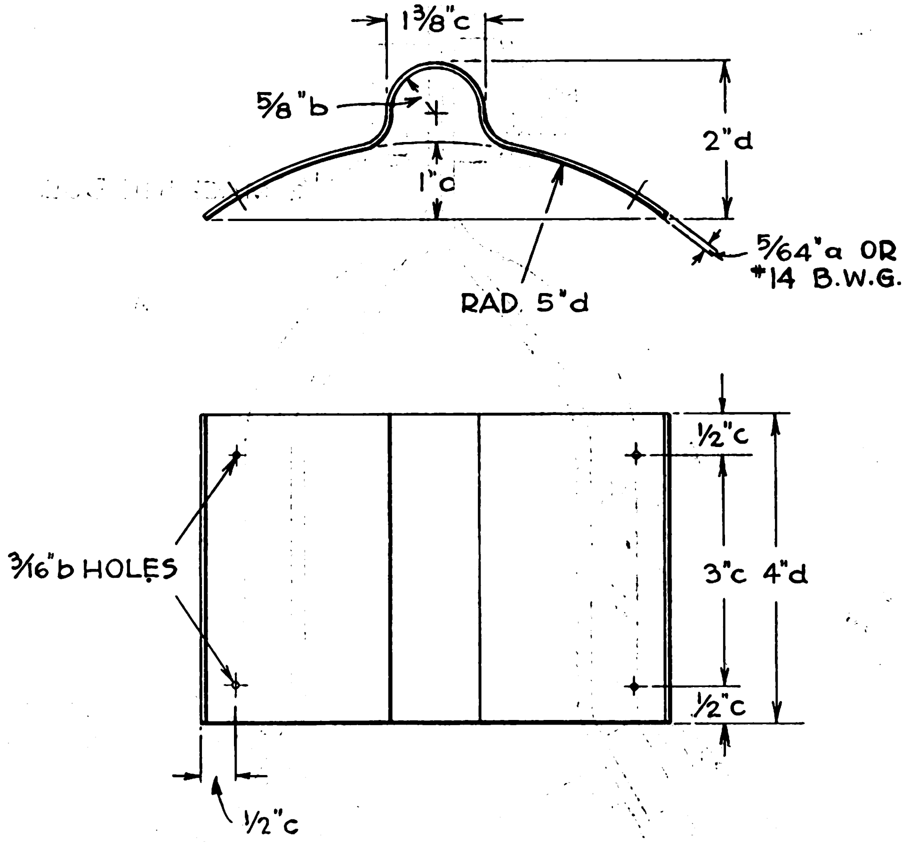
MATERIAL:
STEEL
D200-22

FINISH:
HOT GALVANIZED
D210-22

FIG. 10.

D299-28T
(TENTATIVE)

MOLDING GUY PLATE


1⅜"c
⅝"b
2"d
1"c
5/64"a OR
#14 B.W.G.
RAD. 5"d
½"c
3/16"b HOLES
3"c 4"d
½"c
½"c

NOTE

THIS PLATE TO BE MADE FROM 4"x8" FLAT.

ALLOWABLE VARIATIONS		
	OVER	UNDER
a	1/64"	1/64"
b	1/32"	1/32"
c	1/16"	1/16"
d	⅛"	⅛"

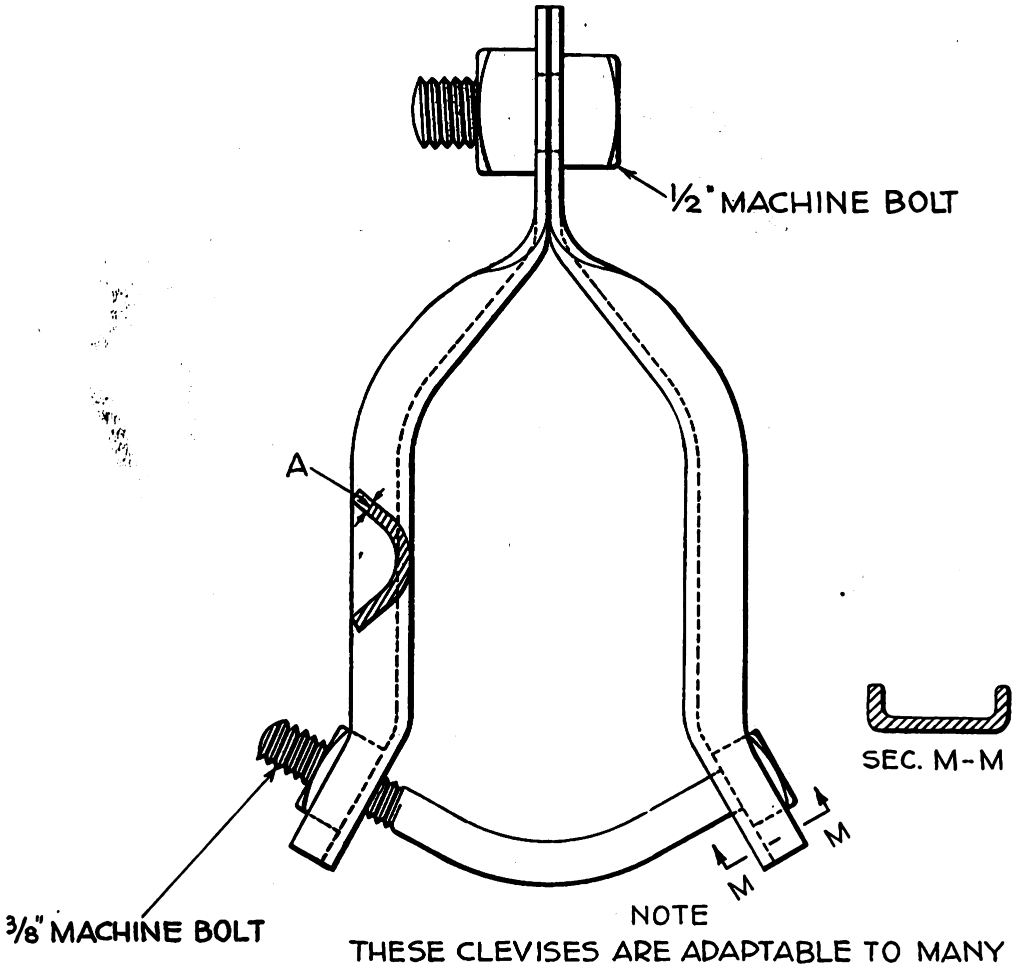
MATERIAL:
STEEL
D200-22

FINISH:
HOT GALVANIZED
D 210-22

FIG. 11.

D322-28T
(TENTATIVE)

PRESSED STEEL SPLIT CLEVIS
(PATENTED)



½" MACHINE BOLT
A
SEC. M-M
M
M
⅜" MACHINE BOLT

NOTE
THESE CLEVISES ARE ADAPTABLE TO MANY SIZES AND TYPES OF STRAIN INSULATORS.

SIZE	A
SMALL	#12 B.W.G.
LARGE	#11 B.W.G.

MATERIAL:
STEEL
D200-22
D209 22

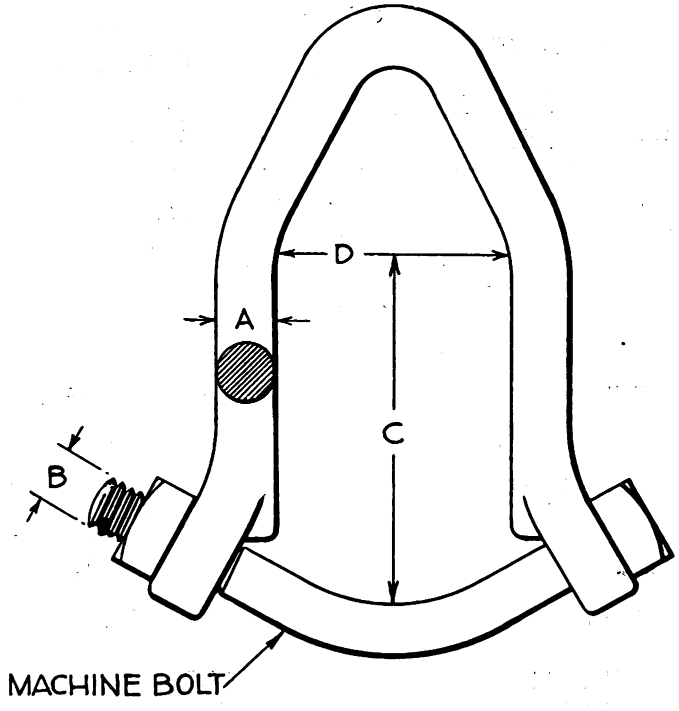
FINISH:
HOT
GALVANIZED
D210-22

FIG. 12.

D324-28T

(TENTATIVE)

DROP FORGED ONE PIECE CLEVIS
(OUTLINE DRAWING)



DIMENSIONS "C" & "D" SHOULD BE SUCH AS TO FIT GUY STRAIN INSULATOR USED

SIZE	A	B
LIGHT	7/16"	3/8"
HEAVY	1/2"	1/2"

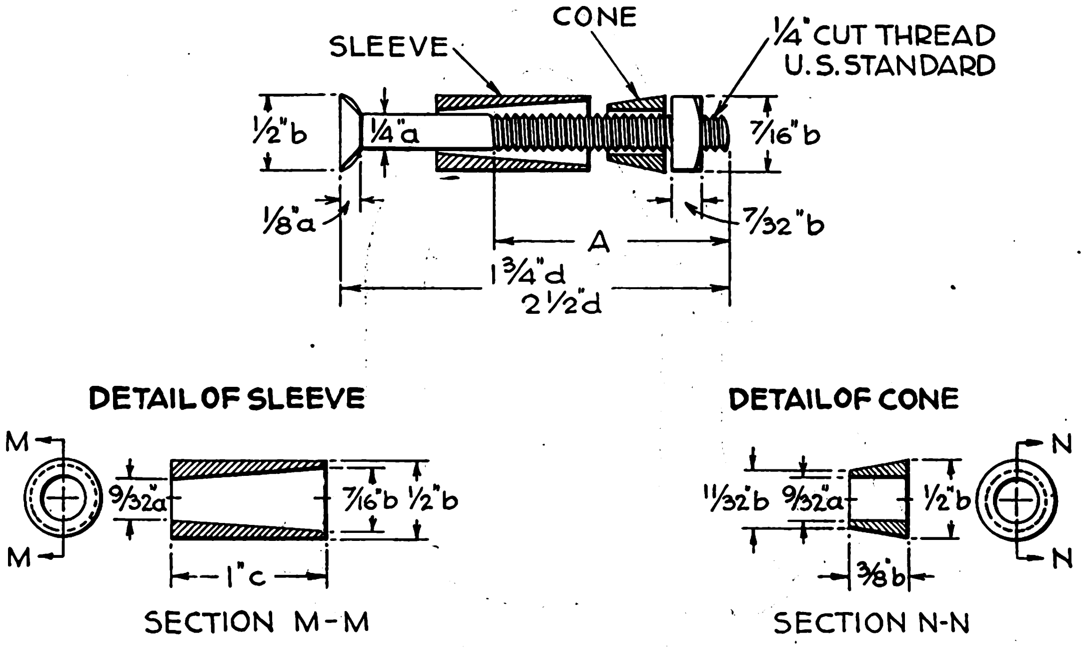
MATERIAL
STEEL
D200-22
D209-22

FINISH
HOT
GALVANIZED
D210-22

FIG. 13.

D330-28T
(TENTATIVE)

1/4 IN. EXPANSION BOLT


CONE
SLEEVE
1/4" CUT THREAD
U.S. STANDARD
1/2"b
1/4"a
7/16"b
1/8"a
7/32"b
A
1 3/4"d
2 1/2"d
DETAIL OF SLEEVE
M
M
9/32"a
7/16"b
1/2"b
1"c
SECTION M-M
DETAIL OF CONE
N
N
11/32"b
9/32"a
1/2"b
3/8"b
SECTION N-N

MATERIAL	FINISH
LEAD	NONE

MATERIAL	FINISH
LEAD	NONE

SIZE OF BOLT	A
1/4" x 1 3/4"	1" f
1/4" x 2 1/2"	1 1/2" f

ALLOWABLE VARIATIONS		
	OVER	UNDER
a	1/64"	1/64"
b	1/32"	1/32"
c	1/16"	1/16"
d	1/8"	1/8"
f	1/4"	1/4"

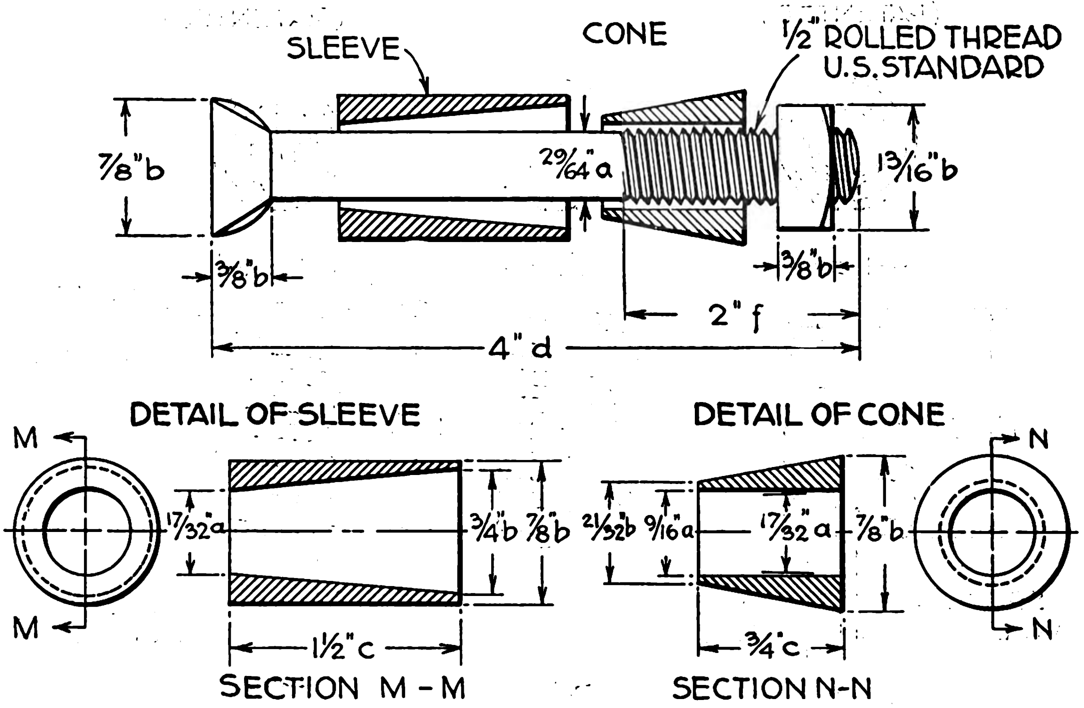
MATERIAL
STEEL
D200-22
D209-22

FINISH
ELECTRO
GALVANIZED
D210-22

FIG. 14.

D332-28T
(TENTATIVE)

½ IN. EXPANSION BOLT


SLEEVE
CONE
½" ROLLED THREAD U.S. STANDARD
⅞"b
29/64"a
13/16"b
⅜"b
⅜"b
2" f
4" d
DETAIL OF SLEEVE
DETAIL OF CONE
M
M
N
N
17/32"a
¾"b
⅞"b
21/32"b
9/16"a
17/32"a
⅞"b
1½"c
¾"c
SECTION M - M
SECTION N-N

MATERIAL
LEAD ALLOY
(0.5% ANTIMONY)

FINISH
NONE

MATERIAL
CAST IRON

FINISH
NONE

ALLOWABLE VARIATIONS		
	OVER	UNDER
a	1/64"	1/64"
b	1/32"	1/32"
c	1/16"	1/16"
d	⅛"	⅛"
f	¼"	¼"

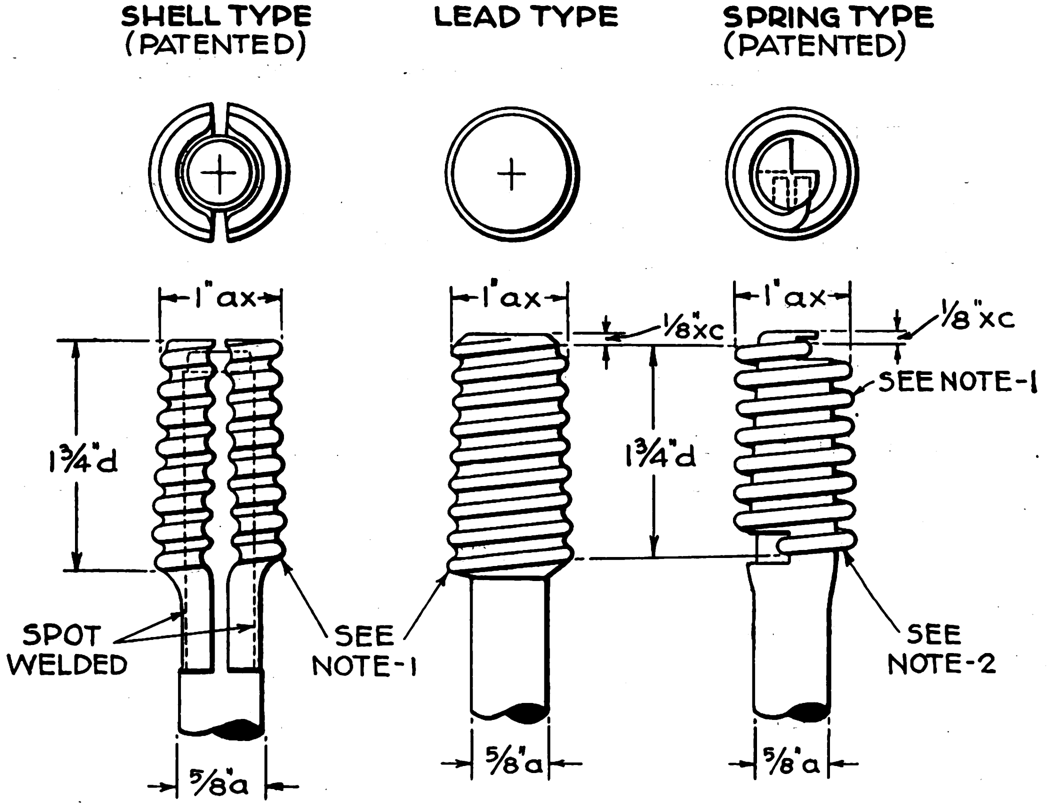
MATERIAL:
STEEL
D200-22
D209-22

FINISH:
HOT
GALVANIZED
D210-22

FIG. 15.

D340-28T
PART-1
(TENTATIVE)

1 IN. STEEL PIN
(LOW VOLTAGE)


SHELL TYPE
(PATENTED)
LEAD TYPE
SPRING TYPE
(PATENTED)
1"ax
1"ax
1"ax
1/8"xc
1/8"xc
1 3/4"d
1 3/4"d
SEE NOTE-1
SPOT WELDED
SEE NOTE-1
SEE NOTE-2
5/8"a
5/8"a
5/8"a

NOTES

1 - 4 THREADS PER INCH, TAPERING 1/16 IN. IN DIAMETER TO 1 IN. IN LENGTH.

2 - PIN MAY BE MADE WITH PRESSED METAL, LEAD HEAD, OR COPPER CLAD SPRING TYPE OF THREAD.

3 - FOR DETAILS OF THREAD SEE D992-993-994.

ALLOWABLE VARIATIONS		
	OVER	UNDER
a	1/64"	1/64"
c	1/16"	1/16"
d	1/8"	1/8"
ax	1/64"	0"
xc	0"	1/16"

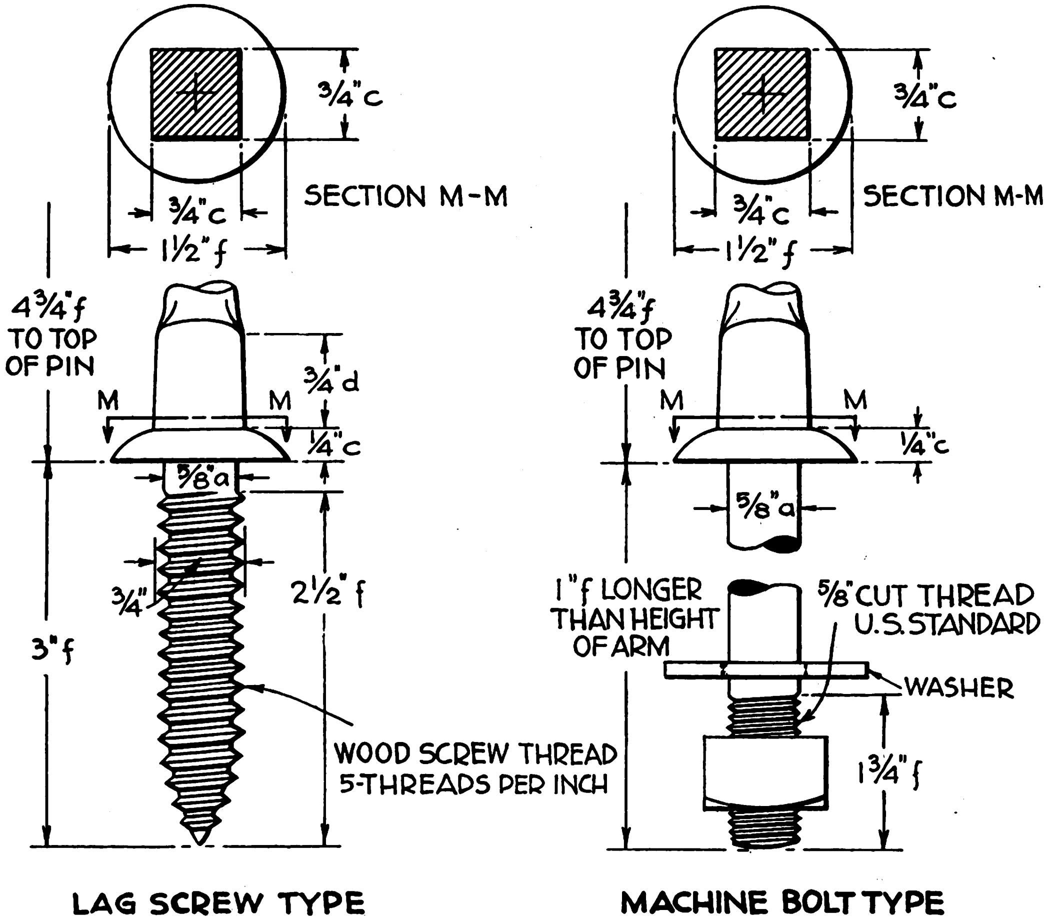
MATERIAL:
STEEL
D200-22

FINISH:
HOT GALVANIZED
D210-22

FIG. 16.

D 340-28T
PART - 2
(TENTATIVE)

1 IN. STEEL PIN
(LOW VOLTAGE)


3/4"c
SECTION M-M
3/4"c
1½"f
4¾"f TO TOP OF PIN
M
M
3/4"d
1/4"c
5/8"a
3/4"
2½"f
3"f
WOOD SCREW THREAD 5-THREADS PER INCH
3/4"c
SECTION M-M
3/4"c
1½"f
4¾"f TO TOP OF PIN
M
M
1/4"c
5/8"a
1"f LONGER THAN HEIGHT OF ARM
5/8"CUT THREAD U.S. STANDARD
WASHER
1¾"f

LAG SCREW TYPE

MACHINE BOLT TYPE

ALLOWABLE VARIATIONS		
	OVER	UNDER
c	1/16"	1/16"
d	1/8"	1/8"
f	1/4"	1/4"

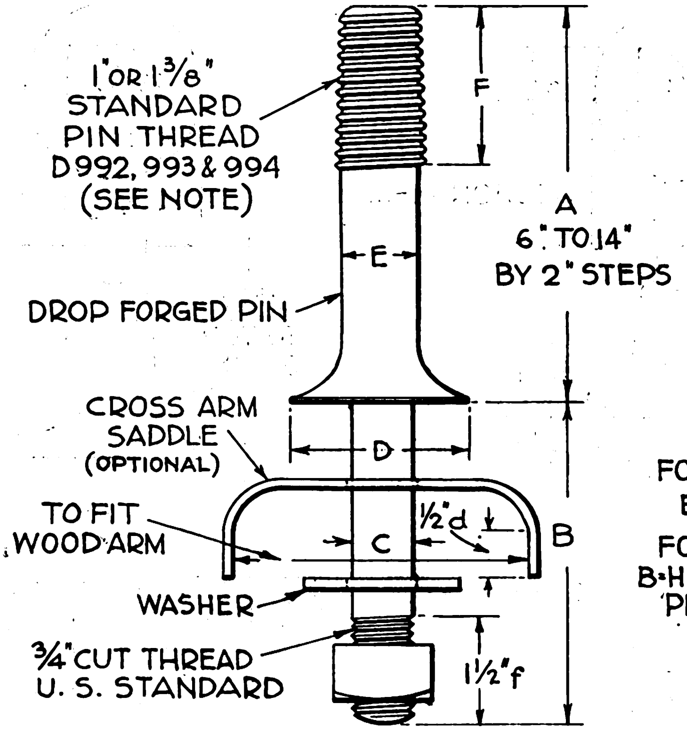
MATERIAL:
STEEL
D 200-22
D 209-22

FINISH:
HOT
GALVANIZED
D 210-22

FIG. 17.

D350-28T
(TENTATIVE)

STEEL PIN
(MEDIUM VOLTAGE)


1" OR 1⅜" STANDARD PIN THREAD D992, 993 & 994 (SEE NOTE)
F
A 6" TO 14" BY 2" STEPS
E
DROP FORGED PIN
CROSS ARM SADDLE (OPTIONAL)
D
TO FIT WOOD ARM
C
½"d
B
WASHER
¾" CUT THREAD U. S. STANDARD
1½"f

FOR STEEL ARM:
B = 1¾"f

FOR WOOD ARM:
B = HEIGHT OF ARM PLUS APPROX. 1 IN.

NOTE

A ZINC SEPARABLE THIMBLE MAY BE USED INSTEAD.

DIA. OF PIN THREAD	C	D	E	F
1"	¾"a	2½"f	¾"a	2"d
1⅜"	¾"a	*	1⅛"d	2½"d

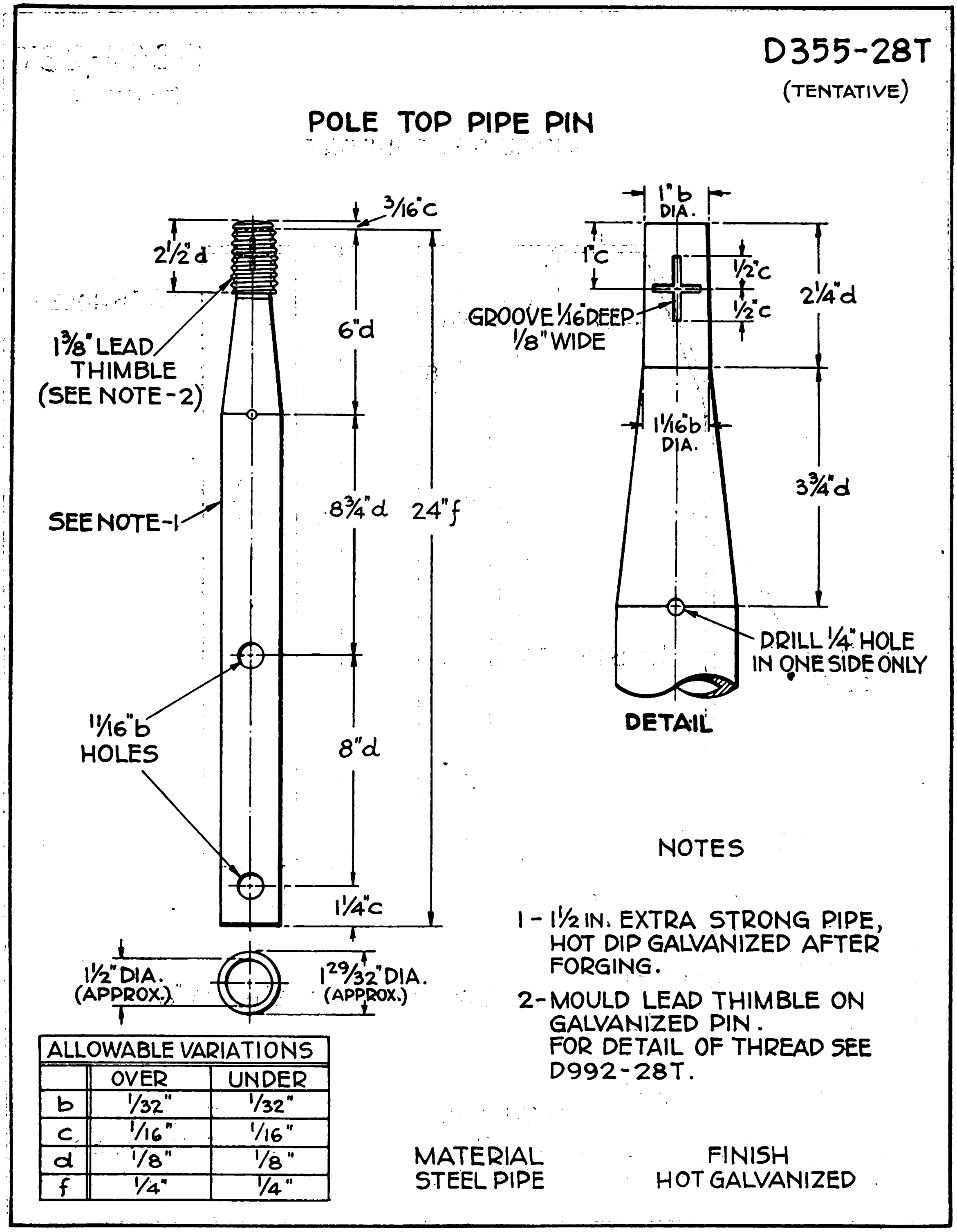
* D = 3"d, WHERE A = 6" & 8".
D = 3¾"d, WHERE A = 10" OR LONGER

ALLOWABLE VARIATIONS		
	OVER	UNDER
a	1/64"	1/64"
d	⅛"	⅛"
f	¼"	¼"

MATERIAL:
STEEL
D 200-22
D 209-22

FINISH:
HOT
GALVANIZED
D210-22

FIG. 18.


3/16"c
2½"d
1⅜" LEAD THIMBLE (SEE NOTE-2)
6"d
8¾"d
24"f
SEE NOTE-1
11/16"b HOLES
8"d
1¼"c
1½" DIA. (APPROX.)
1 29/32" DIA. (APPROX.)
1"b DIA.
1"c
½"c
½"c
2¼"d
GROOVE 1/16 DEEP 1/8" WIDE
1 1/16"b DIA.
3¾"d
DRILL ¼" HOLE IN ONE SIDE ONLY
DETAIL

D355-28T
(TENTATIVE)

POLE TOP PIPE PIN

ALLOWABLE VARIATIONS

	OVER	UNDER
b	1/32"	1/32"
c	1/16"	1/16"
d	1/8"	1/8"
f	1/4"	1/4"

NOTES

1 - 1½ IN. EXTRA STRONG PIPE, HOT DIP GALVANIZED AFTER FORGING.

2 - MOULD LEAD THIMBLE ON GALVANIZED PIN. FOR DETAIL OF THREAD SEE D992-28T.

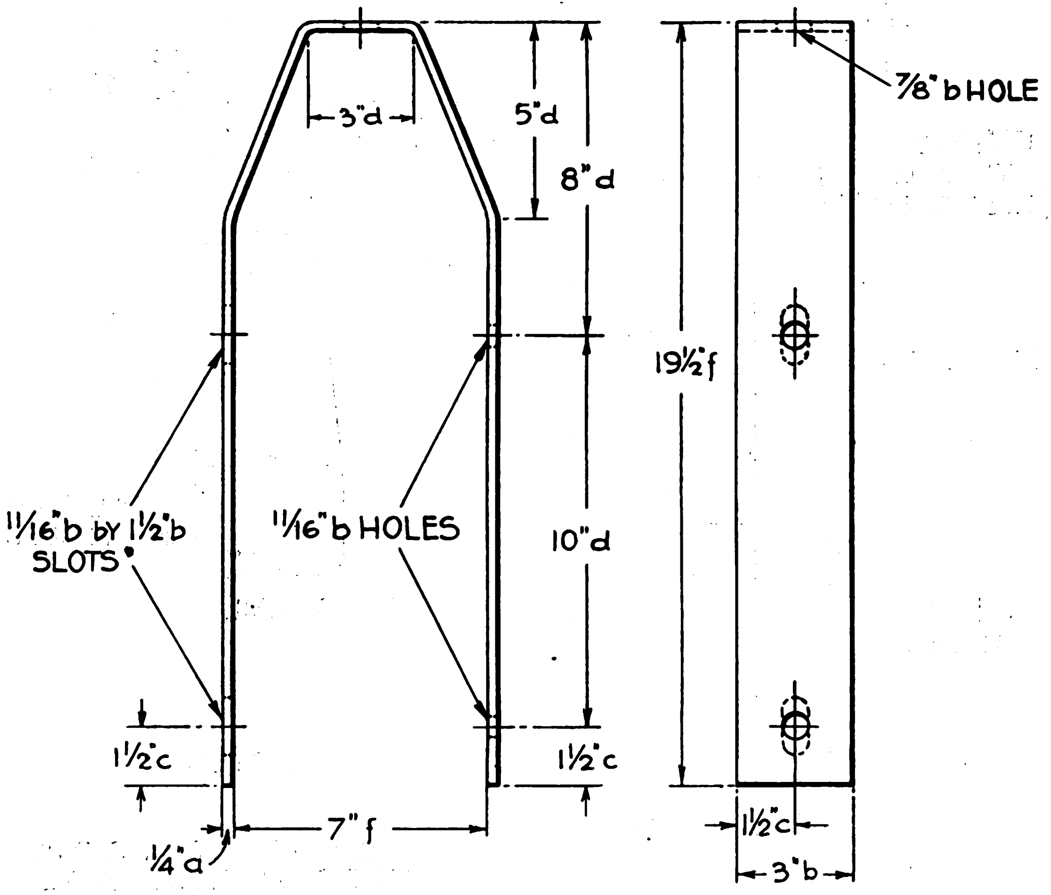
MATERIAL
STEEL PIPE

FINISH
HOT GALVANIZED

FIG. 19.

D362-28T
(TENTATIVE)

RIDGE PIN SUPPORT


3"d
5"d
8"d
10"d
19½"f
7/8" b HOLE
11/16" b BY 1½" b SLOTS •
11/16" b HOLES
1½" c
1½" c
¼" a
7" f
1½" c
3" b

SIZE OF FLAT 3" b x ¼" a

ALLOWABLE VARIATIONS		
	OVER	UNDER
a	1/64"	1/64"
b	1/32"	1/32"
c	1/16"	1/16"
d	1/8"	1/8"
f	¼"	¼"

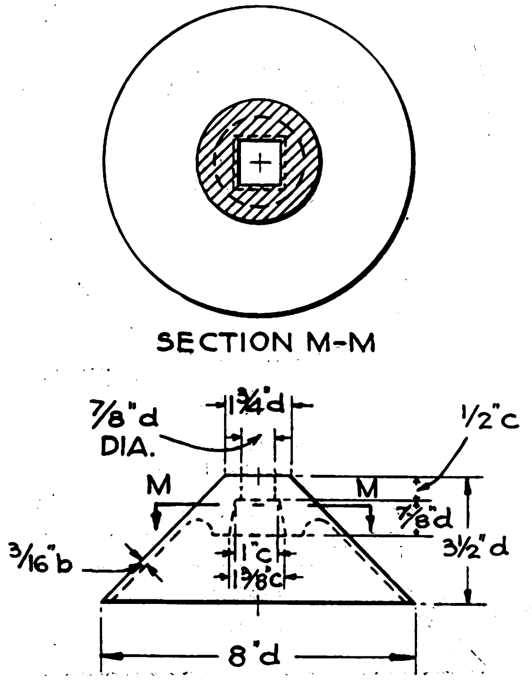
MATERIAL:
STEEL
D200-22

FINISH:
HOT GALVANIZED
D210-22

FIG. 20.

D430-28T
(TENTATIVE)

8 IN. ANCHOR PLATE


SECTION M-M
7/8"d
DIA.
1 3/4"d
1/2"c
M
M
7/8"d
3 1/2"d
3/16"b
1"c
1 3/8"c
8"d

NOTE

THE OUTER SURFACE OF THE ANCHOR PLATE MAY BE MADE WITH GROOVES, RIDGES, OR RIBS.

ALLOWABLE VARIATIONS		
	OVER	UNDER
b	1/32"	1/32"
c	1/16"	1/16"
d	1/8"	1/8"

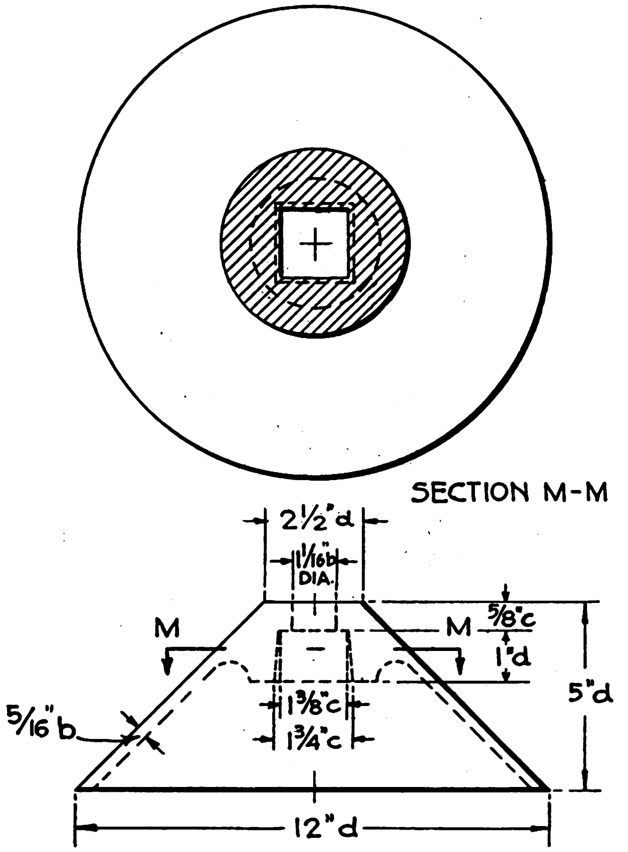
MATERIAL:
MALLEABLE IRON OR
GRAY IRON CASTING

FINISH:
NONE

FIG. 21.

D431-28T
(TENTATIVE)

12 IN. ANCHOR PLATE


SECTION M-M
2½"d
1/16"b DIA.
M
M
5/8"c
1"d
5"d
5/16"b
1⅜"c
1¾"c
12"d

NOTE
THE OUTER SURFACE OF THE ANCHOR PLATE MAY BE MADE WITH GROOVES, RIDGES, OR RIBS.

ALLOWABLE VARIATIONS		
	OVER	UNDER
b	1/32"	1/32"
c	1/16"	1/16"
d	⅛"	⅛"

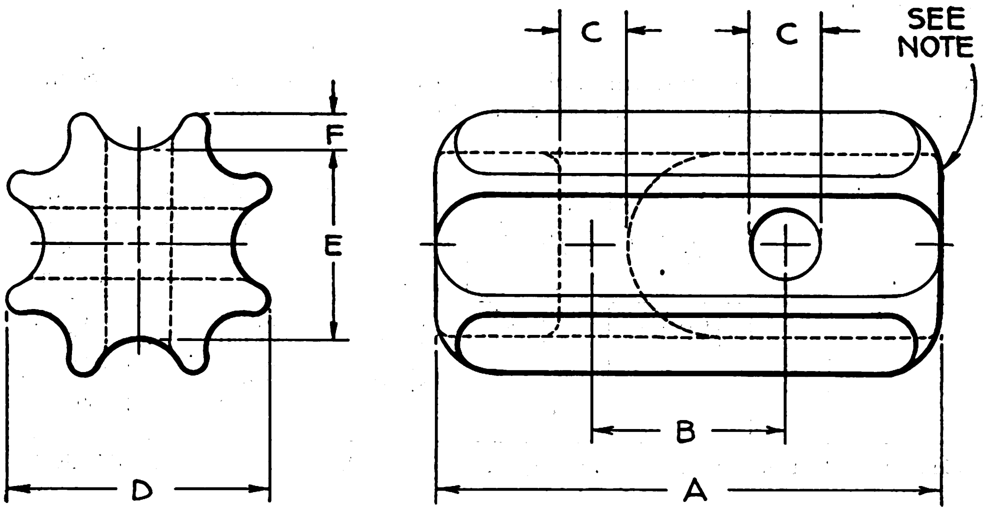
MATERIAL:
MALLEABLE IRON OR
GRAY IRON CASTING

FINISH:
NONE

FIG. 22.

D 570-28T
(TENTATIVE)

MULTIFIN GUY STRAIN INSULATOR



SIZE	A	B	C	D	E	F	STRENGTH IN COMPRESSION	DRY ARC-OVER
SMALL	3½" f	1⅝" d	9/16" c	2⅝" d	1⅞" d	⅜" c	10,000 LB.	30,000 V.
MEDIUM	5⅜" f	2" d	¾" d	3¼" d	2¼" d	½" c	12,000 LB.	35,000 V.
LARGE	6¾" f	2⅝" f	1" d	3½" d	2⅜" d	9/16" c	20,000 LB.	40,000 V.

ALLOWABLE VARIATIONS		
	OVER	UNDER
c	1/16"	1/16"
d	⅛"	⅛"
f	¼"	¼"

NOTE

ONE END OF INSULATOR
MAY BE UNGLAZED

MATERIAL:
PORCELAIN
WET PROCESS

FINISH:
BROWN
GLAZED

FIG. 23

D 650-28 T
(Tentative)

GALVANIZED STEEL STRAND

Scope

This suggested specification covers galvanized concentric lay steel strand, made of round steel wires laid helically around a center wire. The center wire shall have the same quality and characteristics as the outer wires.

General

When ordering galvanized steel strand under this suggested specification the size and the strength rating of strand must be specified.

Variations

Each wire shall be accurate and uniform in diameter and of circular cross-section. The diameter of the wires 0.1 inch or larger shall not vary more than 1 per cent over or under. The diameter of wires less than 0.1 inch shall not vary more than one mil over or under the specified diameter.

Finish

Each wire shall be free from scale, splints, flaws, inequalities, and all other imperfections. The wires shall fit snugly around the center wire.

Material

The strand shall be made of steel of such quality as to comply with the strength requirements given in the following table:

Nominal Diameter	Number of Wires	Size of Individual Wires	Approx. Wt. Per 1000 Ft.	BREAKING STRENGTH, Min.			
				Standard	Siemens-Martin	High Strength	Extra-High Strength
¼ in.	7	14 BWG	121 lb.	1,900 lb.	3,060 lb.	5,100 lb.	7,600 lb.
⁵⁄₁₆	7	12	205	3,200	4,860	8,100	12,100
⅜	7	11	296	4,250	6,800	11,500	17,250
⁷⁄₁₆	7	9	399	5,200	9,000	15,000	22,500
½	7	8	517	7,400	11,000	18,000	27,000

(The breaking strength of the strand is taken as 90% of the sum of the breaking strengths of individual wires.)

Test of Breaking Strength

Samples shall be selected at random from finished strand and should be at least five feet in length, properly socketed and tested in a tensile testing machine. If the breaking strength of any test sample is found to be below the stated minimum value, tests shall be made upon two additional samples from the same coil or reel, and the average of the three tests shall be taken as the test value. Tests, wherein the strength is below specified minimum values, but which are, obviously, due to improperly applied sockets, shall not be considered.

When desired, tensile tests may be made on strand using gripping jaws of the testing machine in place of socketed specimens. If the strength values obtained meet the requirements of the table, tests on socketed specimens will not be required.

As an alternative to the above test of strand, breaking strength test may be made on each of the seven individual wires. Each wire shall have a strength of at least 15.9 per cent of the rated breaking strength of the 7-wire strand.

Joints

Joints may be made in wire when finished and ready for stranding. All joints shall be so made as to develop the ultimate strength of the wire. No joints shall appear in a completed strand closer than 150 feet.

Pitch and Lay

The pitch of the strand shall not be less than 12 nor more than 16 diameters of the completed strand, and the lay may be either right or left, as specified by the purchaser.

Galvanizing

Each wire shall be galvanized before stranding, and shall comply with suggested specification for hot galvanizing D 210-22.

Bending Test

Each wire of which the strand is composed shall withstand, without fracture of the steel, or the galvanizing on the outside of the bend, five consecutive wraps about a mandrel as follows:

Size of Wire	Size of Mandrel
14 BWG	¼ in.
12	⁵⁄₁₆
11	⅜
9	⁷⁄₁₆
8	½

In case the wire should fail on the first trial, two additional tests shall be made, and if no further failure occurs on either of these tests the wire shall be considered acceptable.

Packing

The strand shall be furnished in coils or on reels in lengths as specified by the purchaser.

Marking

Each coil or reel shall be tagged or marked inside and outside with the purchaser's name, address, the purchaser's order number, the size, kind and net weight of the wire, and the manufacturer's name.

Inspection

Inspection and acceptance may be made either at the point of manufacture or upon delivery of the finished product. The manufacturer shall give to the purchaser, or his representative, such access to his works during working hours as is reasonable and necessary to determine the suitability of the material to be supplied, and shall furnish all necessary apparatus, labor and other facilities for making the tests herein called for without cost to the purchaser. The manufacturer shall eliminate all strand that he considers defective according to this suggested specification, before offering any lot for inspection or before shipment. Neither inspection, waiving of inspection nor the purchaser's acceptance shall release the manufacturer from obligation to furnish the material in accordance with this suggested specification.

Strand not conforming with this suggested specification shall be rejected and the manufacturer shall replace such rejected strand with strand complying with this suggested specification at his own expense, or shall allow credit for such rejected strand.

D 660-28 T
(Tentative)

COPPER-COVERED STEEL STRAND

Scope

This suggested specification covers concentric lay, copper-covered steel strand made of round copper-covered steel wires laid helically around a center wire. The center wire shall have the same quality and characteristics as the outer wires.

General

When ordering copper-covered steel strand under this suggested specification, the size and strength rating of strand must be specified.

Variations

Each wire shall be accurate and uniform in diameter and of circular cross section. The variations in diameter shall not be more than 1½ per cent over or under the specified diameter.

Finish

Each wire shall be free from scale, splints, flaws, inequalities and all other imperfections. The wires shall fit snugly around the center wire.

Material

The individual wires comprising the strand shall be composed of a steel core with a copper covering permanently welded thereto. The wires shall be of such quality as to comply with the requirements for breaking strength of strand, as given in the following table:

Nominal Diameter	Number of Wires	Size of Individual Wires	Approximate Weight per 1000 Ft.	BREAKING STRENGTH, Min.	
				Standard	Extra-High Strength
5/16 in.	7	10 A. W. G.	209 lb.	5,600 lb.	....
11/32	7	9	267	6,790	....
3/8	7	8	332	8,400	11,460 lb.
7/16	7	7	418	10,160	14,420
1/2	7	6	526	12,600	18,200
9/16	7	5	663	15,400	22,930
5/8	7	4	836	18,550	28,980

(The breaking strength of the strand is taken as 90% of the sum of the breaking strengths of the individual wires).

Test of Breaking Strength

Samples shall be selected at random from finished strand and should be at least five feet in length, properly socketed and tested in a tensile testing machine. If the breaking strength of any test sample is found to be below the stated minimum value, tests shall be made upon two additional samples from the same coil or reel, and the average of the three tests shall be taken as the test value. Tests, wherein the strength is below specified minimum values, but which are obviously due to improperly applied sockets, shall not be considered.

When desired, tensile tests may be made on strand using gripping jaws of the testing machine in place of socketed specimens. If the strength values obtained meet the requirements of the table, tests on socketed specimens will not be required.

As an alternative to the above test of strand, breaking strength test may be made on each of the seven individual wires. Each wire shall have a strength of at least 15.9 per cent of the rated breaking strength of the 7-wire strand.

Elongation

The elongation shall not be less than 1 per cent in 10 in.

Brazes

Brazes in individual wires shall be made only in the finished size of wire and when ready for stranding. A separation of at least 150 ft. shall be maintained between any two brazes in the completed strand. Brazes shall be made in accordance with the best commercial practice, and the resistance to corrosion and tensile strength of the brazes shall be equal to that of the wire.

Pitch and Lay

The pitch of the strand shall not be less than 12 nor more than 16 diameters of the completed strand, and the lay may be either right or left, as specified by the purchaser. (The direction of the lay shall be considered that direction in which the helically placed wires cross over the axis of the strand as they recede from the observer.)

Conductivity

The amount of copper shall be determined by measuring the electrical conductivity of the wire. The volume conductivity of all seven wires shall average at least 30 per cent, and shall not be less than 27 per cent for any individual wire, being compared with the conductivity of the same size hard-drawn copper wire as a standard of 100 per cent.

Ferroxyl Test

The copper exterior on each wire shall be continuous over the whole length and circumference of the wire, and its thickness shall be ample and adequate to protect the center steel core from exposure where and when installed under corrosive and rusting atmospheric conditions.

In order to determine the necessary thickness of copper throughout the wire, the "Ferroxyl" test shall be made as described below, whereby successive concentric layers of copper are removed from the exterior of the wire. Samples of wire shall be selected at random and shall withstand such accelerated corrosion tests without exposure of steel. Any sample not passing this test shall cause rejection of the entire coil from which the sample was taken.

Each sample of wire to be tested shall, after being cleaned with carbon tetra-chloride or other grease remover, be held in a flame of a Bunsen burner for a length of time sufficient to bring it to a cherry-red heat. It shall then be withdrawn from the heat and allowed to cool in the air.

The sample shall then be placed in an 8 to 10 per cent solution of sulphuric acid, and the oxide thoroughly removed.

The sample shall again be placed in the flame of a Bunsen burner, and the test repeated as before. The above cycle of tests shall be repeated five consecutive times.

After removal from the sulphuric acid solution of the fifth cycle, sample shall be tested for exposed steel by immersing the sample in a Ferroxyl test solution which shall be made up as follows:

10 Grams C. P. Potassium Ferri Cyanide
20 Grams C. P. Sulphuric Acid
1 Liter C. P. water.
Dissolve cyanide in water.
Add acid slowly.

The presence of iron or steel is disclosed by a deep blue mark on the wire or marking in the solution. As this indicator is extremely sensitive, it is essential that the wire and any equipment used in making the test be perfectly clean. If in any test the presence of iron is indicated, the test should be repeated to ascertain whether the indication is due to exposed steel in the wire or to foreign iron rust, filings, scale or other irrelevant causes. The sample of wire shall be bent U-shape and, when immersed in the Ferroxyl solution, shall be held so that the exposed steel on the ends of the wire will not come in contact with the solution.

Test of Weld

The test of the weld between copper and steel shall be made on samples taken from wire rods from which the wire is cold-drawn, in order to observe specimens which have not been cold-worked. The specimens shall be broken by repeated bending, or by torsion, or by both.

The finished wire, or larger sizes of wire, may also be tested in like manner. Any indication of separation of the copper from the steel on any specimens shall cause rejection of entire lot.

Packing

The strand shall be furnished in coils or on reels in lengths as specified by the purchaser.

Marking

Each coil or reel shall be tagged or marked inside and outside with the purchaser's name, address, the purchaser's order number, the size, kind and net weight of the wire and the manufacturer's name.

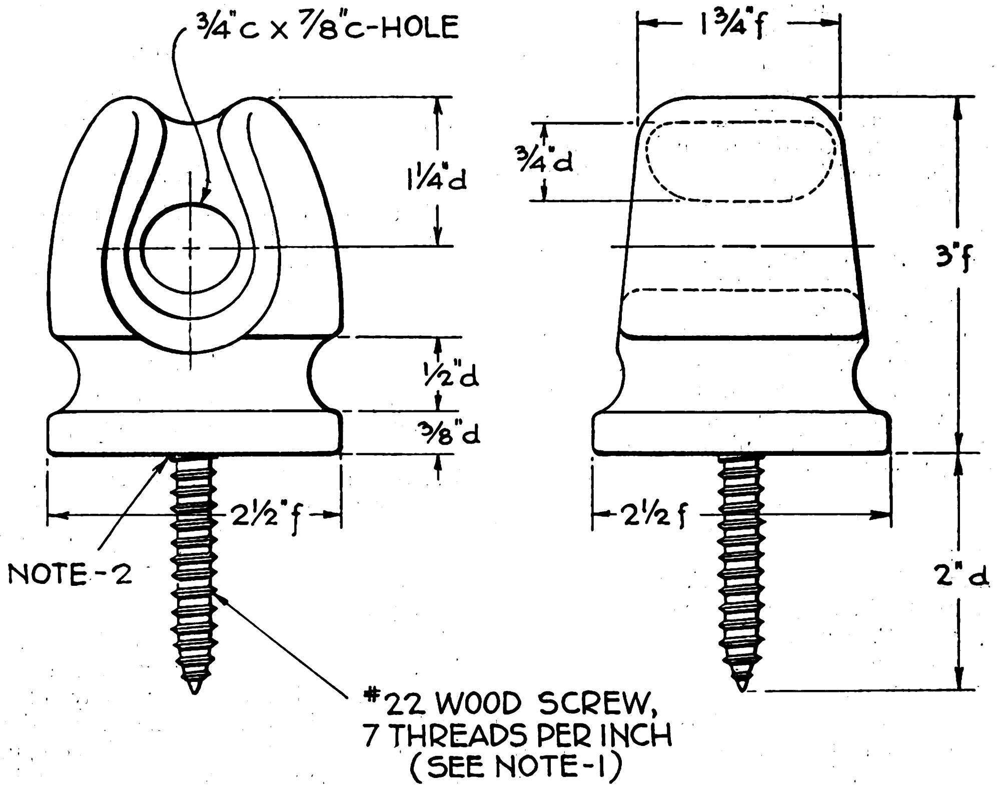
Inspection

Inspection and acceptance may be made either at the point of manufacture or upon delivery of the finished product. The manufacturer shall give to the purchaser, or his representative, such access to his works during working hours as is reasonable and necessary to determine the suitability of the material to be supplied, and shall furnish all necessary apparatus, labor and other facilities for making the tests herein called for without cost to the purchaser. The manufacturer shall eliminate all strand that he considers defective according to this suggested specification, before offering any lot for inspection or before shipment. Neither inspection, waiving of inspection, nor the purchaser's acceptance shall release the manufacturer from obligation to furnish the material in accordance with this suggested specification.

Strand not conforming with this suggested specification shall be rejected, and the manufacturer shall furnish new strand complying with this suggested specification at his own expense, or shall allow credit for such rejected strand.

D900-28T
(TENTATIVE)

WIREHOLDER


3/4"c x 7/8"c-HOLE
1 3/4"f
1 1/4"d
3/4"d
3'f
1/2"d
3/8"d
2 1/2"f
2 1/2 f
2"d
NOTE-2
#22 WOOD SCREW,
7 THREADS PER INCH
(SEE NOTE-1)

NOTES

1 - THIS SCREW SHOULD BE MADE OF RUST RESISTING ALLOY.

2 - SCREW SHOULD BE LEADED INTO INSULATOR.

ALLOWABLE VARIATIONS		
	OVER	UNDER
c	1/16"	1/16"
d	1/8"	1/8"
f	1/4"	1/4"

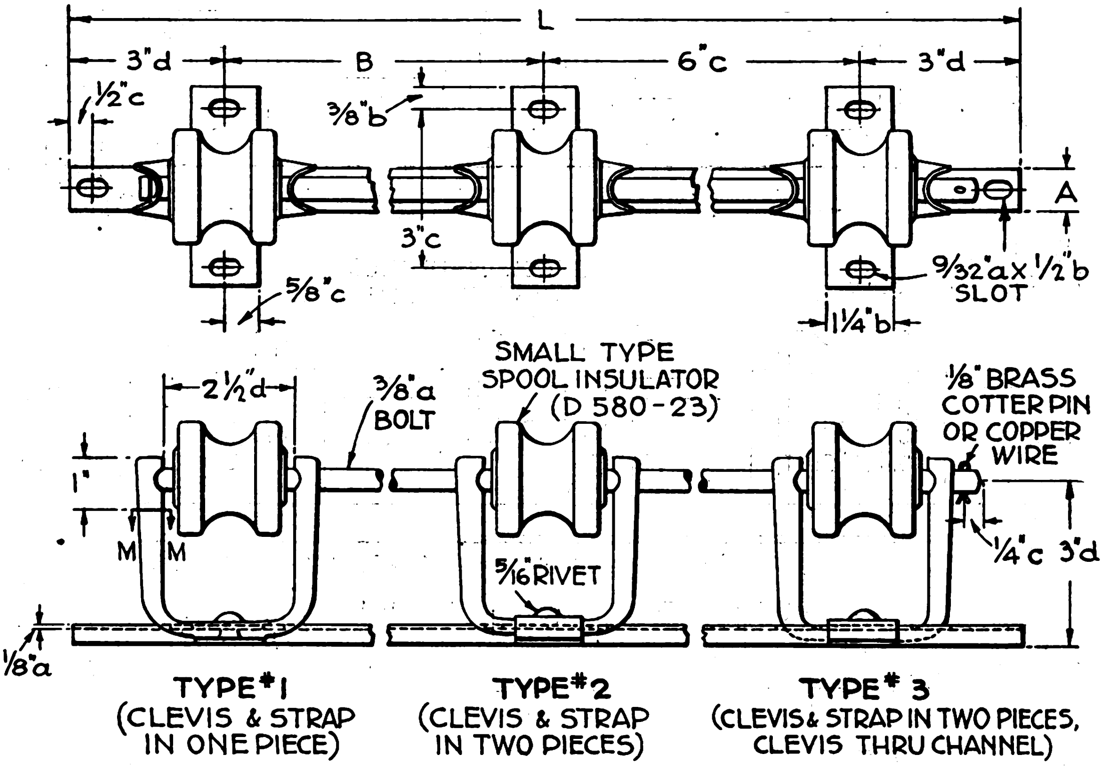
MATERIAL:
PORCELAIN
WET PROCESS

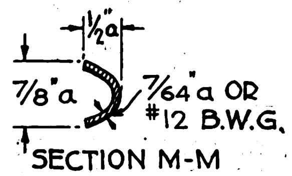
FINISH:
BROWN
GLAZED

FIG. 24.

D910-28T
(TENTATIVE)

SERVICE BRACKET


L
3"d
B
6"c
3"d
½"c
⅜"b
3"c
⅝"c
A
9/32"a x ½"b
SLOT
1¼"b
SMALL TYPE
SPOOL INSULATOR
(D 580-23)
2½"d
⅜"a
BOLT
⅛" BRASS
COTTER PIN
OR COPPER
WIRE
1"
M
M
5/16" RIVET
¼"c
3"d
⅛"a
TYPE #1
(CLEVIS & STRAP
IN ONE PIECE)
TYPE #2
(CLEVIS & STRAP
IN TWO PIECES)
TYPE # 3
(CLEVIS & STRAP IN TWO PIECES,
CLEVIS THRU CHANNEL)


½"a
⅞"a
7/64"a OR
#12 B.W.G.
SECTION M-M

ALLOWABLE VARIATIONS		
	OVER	UNDER
a	1/64"	1/64"
b	1/32"	1/32"
c	1/16"	1/16"
d	⅛"	⅛"

NOTE

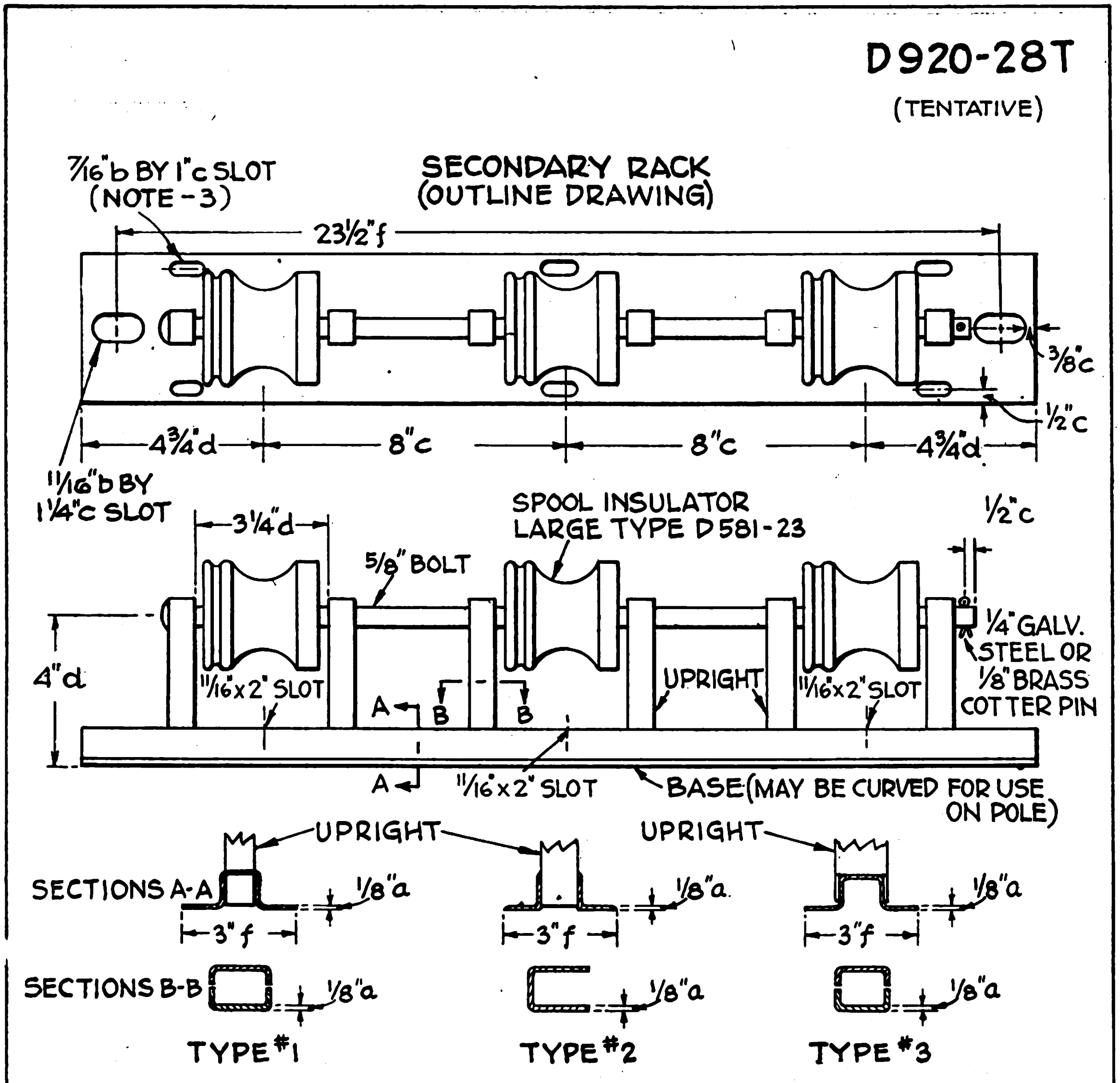
BRACKET MAY BE BUILT IN ONE PIECE, OR AS SHOWN IN TYPES #1, #2, OR #3. OR THEIR EQUIVALENT IN STRENGTH.

TYPE	A	L=12"	L=18"
		B	B
1 & 2	¾"a	0"	6"c
3	1½"a	0"	6"c

MATERIAL:
STEEL
D200-22

FINISH:
HOT GALVANIZED
D210-22

FIG. 25.


D920-28T
(TENTATIVE)
SECONDARY RACK
(OUTLINE DRAWING)
7/16"b BY 1"c SLOT
(NOTE-3)
23½"f
3/8"c
½"c
4¾"d
8"c
8"c
4¾"d
11/16"b BY
1¼"c SLOT
3¼"d
SPOOL INSULATOR
LARGE TYPE D581-23
½"c
5/8" BOLT
4"d
¼" GALV.
STEEL OR
1/8" BRASS
COTTER PIN
11/16"x2" SLOT
A
B
B
UPRIGHT
11/16"x2" SLOT
A
11/16"x2" SLOT
BASE (MAY BE CURVED FOR USE ON POLE)
UPRIGHT
UPRIGHT
SECTIONS A-A
1/8"a
3"f
1/8"a
3"f
1/8"a
3"f
SECTIONS B-B
1/8"a
1/8"a
1/8"a
TYPE #1
TYPE #2
TYPE #3

ALLOWABLE VARIATIONS		
	OVER	UNDER
a	1/64"	1/64"
b	1/32"	1/32
c	1/16"	1/16
d	1/8"	1/8"
f	1/4"	1/4"

NOTES

1-RACK MAY BE BUILT OF ONE PIECE, OR AS SHOWN IN TYPES #1, #2 OR #3, OR THEIR EQUIVALENT IN STRENGTH.

2-UPRIGHTS MAY BE RIVETED OR WELDED TO BASE.

3-ALL 7/16"x1" SLOTS ARE OPTIONAL.

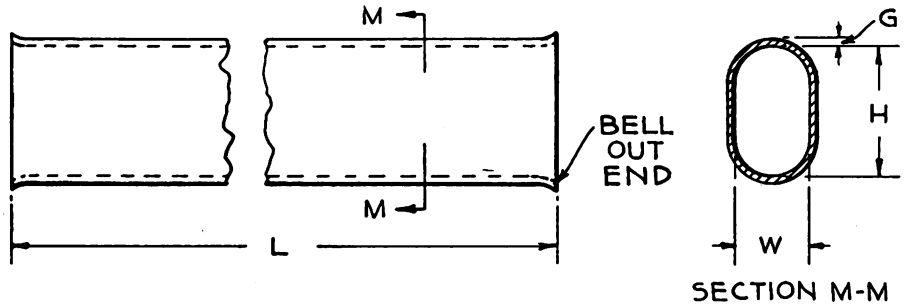
MATERIAL
STEEL
D 200-22

FINISH
HOT GALVANIZED
D 210-22

FIG. 26.

D950-28T
(TENTATIVE)

SPLICING SLEEVE



* SIZE A.W.G.	*NUMBER OF STRANDS	W INCHES	H INCHES	G		L (+ OR - ½") INCHES
				B.W.G.	INCHES	
*10	1	0.111	0.219	* 20	0.035	4
8	1	.140	.276	20	.035	5
6	1	.179	.352	20	.035	6
4	1	.230	.448	19	.042	8
2	1	.292	.564	18	.049	10
0	1	.367	.717	18	.049	12
4	7	.258	.507	19	.042	9
3	7	.287	.565	18	.049	10
2	7	.327	.642	18	.049	11
1	7	.366	.718	18	.049	12
0	7	.412	.809	17	.058	14
00	7	.460	.903	17	.058	16
000	7	.519	1.018	17	.058	18
0000	7	.589	1.156	15	.072	20
250,000 C.M.	19	.637	1.251	15	.072	21

NOTES

1-"H" SHALL NOT BE SMALLER THAN 97¼% NOR LARGER THAN 101½ % OF THE TABULATED VALUE.

2-"W" SHALL NOT BE SMALLER THAN 97% NOR LARGER THAN 107% OF THE TABULATED VALUE.

* SIZE AND KIND OF WIRE SHALL BE STAMPED ON EACH SLEEVE.

MATERIAL
ANNEALED COPPER TUBING

FINISH:
NONE

FIG. 27.

D 970-28 T
(Tentative)

SOLDER

Scope

This suggested specification covers a lead-tin alloy used for solder metal.

General

Solder furnished under this suggested specification shall conform with the current specification of the American Society for Testing Materials. Quotations must be accompanied by samples, representative of the solder to be furnished under this specification.

Material

Each bar of solder shall be uniform in composition with the entire lot. The solder shall be made from new or properly refined metals. The alloy shall conform to the following requirements as to chemical composition:

Composition	String	Wiping
Tin	50%	40%
Lead (approximately)	50%	60%
Antimony (maximum)	0.12%	0.12%

The permissible variation plus or minus in the percentage of tin shall not be over 1 per cent of the tin contents specified above.

Packing

The solder shall be packed in tight wooden boxes containing 100 lb. net weight. Each box shall be marked with the purchaser's name and address, purchaser's order number, the amount and kind of solder, and the manufacturer's name.

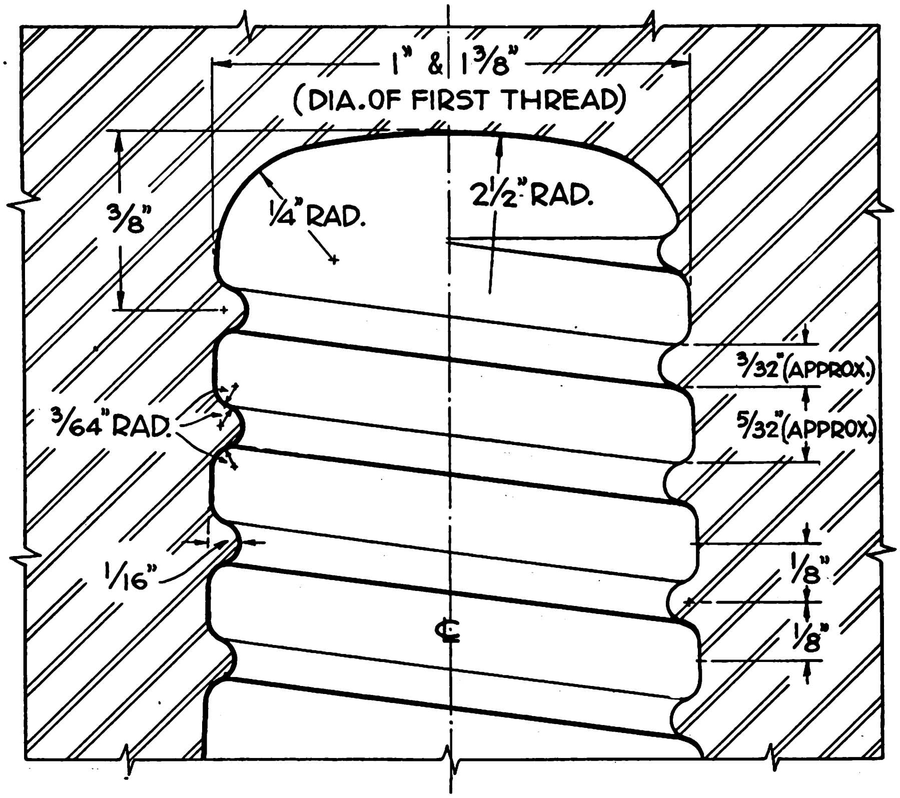
Inspection

Inspection and acceptance may be made either at the point of manufacture or upon delivery of the finished product. The manufacturer shall give the purchaser or his representative such access to his works during working hours as is reasonable and necessary to determine the suitability of the material to be supplied, and shall furnish all the necessary apparatus, labor and other facilities for making the test herein called for, without cost to the purchaser. The manufacturer shall eliminate all solder that he considers defective, according to this suggested specification, before offering any lot for inspection or before shipment. Neither inspection, waiving of inspection, or the purchaser's acceptance shall relieve the manufacturer from the obligation to furnish solder in accordance with this suggested specification.

Solder not conforming with this suggested specification shall be rejected, and the manufacturer shall either replace such rejected solder with solder complying with this suggested specification at his own expense, or shall allow credit for such rejected solder.

D 990-28T
(TENTATIVE)

1 IN. & 1 3/8 IN. THREAD IN INSULATOR



1" & 1 3/8"
(DIA. OF FIRST THREAD)
3/8"
1/4" RAD.
2 1/2" RAD.
3/32" (APPROX.)
5/32" (APPROX.)
3/64" RAD.
1/16"
1/8"
1/8"
℄

NOTES

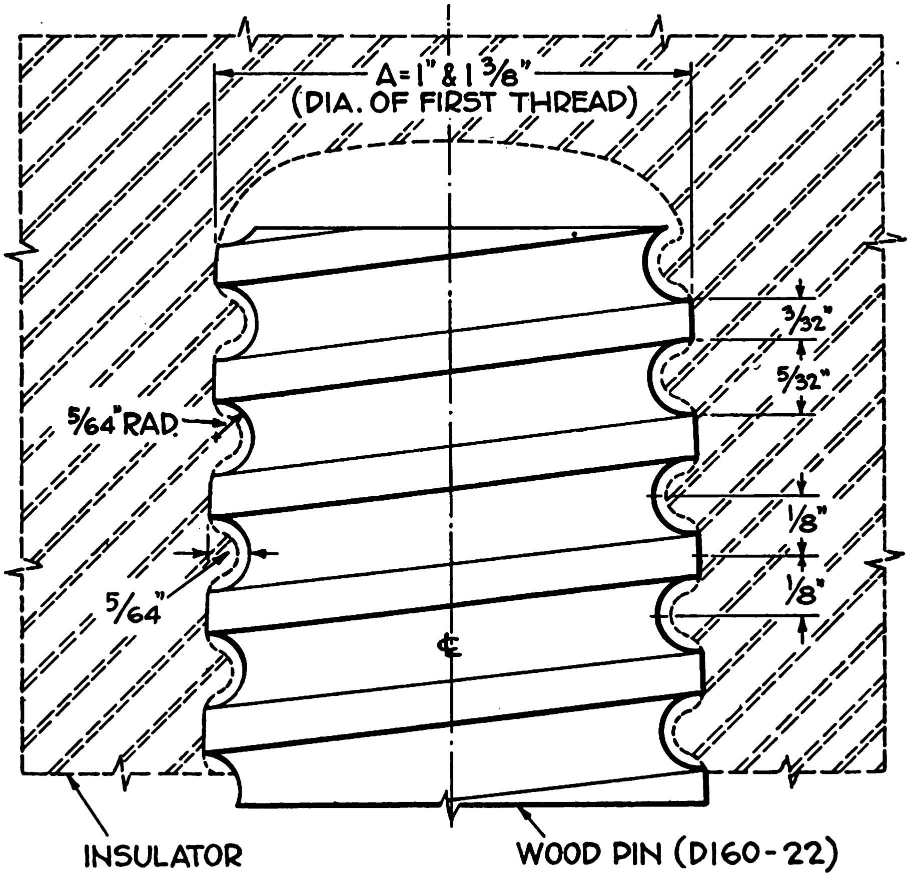
1- 4 THREADS PER INCH, TAPERING 1/16 IN. IN DIAMETER TO 1 IN. IN LENGTH.

2- THREAD FIT TO BE CHECKED WITH INSULATOR GAUGE D995-28T.

FIG. 28.

D991-28T
(TENTATIVE)

1 IN. & 1⅜ IN. WOOD PIN THREAD


A = 1" & 1⅜"
(DIA. OF FIRST THREAD)
3/32"
5/32"
5/64" RAD.
1/8"
1/8"
5/64"
℄
INSULATOR
WOOD PIN (D160-22)

NOMINAL SIZE	A
1-INCH	1" ax
1⅜-INCH	1⅜" ax

ALLOWABLE VARIATIONS		
	OVER	UNDER
ax	1/64"	0"

NOTES

1- 4 THREADS PER INCH, TAPERING 1/16 IN. IN DIAMETER TO 1 IN. IN LENGTH.

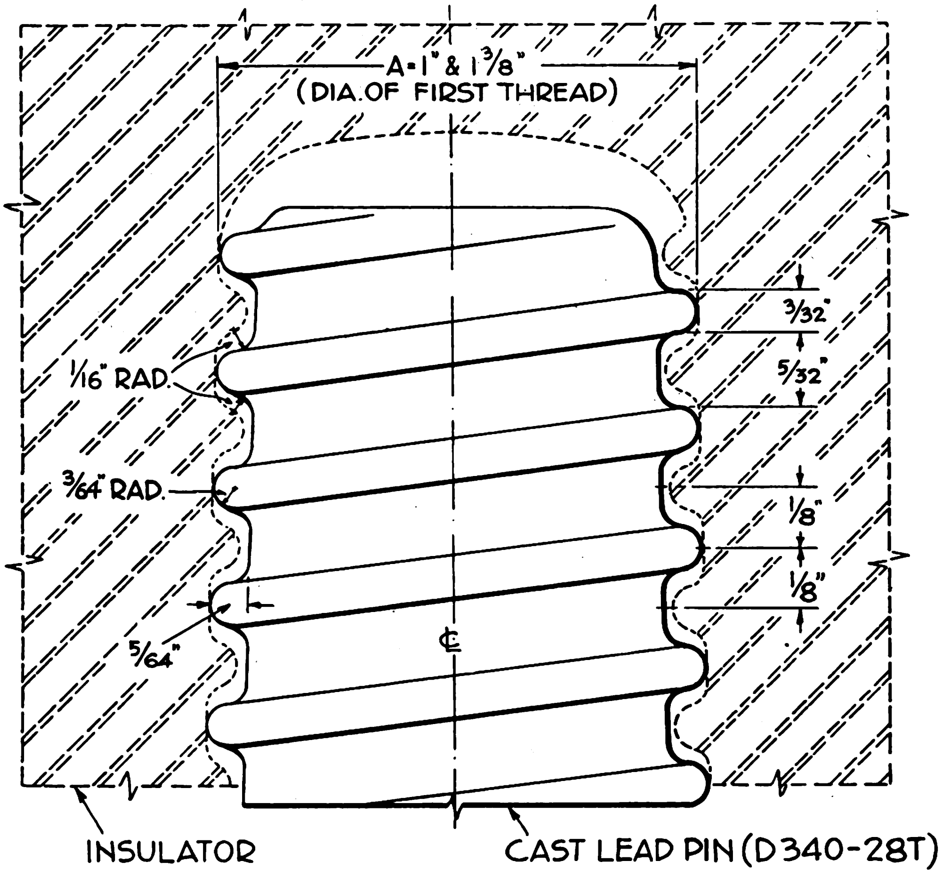
2- ALLOWABLE VARIATION OF 5% OVER OR UNDER ON ALL DIMENSIONS, EXCEPT WHERE SHOWN OTHERWISE.

FIG. 29.

D 992-28T

(TENTATIVE)

1 IN. & 1⅜ IN. CAST LEAD PIN THREAD


A = 1" & 1⅜"
(DIA. OF FIRST THREAD)
3/32"
5/32"
1/16" RAD.
3/64" RAD.
1/8"
1/8"
5/64"
℄
INSULATOR
CAST LEAD PIN (D340-28T)

NOMINAL SIZE	A
1 - INCH	1" ax
1⅜-INCH	1⅜" ax

ALLOWABLE VARIATIONS		
	OVER	UNDER
ax	1/64"	0"

NOTES

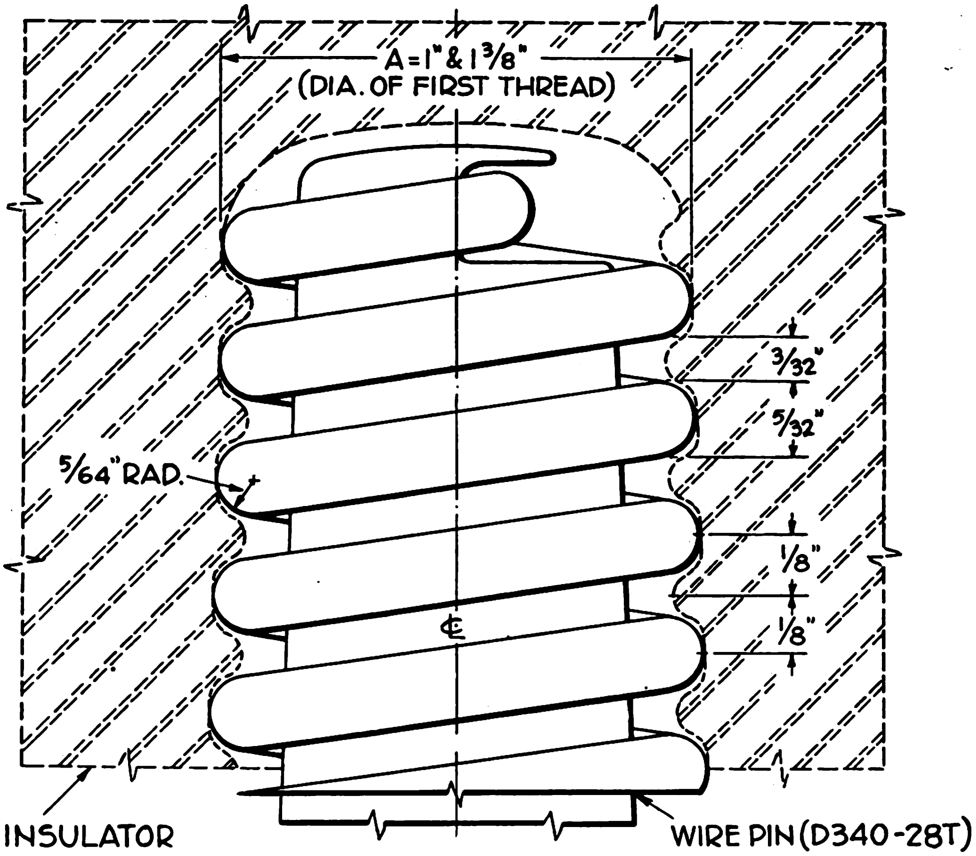
1- 4 THREADS PER INCH, TAPERING 1/16 IN. IN DIAMETER TO 1 IN. IN LENGTH.

2- ALLOWABLE VARIATION OF 5% OVER OR UNDER ON ALL DIMENSIONS, EXCEPT WHERE SHOWN OTHERWISE.

FIG. 30.

D993-28T
(TENTATIVE)

1 IN. & 1$^3/_8$ IN. WIRE PIN THREAD


A = 1" & 1 3/8"
(DIA. OF FIRST THREAD)
3/32"
5/32"
5/64" RAD.
1/8"
1/8"
℄
INSULATOR
WIRE PIN (D340-28T)

NOMINAL SIZE	A
1-INCH	1" ax
1$^3/_8$-INCH	1$^3/_8$" ax

ALLOWABLE VARIATIONS		
	OVER	UNDER
ax	1/64"	0"

NOTES

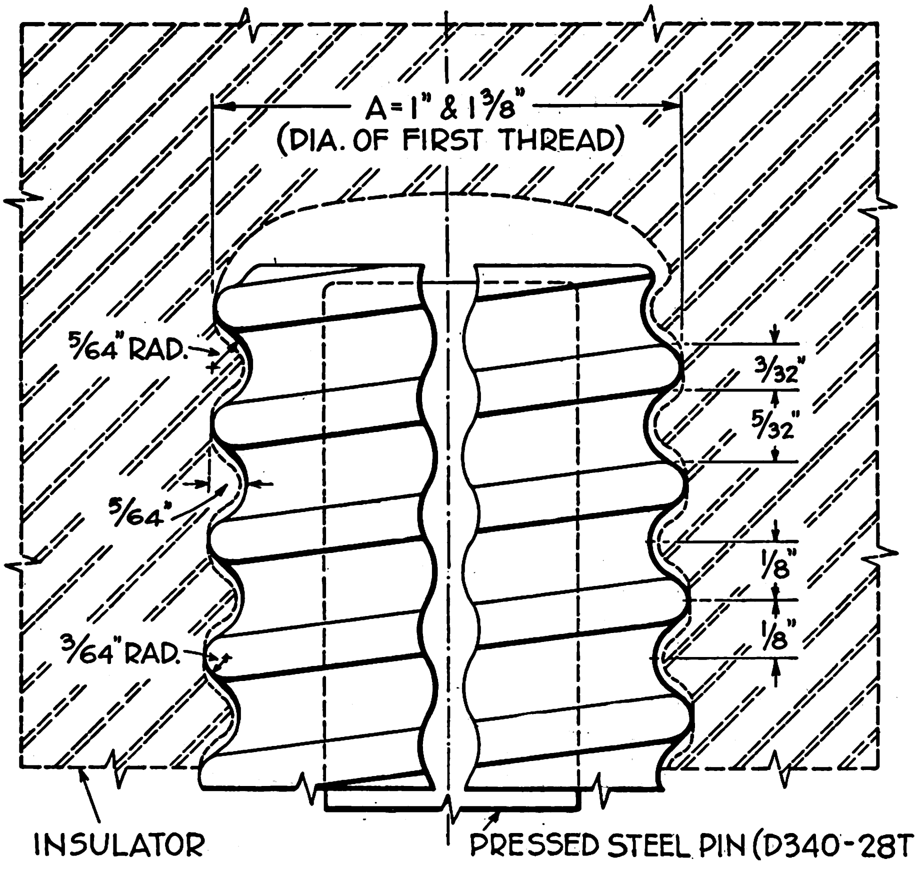
1 - 4 THREADS PER INCH, TAPERING 1/16 IN. IN DIAMETER TO 1 IN. IN LENGTH.

2 - ALLOWABLE VARIATION OF 5% OVER OR UNDER ON ALL DIMENSIONS, EXCEPT WHERE SHOWN OTHERWISE.

FIG. 31.

D994-28T
(TENTATIVE)

1 IN. & 1⅜ IN. PRESSED STEEL PIN THREAD


A = 1" & 1⅜"
(DIA. OF FIRST THREAD)
5/64" RAD.
5/64"
3/64" RAD.
3/32"
5/32"
1/8"
1/8"
INSULATOR
PRESSED STEEL PIN (D340-28T)

NOMINAL SIZE	A
1 - INCH	1" ax
1⅜-INCH	1⅜" ax

ALLOWABLE VARIATIONS		
	OVER	UNDER
ax	1/64"	0"

NOTES

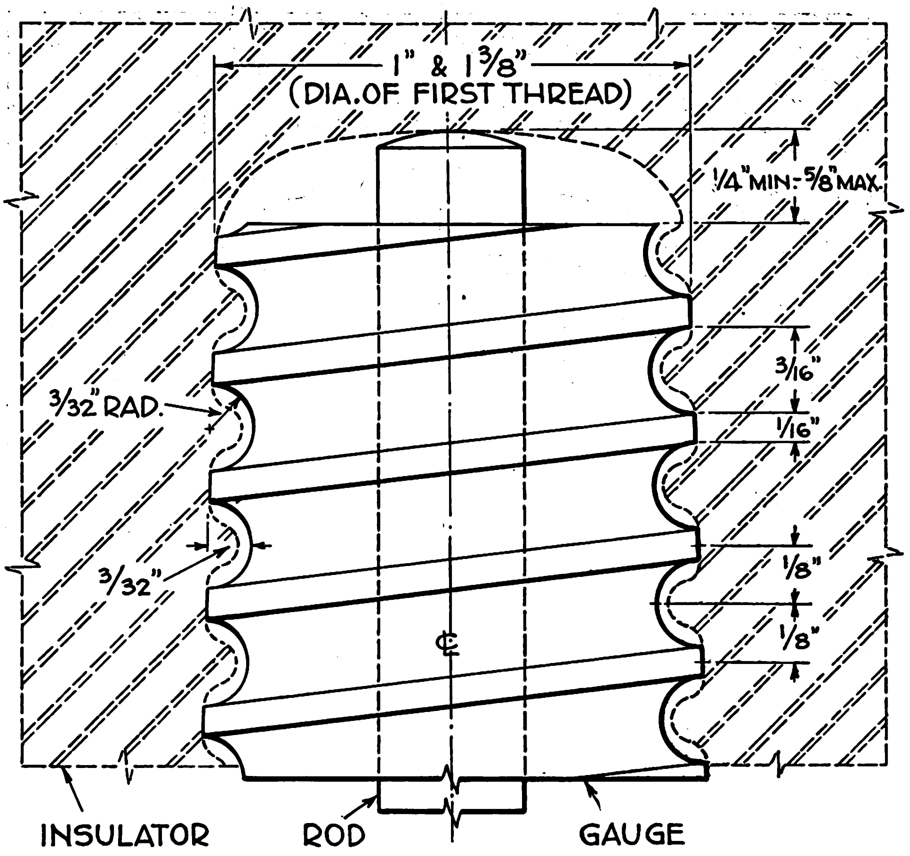
1- 4 THREADS PER INCH, TAPERING 1/16 IN. IN DIAMETER TO 1 IN. IN LENGTH.

2- ALLOWABLE VARIATION OF 5% OVER OR UNDER ON ALL DIMENSIONS, EXCEPT WHERE SHOWN OTHERWISE.

FIG. 32.

D995-28T
(TENTATIVE)

1 IN. & 1 3/8 IN. INSULATOR GAUGE THREAD


1" & 1 3/8"
(DIA. OF FIRST THREAD)
1/4" MIN.-5/8" MAX.
3/16"
1/16"
3/32" RAD.
3/32"
1/8"
1/8"
℄
INSULATOR
ROD
GAUGE

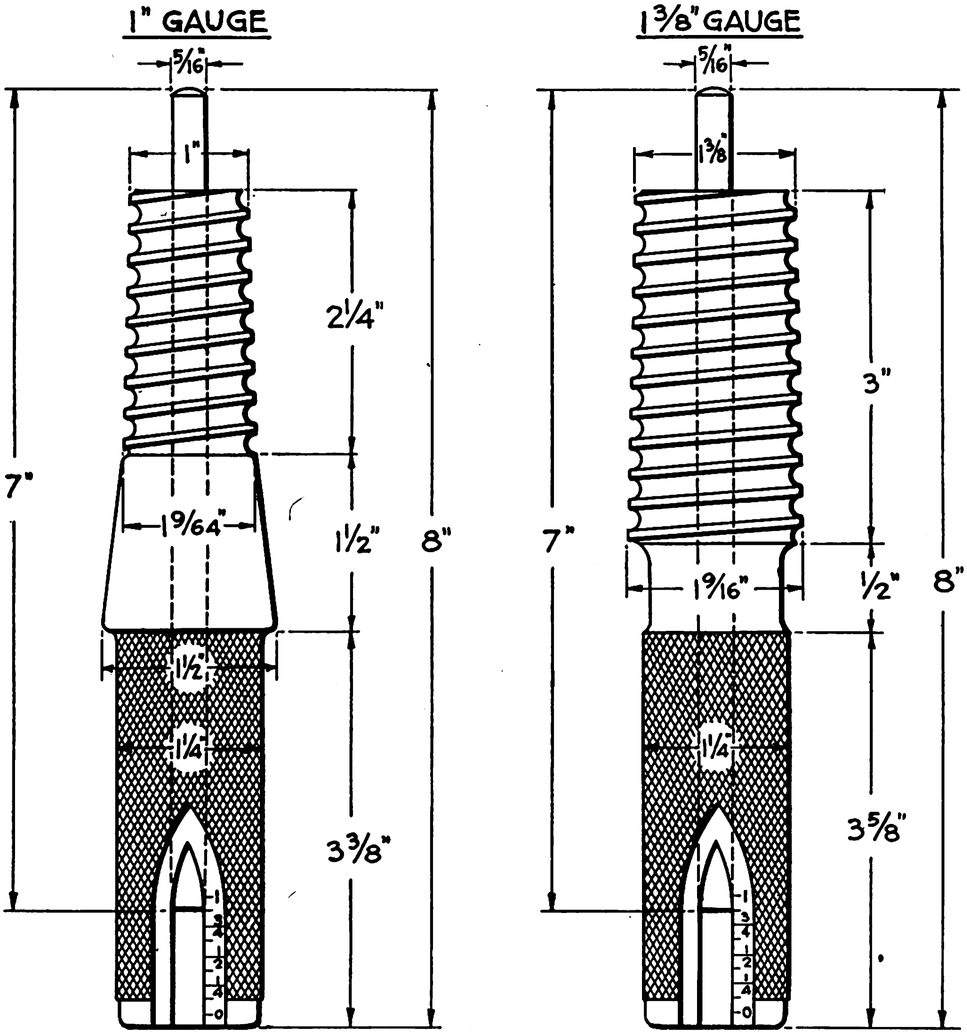
NOTES

1- 4 THREADS PER INCH, TAPERING 1/16 IN. IN DIAMETER TO 1 IN. IN LENGTH.
2- ALLOWABLE VARIATION OF 1/2 % OVER OR UNDER ON ALL DIMENSIONS.
3- ALLOWABLE CLEARANCE BETWEEN TOP OF GAUGE AND BOTTOM OF PINHOLE: 1/4 IN. TO 5/8 IN.
4- NUMBER OF TURNS NECESSARY TO RELEASE THE GAUGE: 3 TURNS MINIMUM.

FIG. 33.

D996-28T
(TENTATIVE)

1 IN. & 1 3/8 IN. INSULATOR GAUGES


1" GAUGE
5/16"
1"
2 1/4"
1 9/64"
1 1/2"
8"
7"
1 1/2"
1 1/4"
3 3/8"
1
3/4
1/2
1/4
0
1 3/8" GAUGE
5/16"
1 3/8"
3"
1 9/16"
1/2"
8"
7"
1 1/4"
3 5/8"
1
3/4
1/2
1/4
0

MATERIAL
TOOL STEEL
FINISH
ALL OVER

NOTES

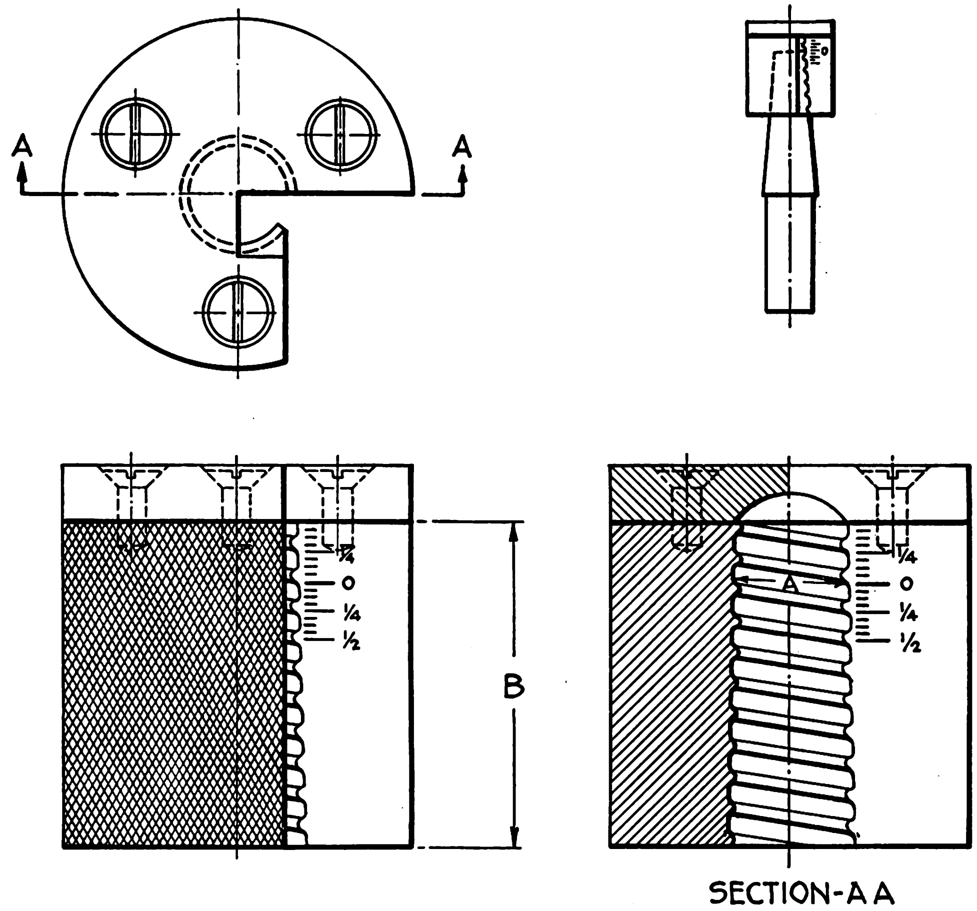
1 - FOR DETAIL OF THREAD SEE D995-28T.

2 - THREADS TO BE ACCURATE DIMENSION FINISH, DRY CUT AND POLISHED AFTER HARDENING. TOLERANCE ± 1/2 %.

FIG. 34.

D997-28T
(TENTATIVE)

1 IN. & 1⅜ IN. INSULATOR PIN GAUGES



GAUGE	A	B
1-INCH	1"	2¾"
1⅜-INCH	1⅜"	3¼"

MATERIAL
TOOL STEEL
FINISH
ALL OVER

NOTES

1- FOR DETAIL OF THREAD SEE D990-28T.

2- THREADS TO BE ACCURATE DIMENSION FINISH, DRY CUT AND POLISHED AFTER HARDENING. TOLERANCE ± ½%.

FIG. 35.

PART III

METHODS OF CONSTRUCTION FOR LOW AND MEDIUM VOLTAGE LINES

Fig. 36 to 48, inclusive, illustrate typical installations of potheads, filled with either compound or oil, in various positions on line arms or buck arms.

Fig. 49 to 56, inclusive, show typical transformer platform installations for low and medium voltage, as used in various sections in this country. It is hoped that the future subcommittee will suggest some method which may lead to standardization of this type of construction.

Fig. 57 to 63, inclusive, illustrate methods of construction using materials covered by Part II of this report.

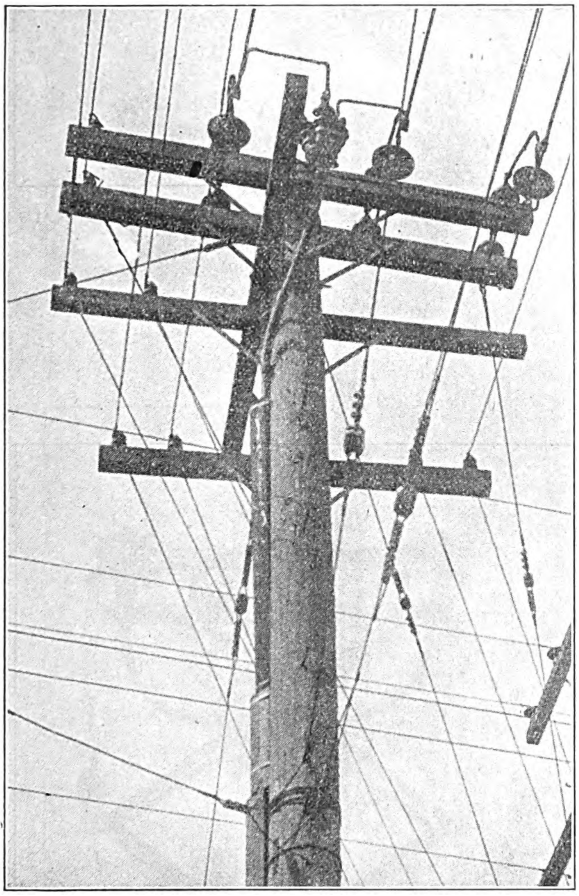


FIG. 36—4-KV. CABLE POLE, 3-COND. CABLE TERMINALS, PACIFIC GAS & ELECTRIC CO.

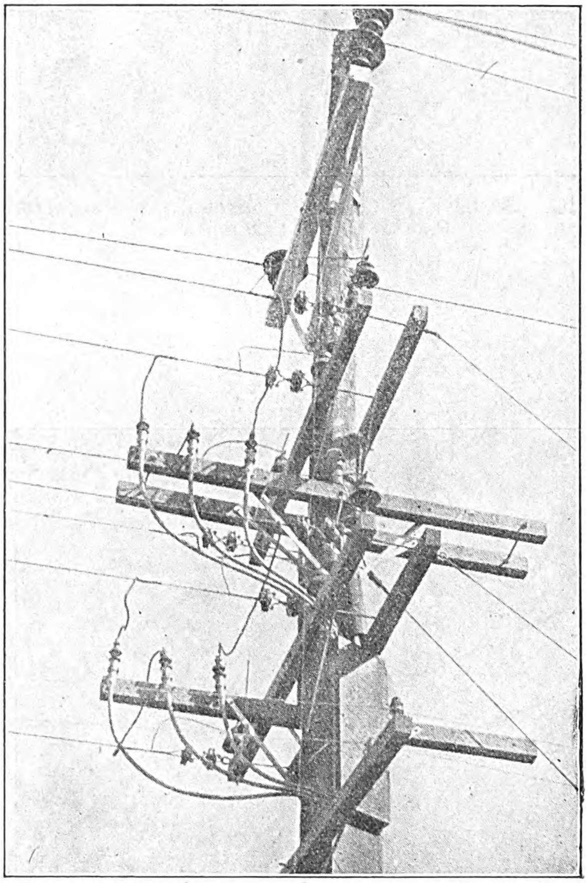


FIG. 37—4-KV. CABLE POLE, 1-COND. TERMINALS, PACIFIC GAS & ELECTRIC CO.

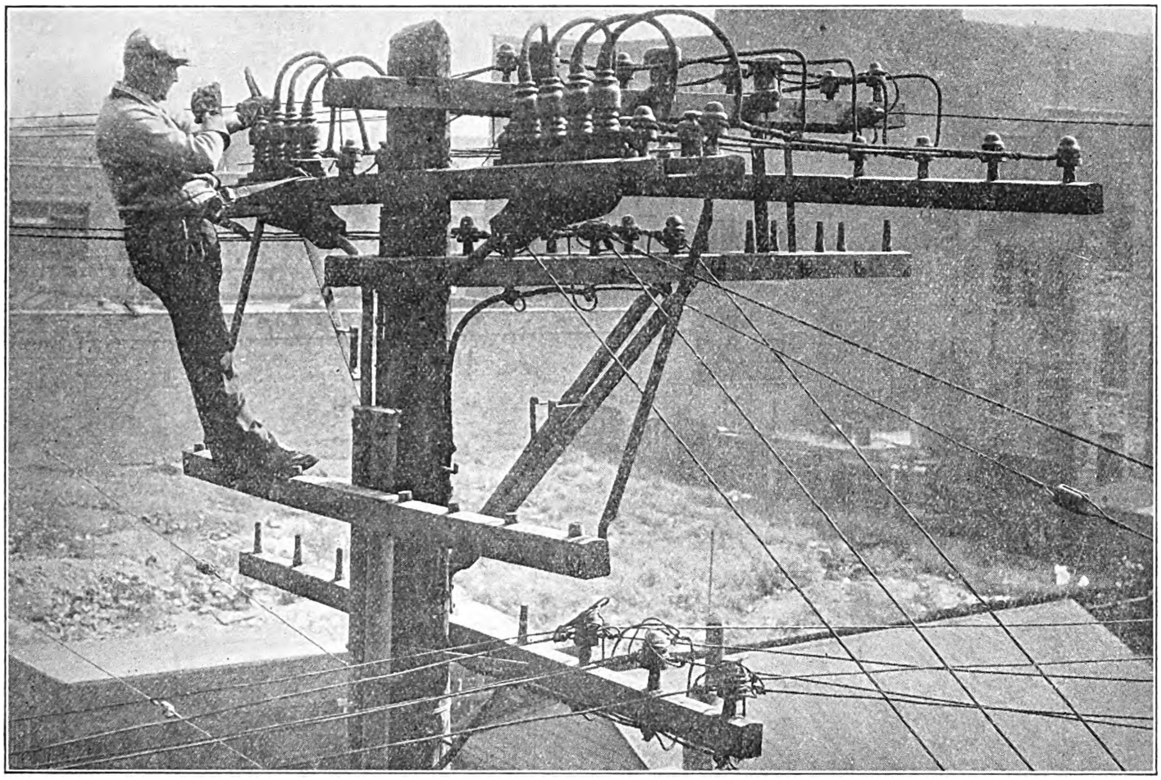


FIG. 42—4-COND., 4-KV. CABLES AND DISCONNECTING POTHEADS UP TO 200 AMPERES, COMMONWEALTH EDISON CO., CHICAGO.

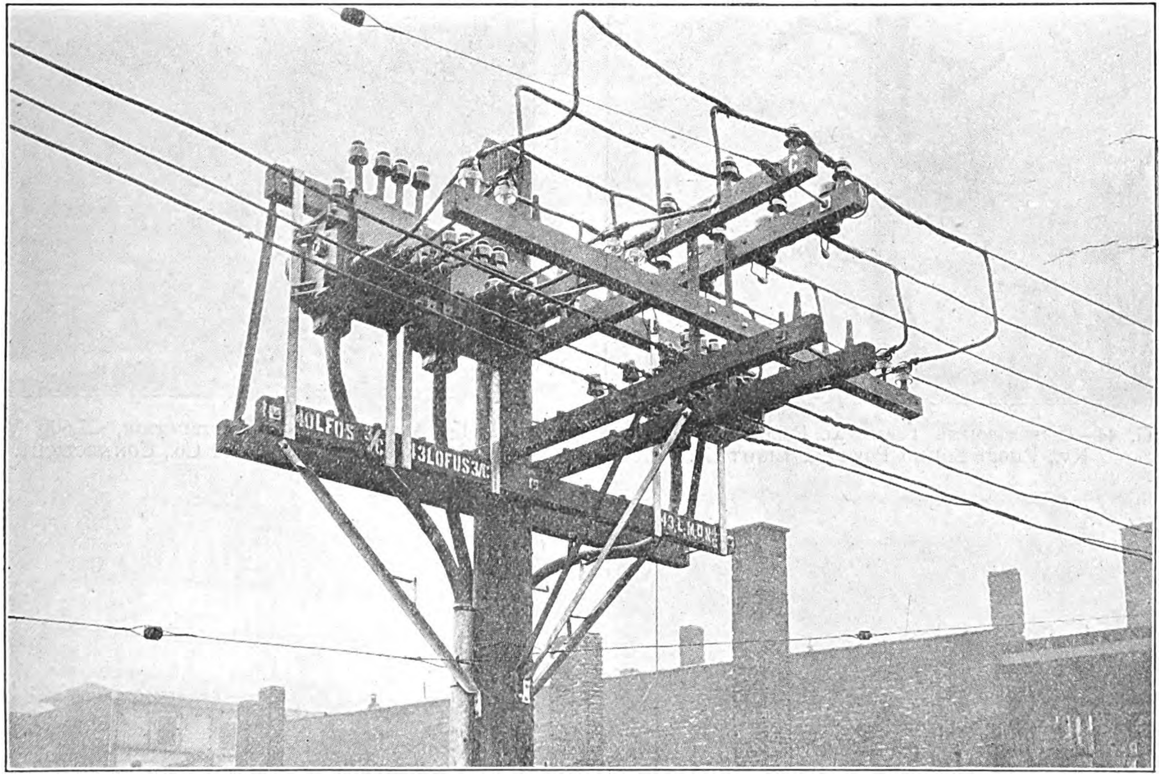

40LFUS 3/C
43LOFUS3/C
43.L.M.O.N.

FIG. 43—400-AMPERE, 4-KV. OIL POTHEADS, COMMONWEALTH EDISON CO.

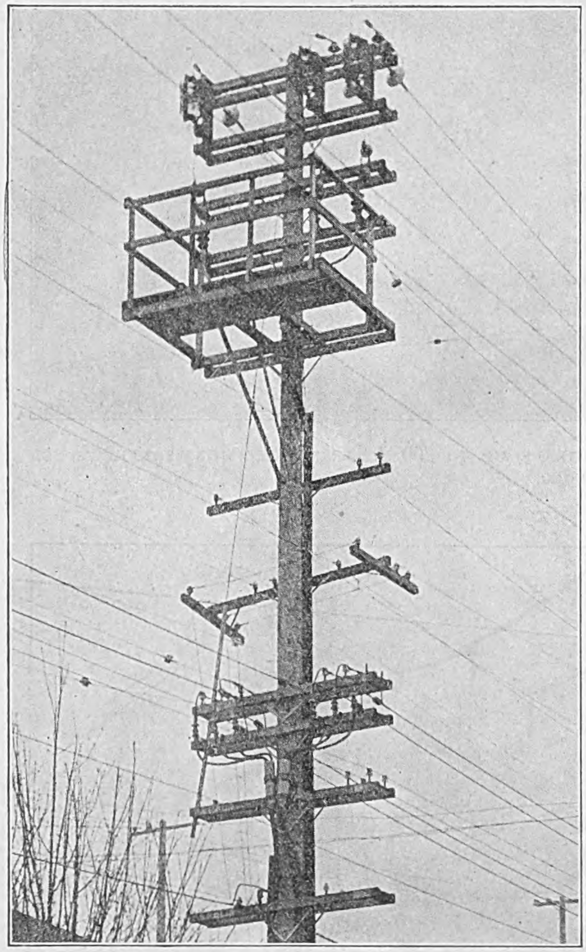


FIG. 44—UNDERGROUND TERMINAL POLE, 13 KV. AND 4 KV., PUGET SOUND POWER & LIGHT CO.

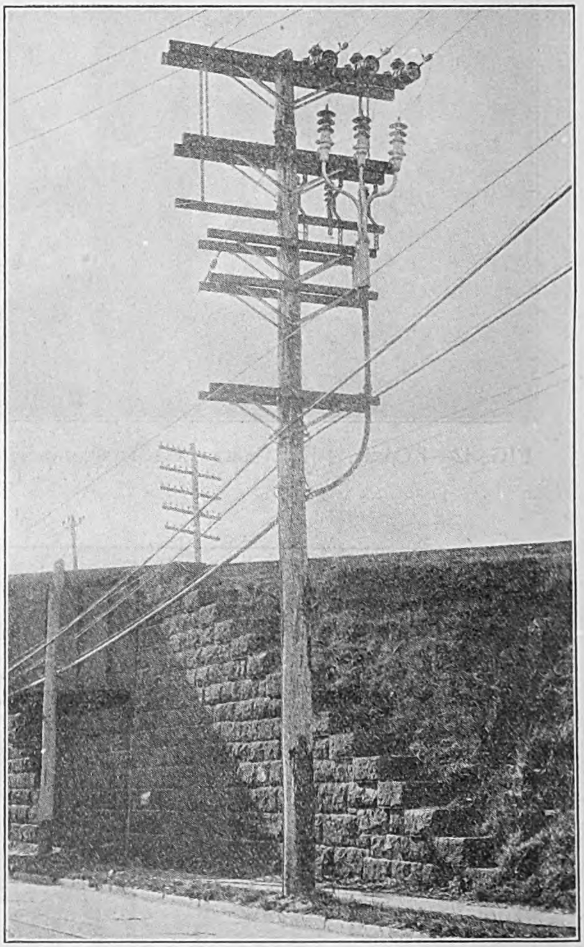


FIG. 45—AERIAL CABLE CONSTRUCTION, 27,600 VOLTS, HARTFORD ELECTRIC LIGHT CO., CONNECTICUT.

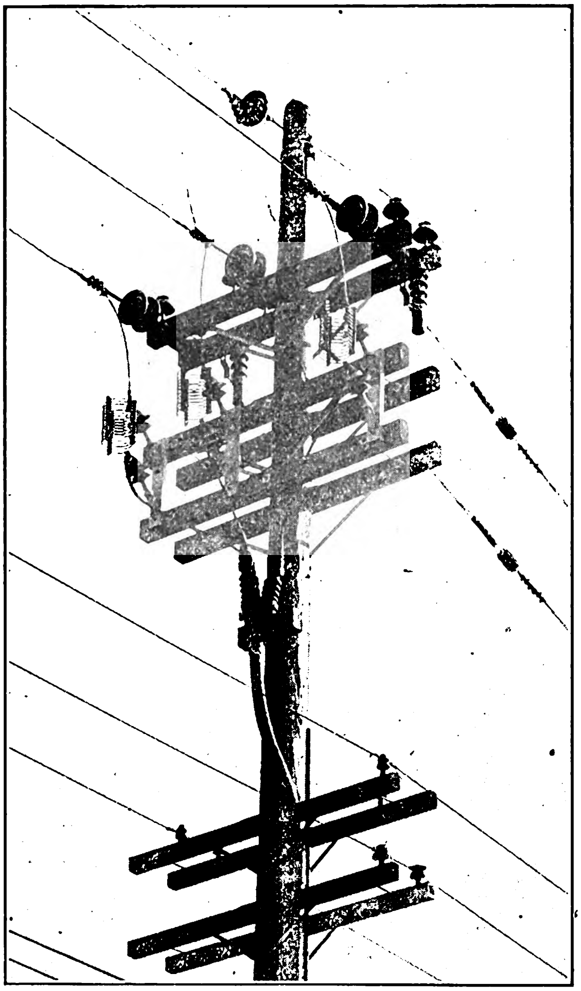


FIG. 46—13-KV. CABLE POLE, UNION GAS & ELECTRIC CO., CINCINNATI, OHIO.

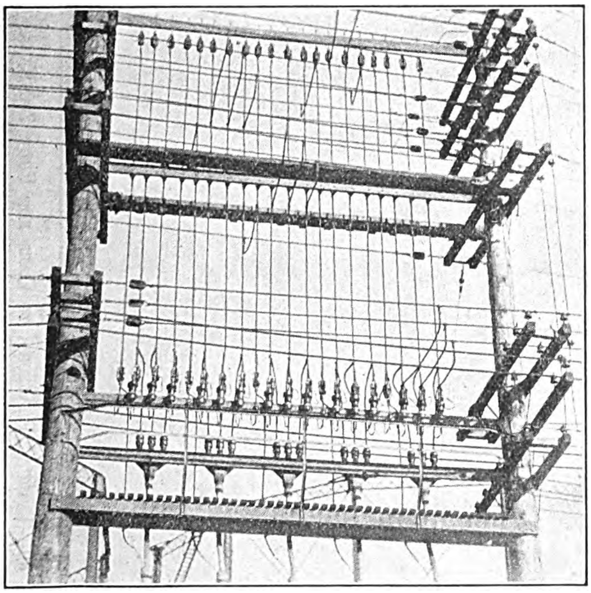


FIG. 47—RACK FOR 4-KV. CABLES FROM SUBSTATION TO LINE, SIOUX CITY GAS & ELECTRIC CO., IOWA.

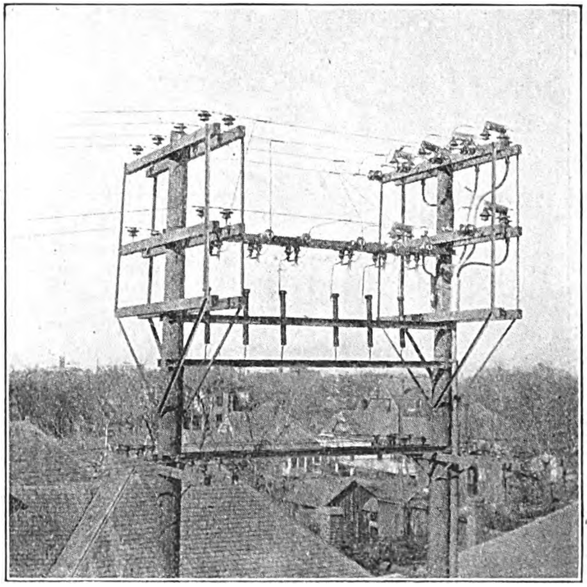


FIG. 48—RACK FOR CABLES AND LIGHTNING ARRESTERS, DALLAS POWER & LIGHT CO., TEXAS.

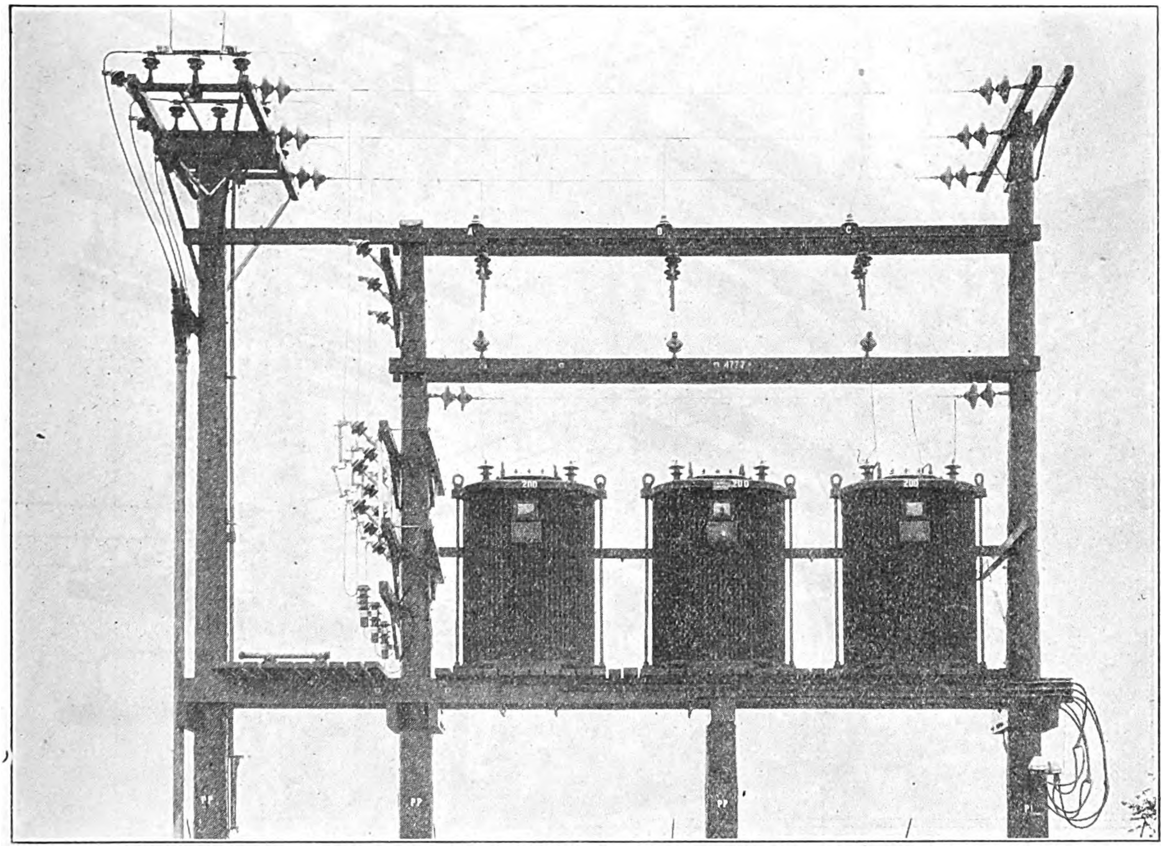


FIG. 50—TYPICAL PLATFORM FOR THREE 200-KV-A., 3-PHASE, 12,000-VOLT BANK, COMMONWEALTH EDISON CO., CHICAGO.

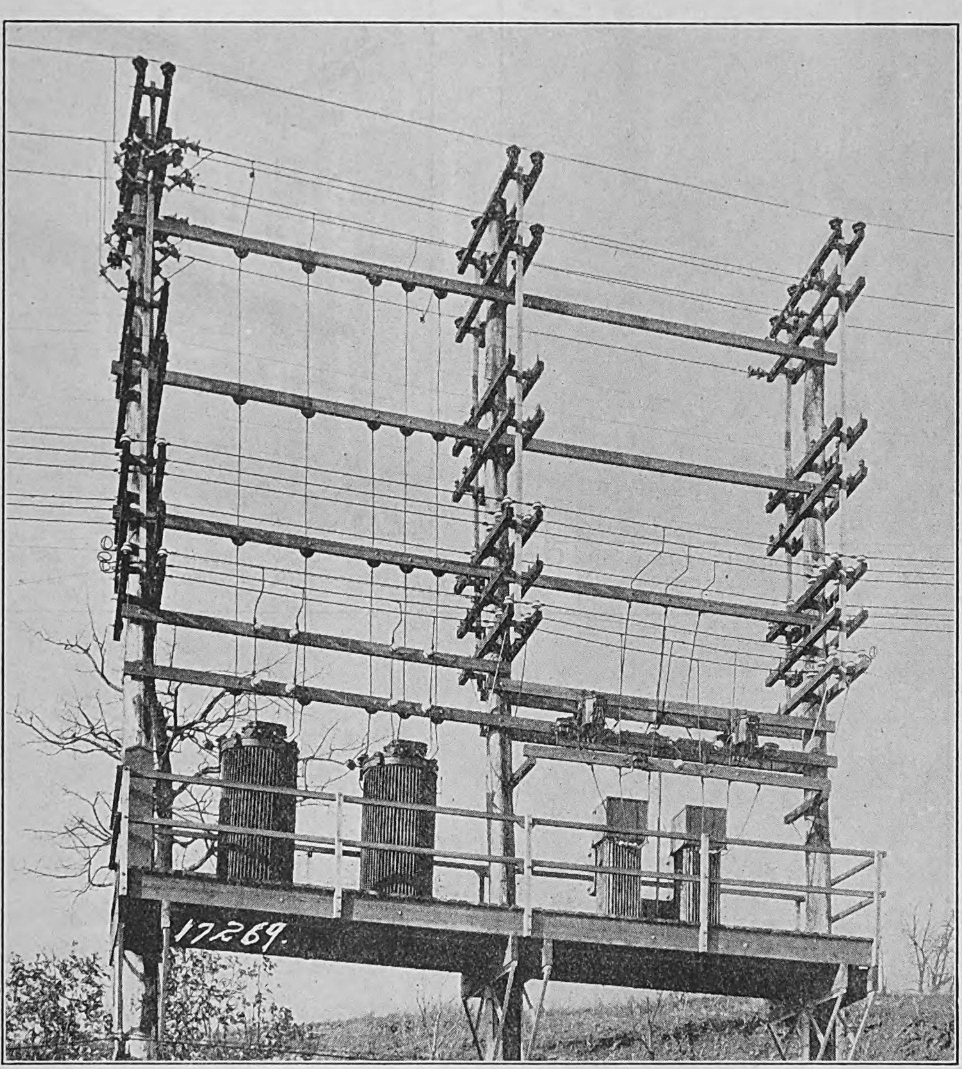


FIG. 52—13,200-VOLT REGULATED TRANSFORMER STATION SHOWING REGULATORS ON 2400-VOLT CIRCUIT, PHILADELPHIA ELECTRIC CO.

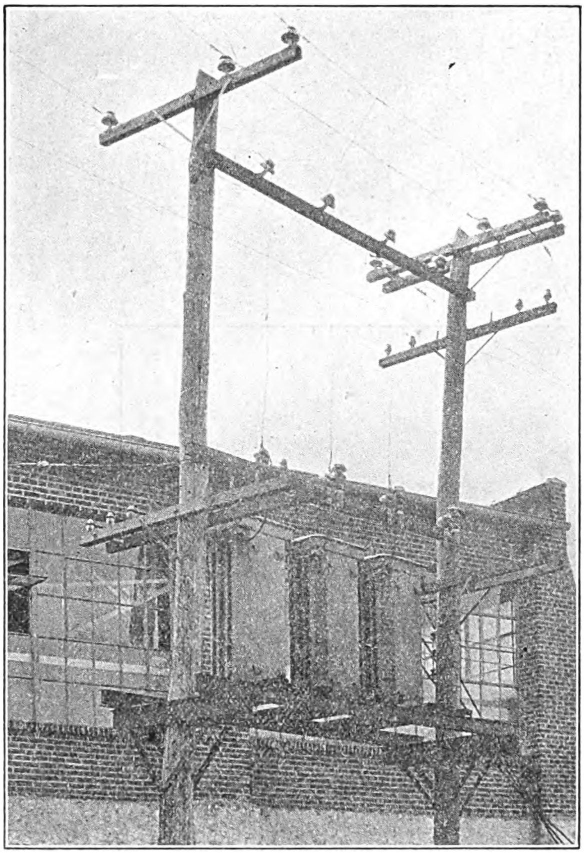


FIG. 53—TYPICAL TRANSFORMER PLATFORM, THE COUNTIES GAS & ELECTRIC CO., NORRISTOWN, PA.

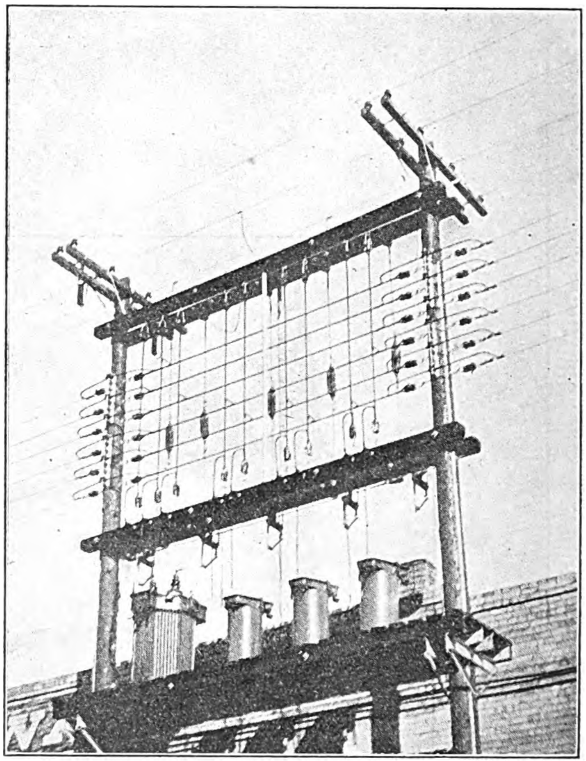


FIG. 54—11,500-VOLT PLATFORM INSTALLATION, TEXAS POWER & LIGHT CO.

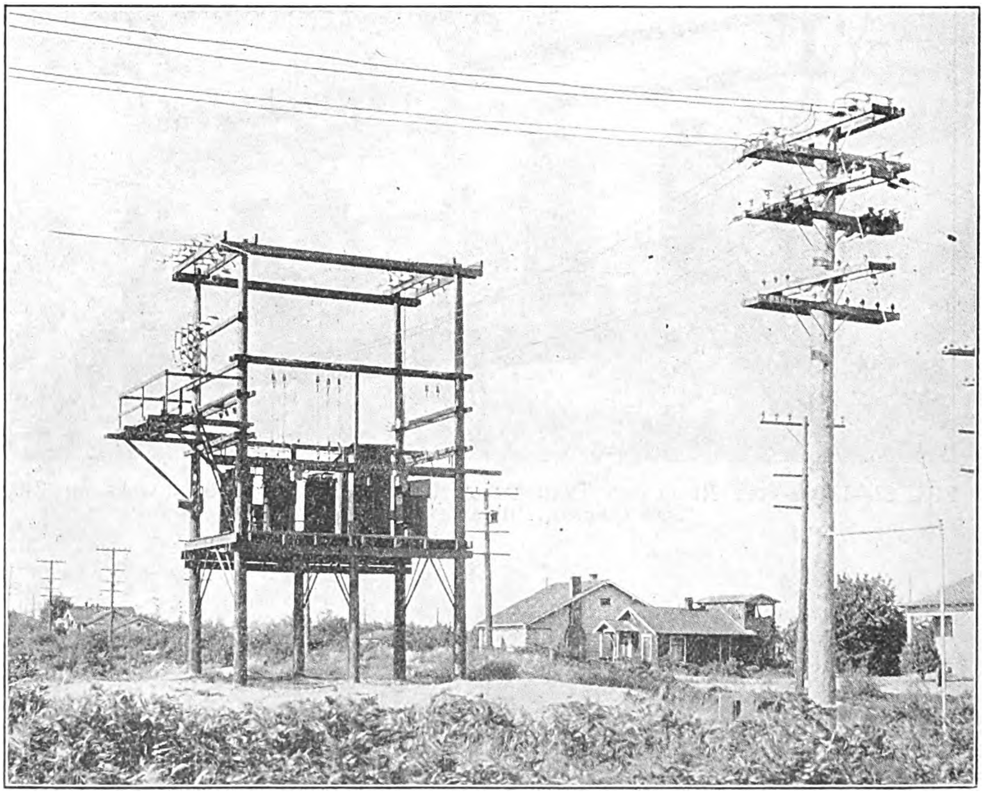


FIG. 55—AUTOMATIC SUBSTATION FOR USE IN NEW URBAN TERRITORY, PUGET SOUND POWER & LIGHT CO.

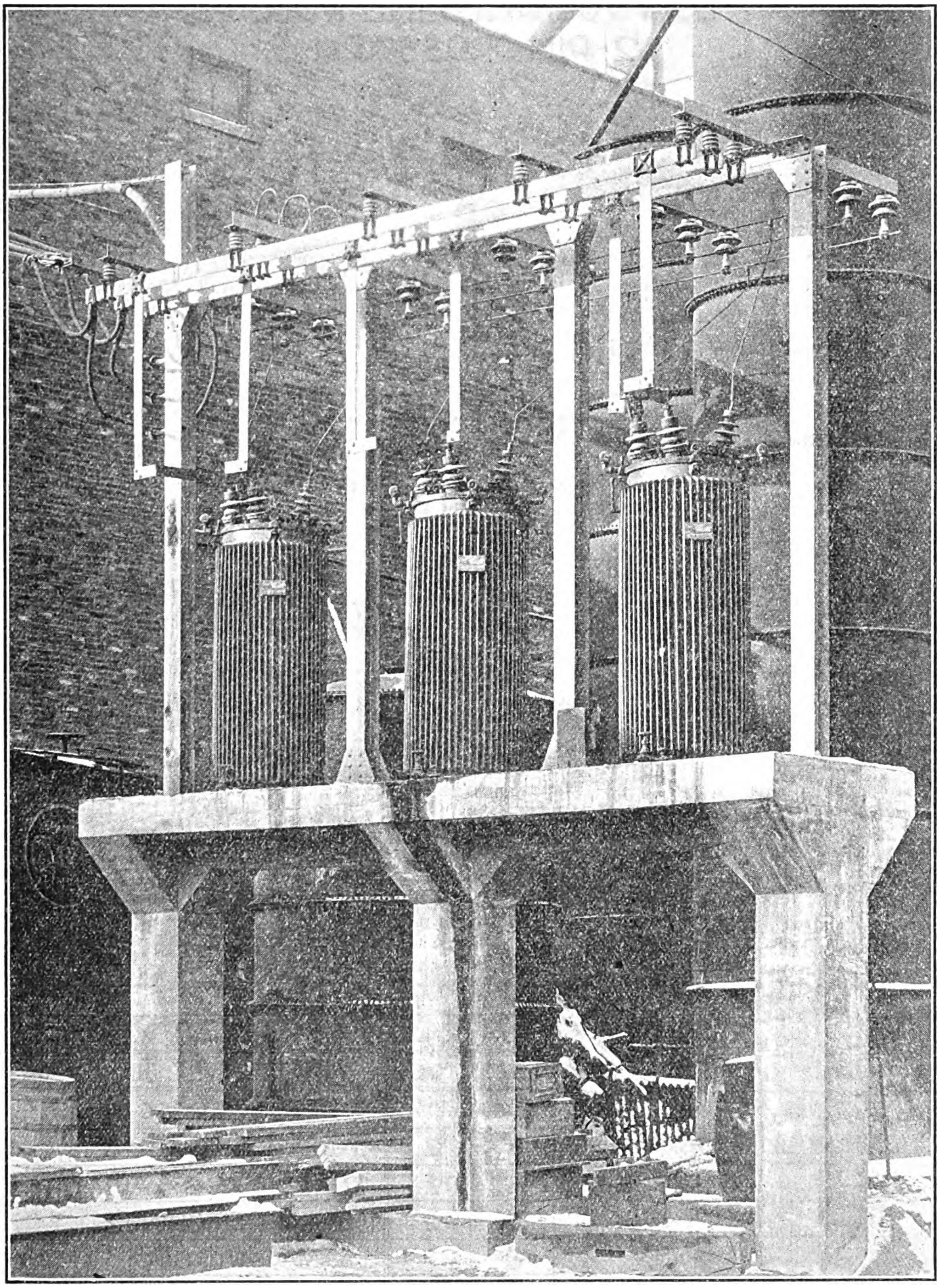
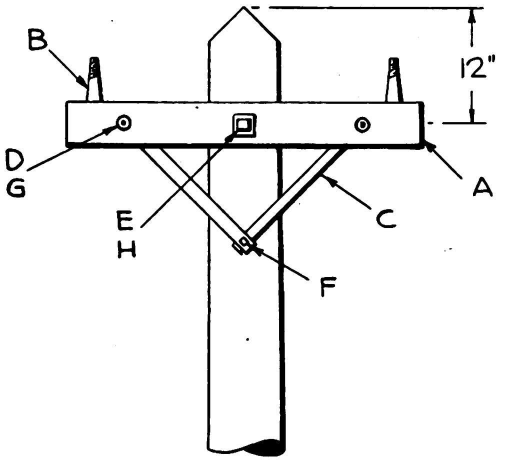


FIG. 56—Standard 13-Kv. Platform Raised for High Water District, Union Gas & Electric Co., Cincinnati, Ohio.

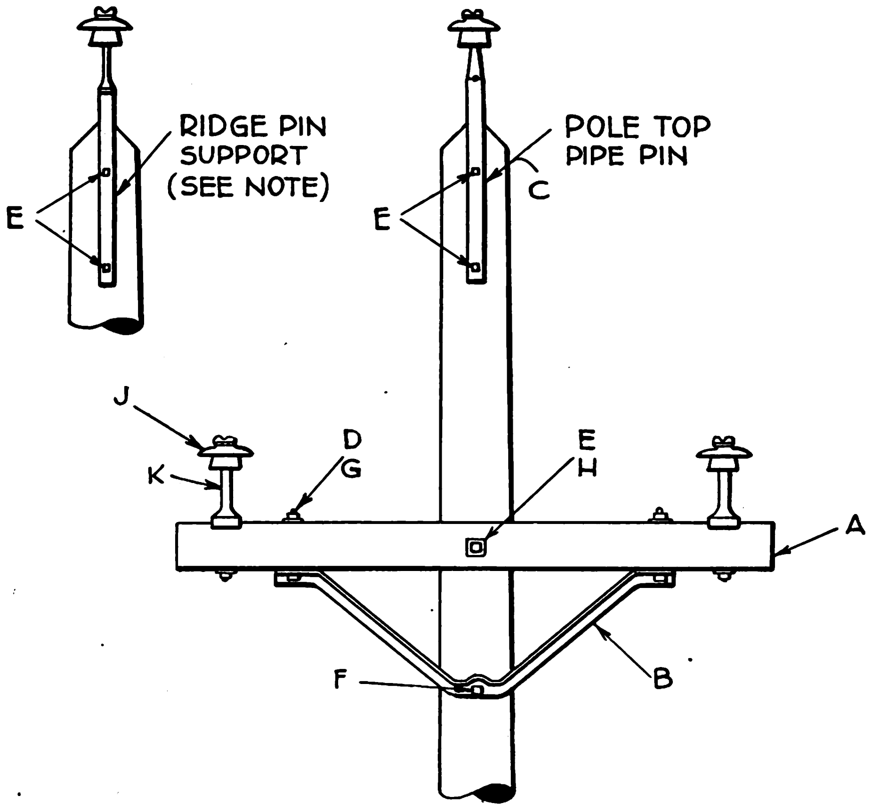
LOW VOLTAGE LINE POLE
2-PIN CROSS ARM



LIST OF MATERIAL		
LOC.	NO.	DESCRIPTION
A	1	2-PIN 3FT. CROSS ARM
B	2	WOOD PIN
C	2	20" FLAT CROSS ARM BRACE
D	2	3/8" x 4½" MACHINE BOLT
E	1	5/8" MACHINE BOLT
F	1	½" LAG SCREW
G	2	7/16" ROUND WASHER
H	2	2¼" SQUARE WASHER

FIG. 57.

MEDIUM VOLTAGE LINE POLE
SINGLE CIRCUIT


RIDGE PIN
SUPPORT
(SEE NOTE)
E
POLE TOP
PIPE PIN
C
E
J
K
D
G
E
H
A
F
B

NOTE

RIDGE PIN SUPPORT MAY BE USED INSTEAD OF THE POLE TOP PIPE PIN.

	LIST OF MATERIAL		
	LOC.	NO.	DESCRIPTION
	A	1	2-PIN 5 FT. CROSS ARM
	B	1	37" ANGLE CROSS ARM BRACE
*	C	1	POLE TOP PIPE PIN
	D	2	½"x 6" MACHINE BOLT
	E	3	⅝" MACHINE BOLT
	F	1	⅝" LAG SCREW
	G	2	9/16" ROUND WASHER
*	H	4	2¼" SQUARE WASHER
	J	3	MEDIUM VOLTAGE INSULATOR
*	K	2	MEDIUM VOLTAGE STEEL PIN

* CORRECT LIST OF MATERIAL IF RIDGE PIN SUPPORT IS USED.

FIG. 58.

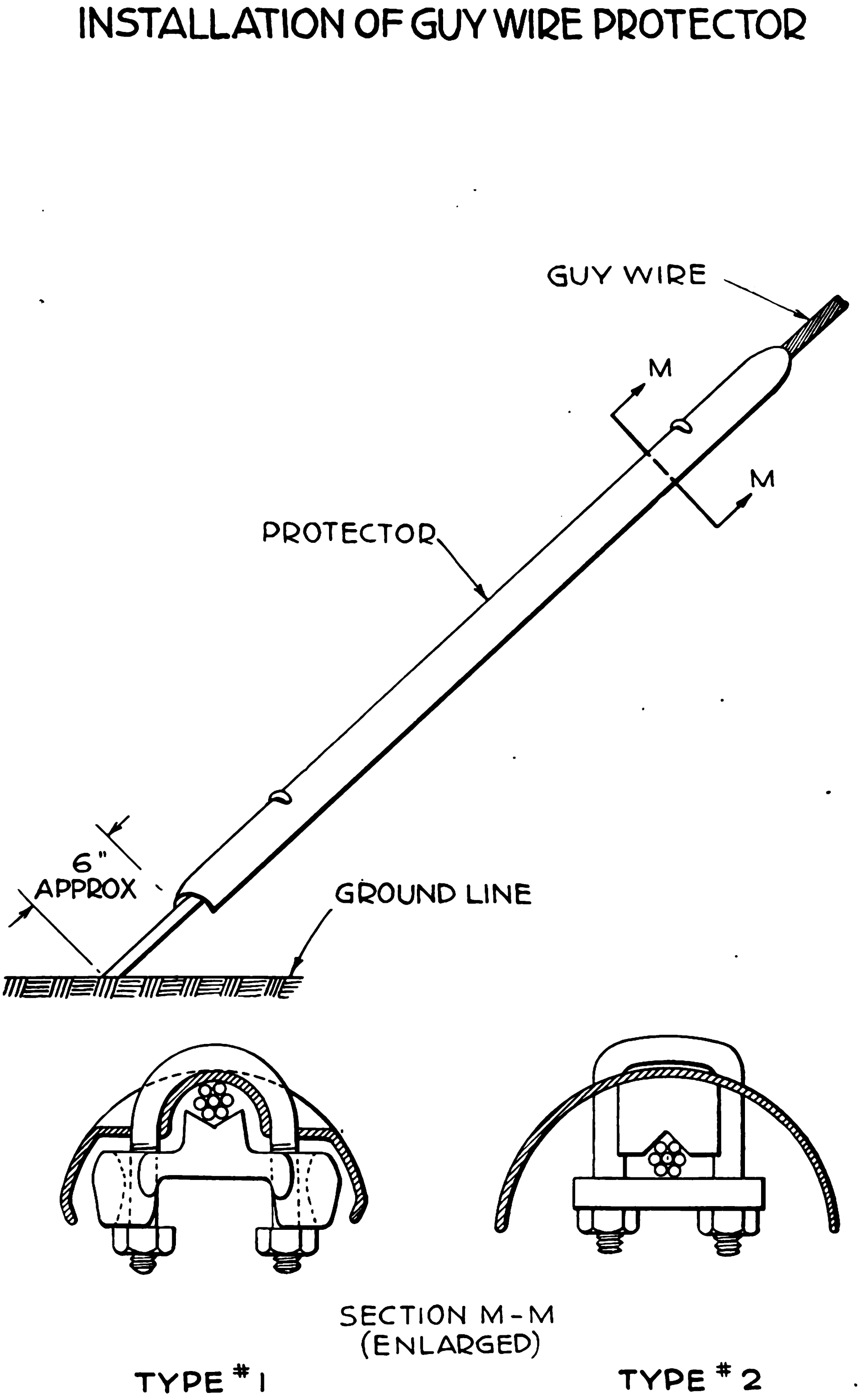
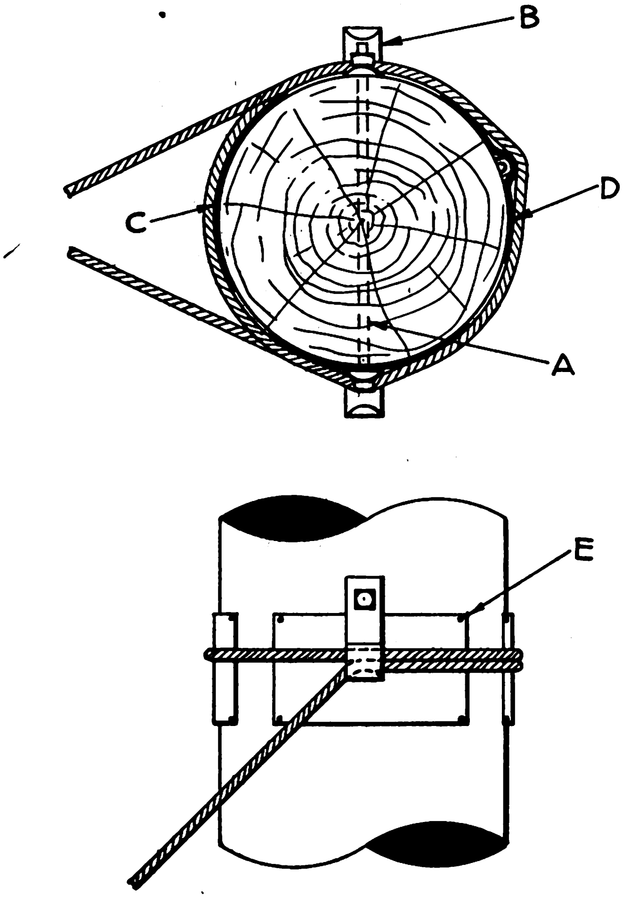

INSTALLATION OF GUY WIRE PROTECTOR
GUY WIRE
M
M
PROTECTOR
6" APPROX
GROUND LINE
SECTION M-M
(ENLARGED)
TYPE # 1
TYPE # 2

FIG. 59.

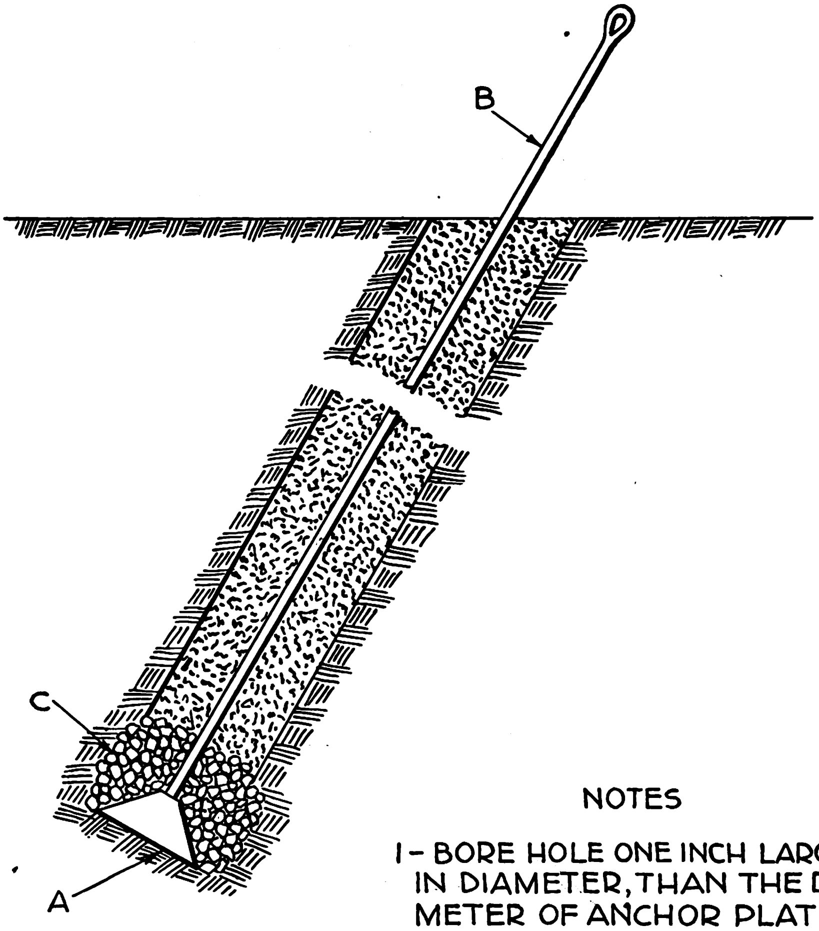
INSTALLATION OF MOLDING GUY PLATE



LIST OF MATERIAL		
LOC.	NO.	DESCRIPTION
A	1	5/8" MACHINE BOLT
B	2	GUY HOOK
C	2	GUY PLATE
D	1	MOLDING GUY PLATE
E	12	8-PENNY NAIL

FIG. 60.

INSTALLATION OF CONE ANCHOR



NOTES

1 - BORE HOLE ONE INCH LARGER IN DIAMETER, THAN THE DIAMETER OF ANCHOR PLATE.

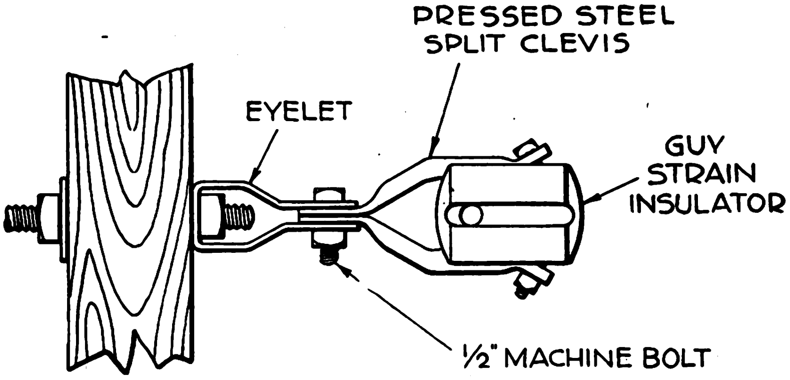
2 - TAMP IN CRUSHED STONE, REPLACE EARTH AND TAMP WELL.

LIST OF MATERIAL

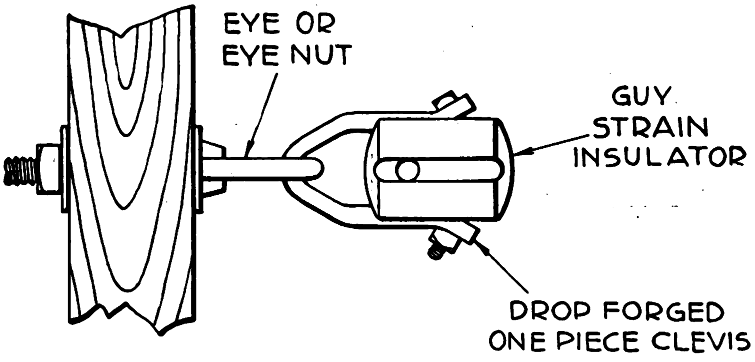
	FOR 8 IN. ANCHOR		FOR 12 IN. ANCHOR	
LOC.	NO.	DESCRIPTION	NO.	DESCRIPTION
A	1	8 IN. ANCHOR PLATE	1	12 IN. ANCHOR PLATE
B	1	5/8 IN. ANCHOR ROD	1	3/4 IN. OR 1 IN. ANCHOR ROD
C	1CU.FT	2 IN. CRUSHED STONE	2CU.FT	2 IN. CRUSHED STONE

FIG. 61.

INSTALLATION OF DEAD END CLEVISES
(FOR LOW VOLTAGE)


PRESSED STEEL
SPLIT CLEVIS
EYELET
GUY
STRAIN
INSULATOR
½" MACHINE BOLT

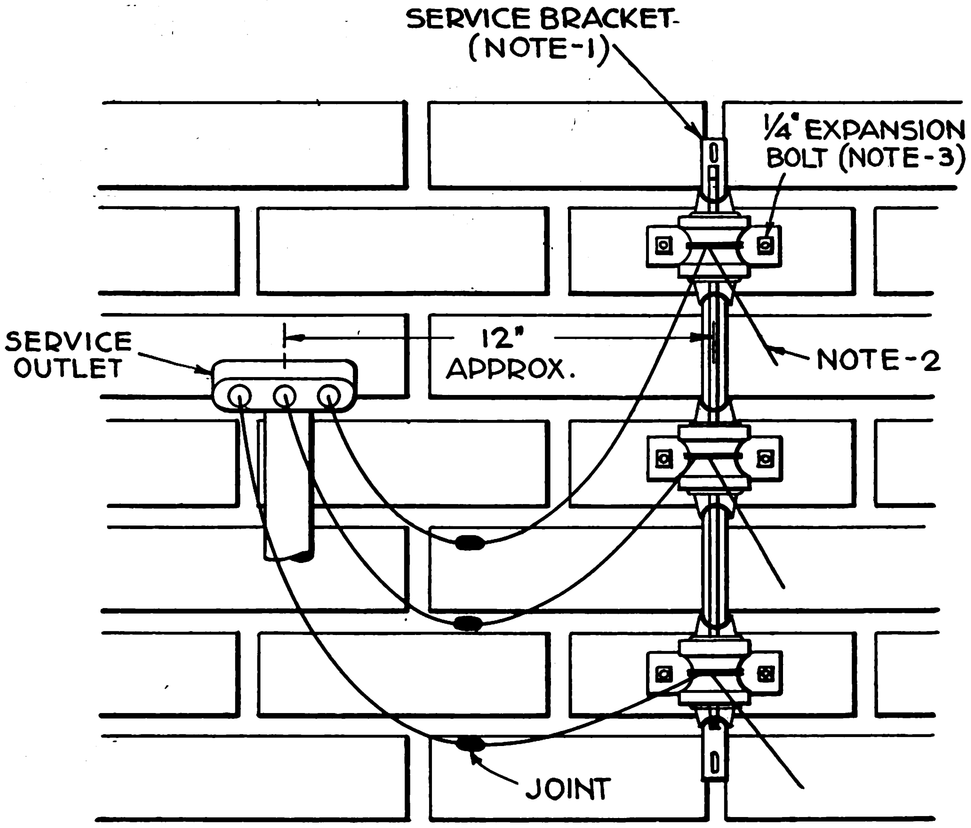
SPLIT CLEVIS


EYE OR
EYE NUT
GUY
STRAIN
INSULATOR
DROP FORGED
ONE PIECE CLEVIS

ONE PIECE CLEVIS

FIG. 62.

INSTALLATION OF SERVICE BRACKET


SERVICE BRACKET (NOTE-1)
¼" EXPANSION BOLT (NOTE-3)
SERVICE OUTLET
12" APPROX.
NOTE-2
JOINT

NOTES

1 - FOR SHORT SPANS, 50 FT. OR LESS, 12 IN. BRACKET MAY BE USED. FOR LONGER SPANS, 50 FT. TO 100 FT., 18 IN. BRACKET SHOULD BE USED.

2 - WIRES UP TO #2 A.W.G. MAY BE DEAD ENDED ON THESE BRACKETS.

3 - USE ¼" x 1¾" EXPANSION BOLTS, WHEN WALL IS GOOD.
USE ¼" x 2½" EXPANSION BOLTS, WHEN WALL IS POOR.
USE ¼" x 2½" LAG SCREWS, WHEN INSTALLING BRACKET ON FRAME WORK.

4 - IF CONDITIONS DEMAND, SERVICE BRACKET MAY BE INSTALLED HORIZONTALLY OR AT 45° ANGLE.

FIG. 63.

POWER STATION CHEMISTRY—PART I

This, the initial report of the Chemists Subcommittee of the Prime Movers Committee, includes extensive bibliographies both on combustion chemistry and corrosion; a preliminary study of the fundamentals of lubrication chemistry, and a tentative standard method for quantitatively determining dissolved oxygen in boiler feed water supplies, raw water excepted.

The bibliography on combustion chemistry is preceded by a review of the developments in this field for the period 1926 *to* 1927.

The bibliography on corrosion has been indexed under the following headings: Theories and Factors, Gases and Pitting, Embrittlement, Corrosion Fatigue, Electrolysis, Oil Corrosion, Laboratory Tests, Prevention of Corrosion by Protective Coatings, Films and Tarnishing, Resistant Alloys, Boiler Water Treatment. The bibliography is current to 1928.

The report on lubrication presents an initial laboratory study on the chemistry of turbine oil. The program aims to supply to the user answers to the following questions:

1. *By what standard can oils be judged suitable for turbine use?*
2. *If turbine oils deteriorate during use, by what methods can the degree of deterioration be determined?*

It is suggested that the basis for judgment of an oil is a chemical one, and test data are cited showing that the criterion for determining the condition of an oil in service should include weekly tests for sludge, water, emulsion and neutralization number, and plotting this data in order to observe the trend of the curves. The change in chemical characteristics of the oil is apparently arrested if definite volumes of new oil, approximately 0.6 *per cent by volume, are added at regular intervals. The report concludes with a bibliography with an abstract of each article.*

A tentative method for determining dissolved oxygen in boiler feed water has been prepared, and is complete with definite sampling instructions, methods for preparing the necessary solutions, and the test procedure. The method may be applied both in the power plant and the laboratory. The subcommittee urges all station operators to follow the details exactly so that a definite standard may be established for correctly estimating the very low amounts of dissolved oxygen found in practice. This method was presented by the related Subcommittee of the Boiler Feed Waters Study Committee, and was tentatively adopted by the Chemists Subcommittee.

STUDY OF CHEMISTRY OF COMBUSTION—A REVIEW FOR YEARS 1926 AND 1927

A review of the publications and papers on the subject of combustion appearing during the more recent years indicates at once that this abundance of material may be classified under various categories, depending upon the phase of combustion with which it is concerned.

Study and research in this field has received a marked impetus in the last decade, stimulated to a great extent by problems of immediate interest encountered in the practical application of combustion phenomena. Numerous examples of such may be cited. A thorough study of explosive and detonative combustion is made necessary in order to prevent gas and dust explosions which so often result in loss of life. Catalytic combustion has been studied much more intensely since the advent of antiknock fuels into the sphere of internal combustion engines. In fact, internal combustion problems embrace a multitude of factors in regard to combustion such as ignition temperatures, flame propagation and flame travel, inflammability, detonation, etc. In order to explain these properties of combustible mixtures, the physical or organic chemist attacks these problems from his respective point of view and the physicist renders assistance through his knowledge of spectroscopy.

Along with these purely scientific and empirical investigations, a number of theories have been formulated which have served to stimulate further scientific research on combustion.

In this report, which attempts to supply a comprehensive study of the chemistry of combustion and closely related phenomena for the years 1926 and 1927, the material has been arranged so far as expedient under the various headings mentioned above.

Catalytic Surface Combustion

In the field of catalytic surface combustion, Bone[1] and his collaborators have been most prominent.

The more recent work comprises a study of the union of carbon monoxide and oxygen in contact with nickel, copper and their oxides as well as a gold surface, and the union of carbon monoxide and other gases with oxygen in contact with a fireclay surface at 500 deg. cent. Regarding the catalytic effect of a gold surface, Bone concludes that the results are explained best by assuming an activation of both gases through association with the surface. This activation is not confined to superficially absorbed gas films of monomolecular thickness, but extends to more deeply occluded gases. In the case of metallic nickel, its catalytic activity, which was enhanced by preliminary exposure to carbon monoxide or carbon

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Publication No. 289-28, Serial Report, Prime Movers Committee.

monoxide-oxygen mixtures at 370 deg. cent., is attributed to the formation of a highly reactive surface film of nickel carbonyl or oxycarbonyl. Since the nickel oxide catalyzed the oxidation of carbon monoxide without any appreciable reduction, the catalytic effect is believed due to the formation of a film of active oxygen upon the surface acting as the effective oxidizing agent. In the case of metallic copper, the formation of a film of volatile copper-carbon monoxide complex greatly reduces its catalytic activity. In contrast with nickel oxide, the copper oxide was rapidly reduced by carbon monoxide in the absence of oxygen. However, the actual cause of the catalytic activity involves the condensation of a film of active oxygen at the surface of the oxide and this film additionally protects the catalyzing surface from reduction by the carbon monoxide.

Experiments with a fireclay surface at 500 deg. cent. shows that the rates of catalytic oxidation of hydrogen, carbon monoxide and methane decreased in the order named. It was found that the catalyzing power of the fireclay could be stimulated temporarily by previous exposure to the combustible gas and that this stimulus could be removed by exposing the surface to oxygen at the reaction temperature.

Bone also published a paper on the results of an exhaustive study of the catalytic combustion of carbon monoxide over catalysts of porous porcelain, granular copper oxide, nickel oxide, gold gauze and silver foil in the presence and absence of water vapor. With a progressive removal of moisture the immediate effect was always to increase the apparent catalyzing power of the surface, presumably by removing from it the film of water molecules that normally lags it. The ultimate effect, which is observed usually after a prolonged drying, is to diminish greatly or even stop completely the catalytic combustion.

Bone, Weston, Fraser and Newitt[2] recently published their results upon the combustion of well-dried carbon monoxide and oxygen mixtures. They found this mixture could be ignited by means of a fairly powerful electric spark, but that combustion was incomplete in most cases, due to the absence of the catalytic effect of water vapor. They concluded that there is some property of the electric spark, presumably its ionizing power, which, if only developed strongly enough, can overcome the high resistance of such an extremely dry mixture to ignition and explosion and by virtue of which it can compensate the system for the absence of water vapor. In a spectroscopic examination of the flames resulting from the combustion of these well-dried mixtures under initial pressures of 25 atmospheres and upward, evidence was found that the water vapor played the part of an oxidizer, reacting with the carbon monoxide to give carbon dioxide and hydrogen. Recent results have shown hydrogen to be more potent than its equivalent of steam as a promoter of the combustion of carbon monoxide.

Although the mechanism of the action exhibited by antiknock compounds is not yet definitely determined, it seems to be the general opinion that the antiknock compounds exert an effect which is decidedly catalytic in character. A very comprehensive survey involving an experimental and theoretical study of antiknock materials has appeared in Ind. Eng. Chem., Vol. 18, p. 334, (1926), under the joint authorship of Church, Mock and Boord. The antiknock properties of a considerable number of metallic organic and inorganic compounds were tested and referred to that of lead tetraethyl, its value being arbitrarily taken as 100. A sufficient number of tests were performed to show that anomalies often existed between the knock suppressing power of a compound when determined in a motor and in an open tube. In a study of the electrical conductivity of the cylinder gases as a function of detonation it was found that the conductivity or gaseous ionization decreased with decreasing detonation in internal combustion engines. The authors also advanced a chemical theory of antiknock materials and their action in suppressing detonation.

An attempt to explain the effect of antiknock compounds recently has been made in another direction. Lind and Bardwell[3] investigated the influence of diethyl selenium upon the rate of the slow oxidation of methane under the ionizing influence of alpha-radiation. Contrary to what might be expected, an acceleration rather than retardation of the rate was observed.

As yet there has been no theory advanced on the mechanism of the action of antiknocks and antidetonants which adequately accounts for all the observed facts. During the last two years a large number of papers have appeared bearing upon both experimental and theoretical aspects. Of the more noteworthy observed facts, there might be mentioned:

1. The decrease in the rate of oxidation of benzaldehyde by lead tetraethyl.[4]
2. The application of autoxidation and antioxygenic action to the problem of the mechanism of the action of antidetonants.[5]
3. The analytical determination of the antiknock property of a gasoline.[6]
4. An attempt to find a relation between the degree of ionization of organic compounds in flames and the amount of detonation in engines burning fuel containing them.[7] No simple relation was found.

Inflammability

Most of the recent work on the limits of inflammability of gaseous mixtures has been performed by Tanaka and Nagai.[8] They have studied the influence of ethyl bromide as well as other organic bromides, iodides, etc., upon the inflammability limits of hydrogen air mixtures. In addition, they investigated the influence of alkyl halides on the inflammability of various mixtures as well as the effect of pressure on the limits of inflammability and the average life period of activated molecules in combustion. In most cases the authors found that Le Chatelier's rule, which applies to the limits of inflammability of combustible mixed gas-air mixtures, was followed more or less accurately. The results of a study on the limits of inflammability of firedamp (methane) in atmospheres which contain black damp (nitrogen) have been published by Coward and Hartwell.[9] They concluded that the addition of moderate amounts of nitrogen to the air would not appreciably diminish the danger of a firedamp explosion under ground.

Ignition

Considerable work has been done by Wheeler[10] and his associates upon the physical conditions and environment affecting the ignition of combustible gas. Much of this work was carried out under the auspices of the Safety in Mines Research Board and was a study of the factors influencing the ignition of gas by momentary flames and hot wires.

In this same category might be mentioned the work done by Coward and Guest[11] on the ignition of natural gas-air mixtures by heated metal bars; and Brewer[12] on the ignition of carbon monoxide-oxygen mixtures by means of electric sparks.

In regard to ignition in homogeneous systems notable work has been done by Tanaka and Nagai[13] in studying the effects of antiknock substances such as diethyl selenide and tetraethyl lead upon the spontaneous ignition temperatures of various inflammable liquids. This work was extended to include a study of the effects produced by the addition of aromatic amines and pyridine, which also show an antiknock effect. Coward and Meiter[14] have published an account of a very comprehensive investigation upon chemical action in the electric spark discharge and the conditions affecting the ignition of methane oxygen mixtures. Walls and Wheeler[15] have made a similar study upon the ignition of paraffin-air mixtures by flames.

Flame Propagation and Flame Travel

Ellis and Wheeler[16] have been occupied with a study of the movement of flames in closed vessels. In the case of the combustion of carbon monoxide-air mixtures they found that the flame speed usually consisted of two phases: (1) A speed uniform from the center of the sphere outward to near the walls and (2) a decreased speed due to a compression of the exploded and unexploded gases.

Chapman and Wheeler[17] studied the effects produced by the shape of the vessel upon the flame speed in a mixture of methane and air. They found that constricting rings placed in the tubular combustion chamber increased the speeds up to a certain limit.

The mechanism of the uniform movement in the propagation of flame has been studied for methane-air mixtures by Coward and Jones.[18] Their results indicated that the speed was dependent upon the heat developed, the thermal capacity of the gases and the rate of chemical reaction.

Jones and Perrott[19] made a study of the amounts of oxygen necessary to propagate the flames in hydrogen, carbon monoxide, and methane-air mixtures. This research was performed with a view to its practical application to conditions existing in mines.

Ellis[20] reports a study of flame movement in a Safety in Mines Research Board publication.

Bone, Fraser and Winter[21] have made a study of flame speeds for mixtures of hydrogen, acetylene and ethylene with oxygen and applied the results to the supposed law of flame speeds. The laws appeared not to hold.

White[22] had an article upon the effect of pressure on the limits for the propagation of flame in ether-air mixtures.

Explosions and Detonations

Saunders[23] and his co-workers have described some work involving a study of ionization in exploding gaseous mixtures. They reached the conclusion that the electrical conductivity of the dry gases, *i.e.*, the degree of ionization was mainly thermal in character for carbon monoxide-oxygen mixtures and discovered that the addition of hydrogen or water vapor greatly increased the ionization during explosion. In a study of the explosions of methane-oxygen mixtures the maximum electrical conductivity was produced when the hydrogen was burned to water and the carbon to carbon dioxide. However, in the acetylene-oxygen mixtures the maximum conductivity was obtained when the carbon was burned only to carbon monoxide, and hydrogen going to water as in the former case.

Egerton and Gates[24] have published a paper on the detonation of gaseous mixtures of acetylene and pentane and one involving a study of detonation in gaseous mixtures at high initial pressures and temperatures.

Spectroscopy

Most of the special studies made upon the combustion of gaseous mixtures during the last two years has been in the ultraviolet region. Work has been done by Clark, Henne and Thee[25] on the ultraviolet spectra of motor fuel flames. The ultraviolet emission lines for lead constitute the most sensitive test for the presence of lead tetraethyl in fuels.

Bone and Newitt[26] obtained a collection of interesting data and photographs in a spectrographic investigation of the ultraviolet radiation from carbon monoxide-oxygen or air mixtures. These results were not interpreted.

Equilibrium and Velocity of Combustion Reactions

Probably the most important work in this field has been reported in a paper by Haslam, Mackie and Reed.[27] Therein they describe the results obtained on the effect of depth of fuel bed and rate of firing upon the heating value, cold gas efficiency and per cent steam decomposed in the manufacture of producer gas. With a fuel bed consisting of anthracite coal they found that an increase in depth and rate of firing produced a corresponding increase in the three latter factors.

Allner[28] in a paper on combustion velocity and equilibria in combustion gives a general discussion and summary of data on the various factors entering into gaseous combustion and their application to practice.

Goff[29] also published a study on the chemical reactions in the gas producer based upon the knowledge of chemical equilibrium on the constitution of gas mixtures.

In this connection, a paper by Leffler[30] on the reaction velocity between carbon dioxide and different species of carbonized fuel might be mentioned.

Additional papers have appeared which are concerned with the chemistry, both structural and reactional, of various fuels. Most of these are discussions and summaries of knowledge obtained at some previous period and do not describe original research. A list of these papers will be found below.

There are a number of other papers related to combustion which do not fall naturally into the categories listed above but which deserve special mention.

A paper by Bone, Newitt and Townsend[31] describes the effect of argon and helium as diluents upon the explosions of hydrogen and carbon monoxide detonating gas mixtures. Helium would seem to influence the explosion reaction in a specific manner.

Harrison and Baxter[32] found that, in the combustion of carbon monoxide, the presence of small amounts of hydrogen produce an effect all out of proportion to the amount present. One-half per cent was found to alter the process completely.

Maxwell, Payman and Wheeler[33] have published the results of a study upon the combustion of complex gaseous mixtures such as (1) hydrogen, (2) three parts hydrogen plus one part carbon monoxide, (3) equal parts of hydrogen and carbon monoxide, (4) one part hydrogen plus three parts carbon monoxide, (5) carbon monoxide with air.

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LUBRICANTS AND INSULATION

Scope

The two major questions regarding turbine lubrication are: (1) By what standards can oils be judged as suitable for turbine use? (2) If turbine oils deteriorate through use, by what methods can the degree of deterioration be determined? It is intended that the work of this Section will result in satisfactory answers to these two questions, and this report is intended merely to give the progress of the work to date and offer tentative conclusions.

Conclusions

The judgment of the suitability of oil for turbine use must be based upon the fundamental chemical characteristics of petroleum rather than upon the ordinary semi-chemical properties indicated by the tests now in common use. What those characteristics will be has not yet been established, but sufficient data are at hand to indicate that suitable tests may be developed.

It is still believed to be a question whether a suitable oil deteriorates in lubricating and chemical quality. Tests have indicated that after a service period estimated as 16,000 hours no material change is produced in those qualities of the oil usually taken as criteria of fitness.

However, during such period of usage certain products develop in the oil, such as sludge, emulsion, water and acidity. Such products may be measured and removed from the oil, and the degree to which they are removed governs the degree to which their development continues. The continued development and removal of such products points to the ultimate consumption of the oil through chemical change. These products introduce undesirable operating conditions and it has been common practice to consider their appearance as evidence of the deterioration of the oil. Our tests have shown that with all surrounding conditions remaining constant the development of these products takes place in cycles; they do not completely disappear, but they appear alternately in large and small amounts. It would also appear that the frequency of these cycles is from 4 to 6 weeks, or sometimes longer. From such observations it would appear that tests at least once a week are desirable if the true condition of the oil is to be found and that tests at less frequent intervals are quite likely to result in false conclusions. Our observations have been that the determination of the amount of sludge in such tests is a criterion by which to judge the condition of the oil. The amount of sludge may be determined in a number of ways: (a) By observation and photography at 100 magnifications, (b) by direct weighing, and (c) by volumetric measurement with the aid of a centrifuge.

In addition to these tentative conclusions pertaining to the two major questions, it is possible to submit certain facts relative to the use of so-called anti-oxidants in turbine oil. It is assumed, and the data quite generally indicates, that the development of objectionable products in turbine oil is a direct function of oxidation. Such being the case, the introduction of a compound designed to react with the oxygen which comes in contact with the oil, should, in a measure, prevent or retard the oxidation of the petroleum hydrocarbons. In the two cases examined to date such is the case. When an oil has a tendency to form oxidation products—sludge—an anti-oxidant will prevent it, but will in turn form oxidation products of its own of a lesser magnitude than those of the petroleum hydrocarbons. With an oil showing little or no tendency to sludge the use of anti-oxidants shows no advantage.

Test Procedure

The tests were carried out in a Funk Sludging Machine. Thirty-two quarts of oil and three quarts of water constituted the charge to be tested. Samples were taken hourly. The tests made are defined as follows:

A. **Sludge and Emulsion.**—Sludge was defined as that material developed in the oil during the test, and which was insoluble in the oil at room temperature, and is the same as that developed in the oil during use through the action of air, heat and water. It was further defined as being insoluble in gasoline at room temperature, and free of oil and moisture at 212 deg. fahr. Emulsion was defined as being that material which separates upon centrifuging and exists between the water and the oil layer in the centrifuge tube.

The amount of sludge and emulsion was determined as follows: Before the different phases of the oil-water mixture, drawn from the machine as a sample, had an opportunity to separate, 100 c.c. was poured into each of two 100 c.c. centrifuge tubes. These volumes were then centrifuged for 30 minutes at 1000 r.p.m. At the end of that time the volume of emulsion was read and recorded. The clear oil was decanted and reserved for the acidity determination. The remaining solution and sludge were filtered through a dry, weighed Gooch crucible, washed thoroughly with gasoline and dried for 1 hour at 212 deg. fahr. The increase in weight of the crucible was taken as the amount of sludge.

B. **Acidity.**—The acidity was defined indirectly as the amount of potassium hydroxide, expressed in milligrams, required to neutralize one gram of oil when used as the titrating reagent in an alcoholic solution and in the presence of phenolphthalein as the indicator. About 20 c.c. of oil was used for this test.

C. **Viscosity.**—The viscosity at 100 deg. fahr. was determined by every fourth sample with the Saybolt Universal Viscosimeter.

D. Such other tests as were performed on the samples before and after sludging were done in accordance with standard methods.

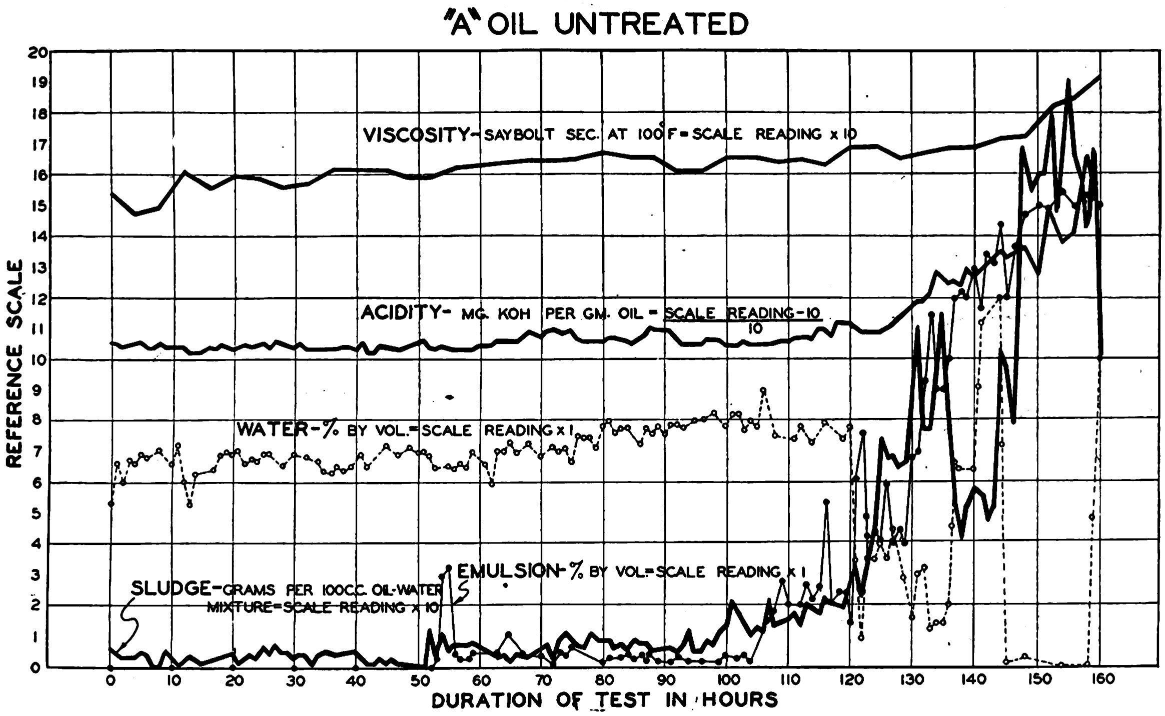
"A" OIL UNTREATED
VISCOSITY- SAYBOLT SEC. AT 100°F = SCALE READING x 10
ACIDITY- MG. KOH PER GM. OIL = SCALE READING-10 / 10
WATER-% BY VOL.= SCALE READING x 1
EMULSION-% BY VOL= SCALE READING x 1
SLUDGE-GRAMS PER 100CC. OIL-WATER MIXTURE=SCALE READING x 10
REFERENCE SCALE
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160
DURATION OF TEST IN HOURS

FIG. 1

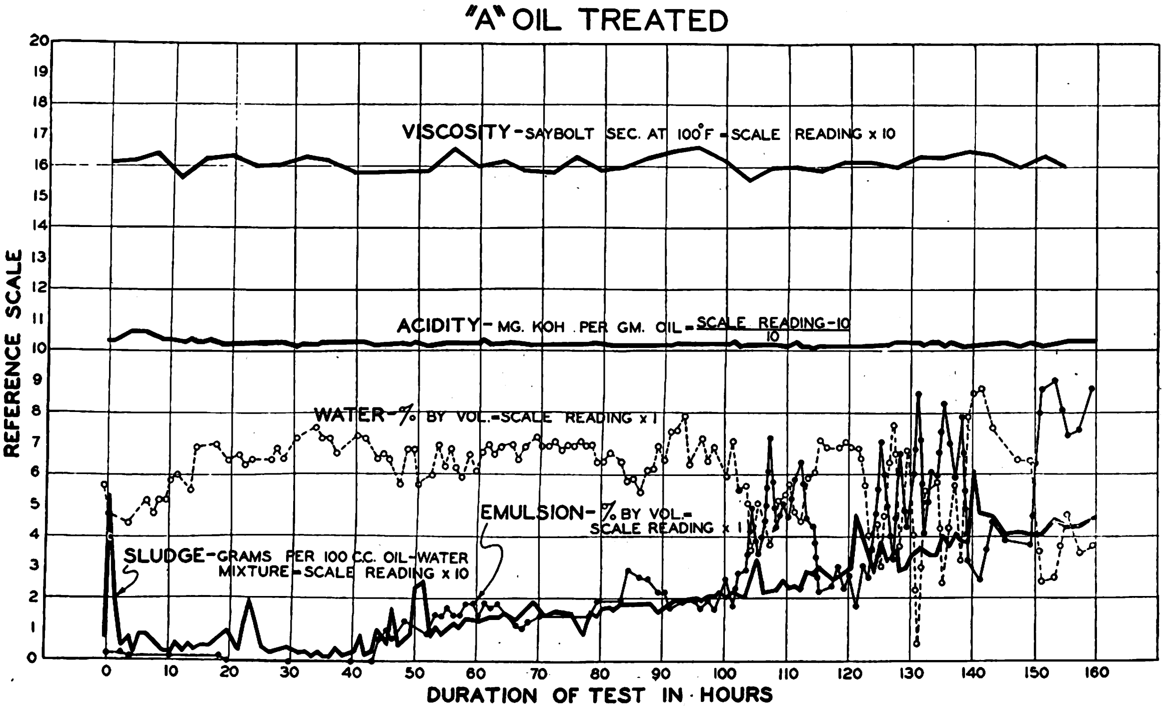
"A" OIL TREATED
VISCOSITY-SAYBOLT SEC. AT 100°F = SCALE READING x 10
ACIDITY- MG. KOH PER GM. OIL = SCALE READING-10 / 10
WATER-% BY VOL.=SCALE READING x 1
EMULSION-% BY VOL.= SCALE READING x 1
SLUDGE-GRAMS PER 100 C.C. OIL-WATER MIXTURE=SCALE READING x 10
REFERENCE SCALE
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160
DURATION OF TEST IN HOURS

FIG. 2

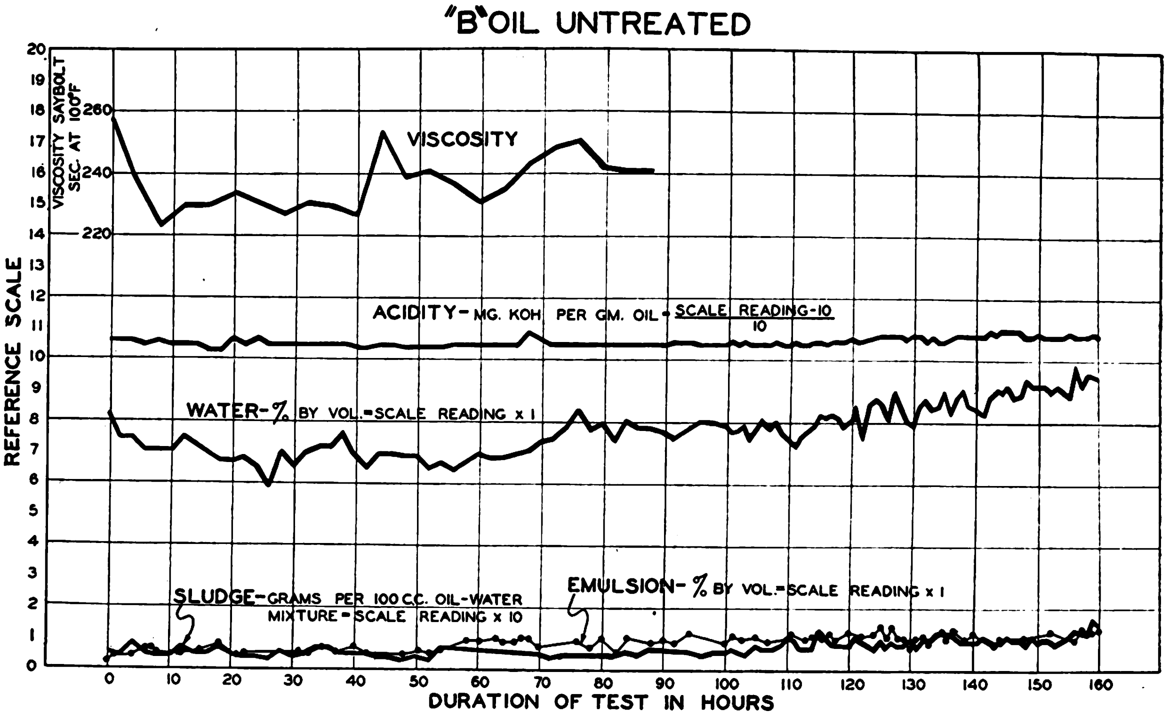
"B" OIL UNTREATED
REFERENCE SCALE
VISCOSITY SAYBOLT SEC. AT 100°F
260
240
220
VISCOSITY
ACIDITY - MG. KOH PER GM. OIL = SCALE READING - 10 / 10
WATER - % BY VOL. = SCALE READING x 1
SLUDGE - GRAMS PER 100 C.C. OIL-WATER MIXTURE = SCALE READING x 10
EMULSION - % BY VOL. = SCALE READING x 1
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160
DURATION OF TEST IN HOURS

FIG. 3.

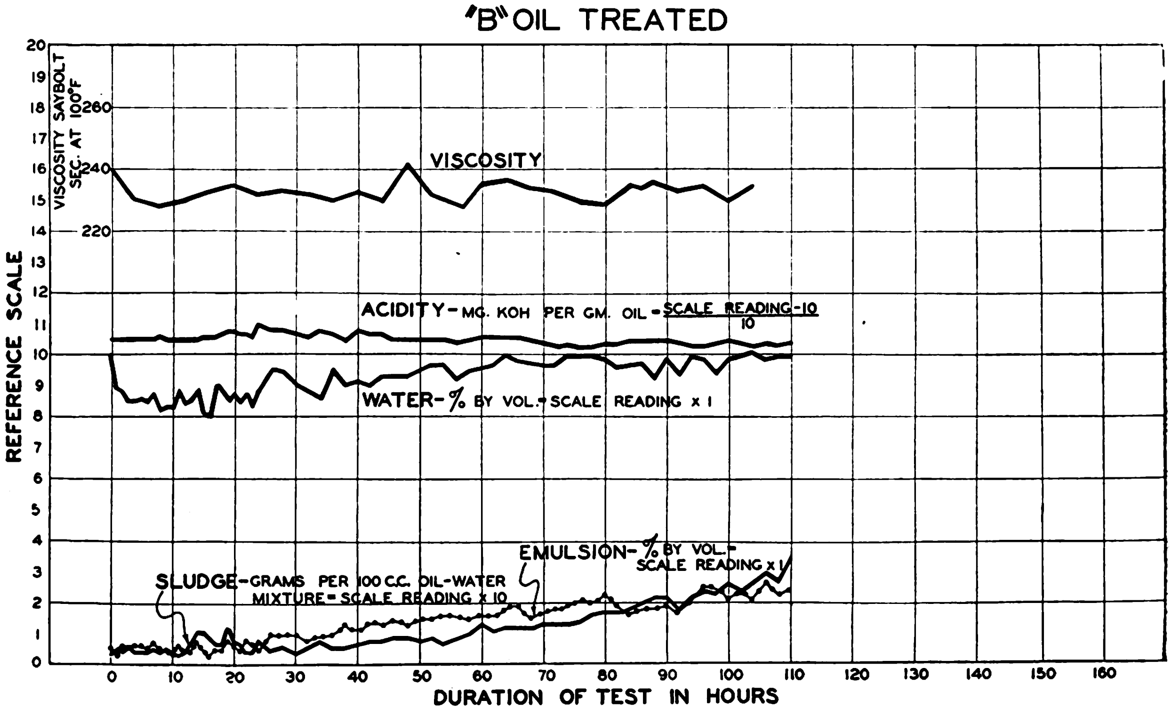
"B" OIL TREATED
REFERENCE SCALE
VISCOSITY SAYBOLT SEC. AT 100°F
260
240
220
VISCOSITY
ACIDITY - MG. KOH PER GM. OIL = SCALE READING - 10 / 10
WATER - % BY VOL. = SCALE READING x 1
EMULSION - % BY VOL. = SCALE READING x 1
SLUDGE - GRAMS PER 100 C.C. OIL-WATER MIXTURE = SCALE READING x 10
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160
DURATION OF TEST IN HOURS

FIG. 4

Results

Table I shows the initial and final state of the oils tested in the sludging machine.

Fig. 1, 2, 3 and 4 show the details of the development of oxidation products in the oils.

TABLE I

PROPERTIES OF OILS BEFORE AND AFTER SLUDGING TEST

	Oil as Received		Oil treated with Anti-Oxidant	
	New	After Test	New	After Test
		Light Oil "A"		
Viscosity, Saybolt Sec. at 100 °F.	166	175	160	161
Flash point, °F.	420	415	410	400
Fire point, °F.	475	480	470	460
Acid value, mg. KOH/gram oil	0	0.56	0	0.04
S.E. No. A.S.T.M. Test	126	394	127	170
Tarry matter, % by weight	0.01	0.06	0.01	0.04
Saponification No.	0	0.93	0	0
Unsaturated hydrocarbons, % by volume	5.4	11.1	5.8	10.8
		Medium Oil "B"		
Viscosity, Saybolt. Sec. at 100° F.	225	225	225	231
Flash point, °F.	405	385	410	395
Fire point, °F.	455	450	455	450
Acid value, mg. KOH/gram oil	0.05	0.09	0.06	0.10
S. E. No. A.S.T.M. Test	238	373	246	350
Tarry matter, % by weight	0.03	0.10	0.05	0.17
Saponification No.	0.06	0.33	0.08	0.33
Unsaturated hydrocarbons, % by volume	7.8	10.8	10.0	10.0

Regarding the significance of these tests as they apply to the fitness of oils for turbine lubrication, the following may be said: The test in the sludging machine is capable of distinguishing between a rapidly oxidizing oil and one that oxidizes at a slower rate. Such information is certainly of prime importance to the user of this type of oil, and a continued critical study of the changes the oils undergo in this test may reveal the nature of the hydrocarbons chiefly responsible for the sludging trouble. At present a study is under way to establish the fundamental differences between the two untreated oils discussed herein. Both are well-known oils, actually giving fairly satisfactory service in use, yet each possesses distinct chemical properties which must to a large degree be responsible for the formation of oxidation products developing to different degrees in each. Further, such properties undoubtedly govern the degree of satisfactory service experienced. By continuing along this line, it is believed the desired end will be reached.

The significance of these tests as applied to the use and the testing of oil while in service lies chiefly in the fact that they illustrate how unreliable spot or periodic tests may be when the results are used to determine the general condition of the oil. The true condition of an oil in service may be ascertained only by following its changes and the conditions to which it is subjected by simple tests at frequent intervals.

Although it is not the intent of this report to discuss methods of handling and reconditioning the oil, the work just finished has developed one very important point: as long as regular definite additions of what may be termed "sweetening" oil are made to the volume in service, the oil remains in apparent excellent condition. Although this practice is in vogue at present, it is doubtful if it has a very definite improvement motive behind it. From the results shown it would appear that 0.6 per cent by volume of fresh oil added to the batch in service at regular intervals would keep the oil in good shape indefinitely. Whether this specific amount of sweetening oil is of particular importance, or whether it must, as was the case in our tests, be accompanied by the withdrawal of an equal amount of the oil in service cannot be stated. Should such be the case, a satisfactory method of handling the situation could be developed and a general improvement in service be experienced.

Too little as yet has been done in the application of anti-oxidants to the field of lubrication to warrant making any definite statements. It appears that direct oxidation of the petroleum hydrocarbons is retarded, but whether other oxidation developments equally undesirable occur has not been established.

It should be borne in mind that the conditions imposed on the oil in these tests were extremely severe with respect to water and oxygen. However, in service, temporary conditions of equal severity may occur, and the effect on the oil examined under those conditions, may be as apparently serious as that observed here. Such effects are temporary, however, and need not be cause for dumping a large quantity of oil. With judicious care these effects may be overcome and the oil quickly restored to its normal condition.

Bibliography Abstracts

The following bibliography abstracts are submitted:

1927

EVALUATION OF TRANSFORMER OILS. By J. G. Ford, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa. J. Ind. Eng. Chem., Vol. 19, Oct., 1927, pp. 1165 to 1171.

Sludging is caused by oxygen being in continual contact with oil. Oil readily dissolves oxygen. Heat and light accelerates oxidation of oil. Some oils, chiefly the water-white type, form little or no sludge, but produce on oxidation considerable amounts of organic acids. Mineral oils slowly oxidize even at room temperature, in the presence of light, moisture and oxygen. Two criticisms of the majority of oil tests are that the time consumed in making them is disadvantageous, and it is difficult to reproduce results.

Unsaturated hydrocarbons play an important rôle in the oxidation of oils. There is a definite relationship between the quantity of sludge formed and the unsaturated hydrocarbons as measured by 95 per cent sulphuric acid absorption. The oxidation of saturated hydrocarbons is retarded by the presence of unsaturated compounds. Small amounts of unsaturated hydrocarbons retard oxidation only temporarily, and finally large quantities of sludge are precipitated. With oils containing over 5 per cent unsaturated hydrocarbons the quantity of sludge formed appears to be independent of the base of the oil. Although the method for the determination of naphthenes is not entirely free from error, it is of value for determining the approximate source of an oil and for showing how it will act under certain conditions. High molecular weight naphthene hydrocarbons do not appear to be as sensitive to oxidation as those of low molecular weight. Mixtures of high molecular weight naphthene with paraffin hydrocarbons give an oil with high resistance to oxidation. No general rule can be given concerning the effect of different temperatures on the rate of oxidation of different oils. Temperatures other than operating temperatures will give false results with certain oils.

Methods are described for determining naphthene and paraffin hydrocarbons and for the determination of unsaturated hydrocarbons. Data are given showing the effect of acid on precipitation of sludge, also the effect of temperature on the rate of oxidation.

EVALUATION OF TURBINE OILS. By T. H. Rogers and C. E. Miller. Ind. Eng. Chem. 19, 308-12 (1927). Abstr. Chem. Abstracts, Vol. 21, 1927, p. 1346.

A stability test has been developed for the evaluation of turbine oils in which moist O_2 is passed through the oil at 100 deg. cent. in the presence of iron. Determinations of the acidity and demulsibility of the samples taken periodically along with the sludging time serve as a measure of the degree of oxidation and its effect on turbine service. By comparative turbine test runs it has been established that this stability test substantially duplicates the behavior of oils in a dry turbine.

REFINING TRANSFORMER AND TURBINE OILS. By N. Butkov Neftyanoe Khozyaistvo 10, 388-92 (1926). Abstr. Chem. Abstracts, Vol. 21, 1927, p. 2554.

To identify the anti-oxidizing agent of the petroleum-resins, O_2 was passed at 120 deg. cent. through a transformer oil to which naphthalene, phenol, aniline, a-naphthol, anthracene and a-naphthylamine had been added. The first three substances had little effect but the last three had a strong anti-oxidizing action. The presence of 1.5 per cent of a-naphthylamine reduced the acidity after passing O_2 for 60 hr. from 21.05 to 0.18 mg. of KOH. If the acid constituents be removed from acid-refined oil by SiO_2 gel instead of alkali, the stability of the oil is improved because of the absence of Na salts of the organic acids. The tendency of the paraffin wax to oxidize is increased by treatment with strong alkali solutions after oleum refining. The treatment of the oil with SiO_2 gel occupies 1.5 hr. The gel absorbs 1 per cent of sulphuric acids, which may be recovered, and the gel may be regenerated by heating. It is proposed to substitute H_2SO_4 in refining by the O_2 of the air. On passing air at 100 deg. cent. for 12 hr. and treatment with 20 per cent of SiO_2 gel a light oil of d.0.885 and acidity 0.02 was obtained. On passing O_2 at 120 deg. cent. for 36 hr. the acidity was 0.03. Pb vessels cannot be employed. An increase of pressure of the air to 2 atmosphere shortens the process by 3 hr. Turbine oil treated by this process is less liable to emulsify.

REPORT OF SUBCOMMITTEE XI ON TURBINE OILS. By James T. B. Bowles. Proc. A. S. T. M. 26, pt. 1, 370-380 (1926). Abstr. Chem. Abstr., Vol. 21, 1927, p. 1346.

Collaborative results in the A. S. T. M. steam emulsion test and on the Herschel demulsibility test showed a considerable variation between different laboratories in both methods, but the variation was clearly much less with the steam emulsion test (about 15 per cent average departure from the mean) than with the Herschel demulsibility test (over 40 per cent average departure from the mean). The results are interpreted as proving that the former gives more concordant results than the latter. Collaborative results are given of the Funk sludging machine tests after running 50 hr. with the addition of H_2O, showing fair agreement between all the laboratories except one. The test is not intended to take the place of the steam emulsion or of the Herschel demulsibility tests, but was developed to test out large samples of oil under conditions approximating those found in a turbine. The results obtained show only a fair agreement and finer gradation is obtained with the steam emulsion test. Detailed directions are given for running the 50 hr. test with the Funk sludge accelerator.

R. T. HASLEM and P. K. FROLICH. Deterioration of Mineral Oils I. Mechanism of Oxidation and Action of Negative Catalysts as Determined by a Dynamic Method. Ind. Eng. Chem. 19, 292-6 (1927). Abstr. Chem. Abstr., Vol. 21, 1927, p. 1345.

H. and F. oxidize medicinal oil in a current of air or O_2 at 130 deg. and 140 deg. cent. After a period of inhibition, oxidation starts, as shown by color, viscosity, acidity and total O_2 absorbed. The mechanism of oxidation is discussed, together with the action of several catalysts.

G. BAUM. Methods of Investigating Transformer, Switch and Turbine Oils. Z. Agnew. Chem. 39, 473-5, 1926. Also in Petroleum Z22, 562-3, 1926, and Abstr. Chem. Abstr., Vol. 21, 1927, p. 1005.

The methods of test are discussed critically. B proposes that the A. E. G. oxidation test (Na_2O_2) be compared with the Schwarz-Marcusson (50 hr. at 120 deg. cent.) and the umpire method (70 hr. at 120 deg. cent., and 2 bubbles of O_2 per second) in the hope that the simpler method (Na_2O_2) may be proved useful. Oils that form less "tar" than the allowable quantity frequently give unsatisfactory service. More significant tests must be devised. The proposal of von der Heyden and Typken that the sludge formed be considered a criterion of the quality of the oil is accepted as promising, but air should be used instead of oxygen, and only the insoluble sludge should be considered. Sludge precipitated by petroleum ether should be ignored. Oils should be accepted for the uses in question only when they are low in "unsaturated constituents," as determined by the following test: 5 c.c. of oil and 5 c.c. of H_2SO_4 (1.84 sp. gr.) are put into a graduated centrifuge bottle (15 c.c.) and are mixed by air bubbles for 0.5 hr. through a glass capillary. After centrifuging at 3000 r.p.m. for 10 min. the increase of volume of the aid layer is determined. An increase of 5 per cent is the maximum allowable. Discussion of the address is appended.

1926

THE USE OF ANTIOXIDANTS IN OILS. Anonymous. Rubber Age (NY) 20, 27, 30, 1926. Abstr. Chem. Abstracts, Vol. 20, 1926, p. 3801.

Aldol—a-naphthylamine ("agerite") has already proved itself of great value in retarding the oxidation and therefore the deterioration of vulcanized rubber. Similarly, its addition to mineral oils, in which it is soluble, stabilizes the oils so that their electrical resistivity after prolonged heating is far higher than the corresponding untreated oils under the same conditions.

L. A. GLOUCHMAN and N. L. ALCHENA. The Konradson Demulsification Test for Turbine Oils Azerbaidj Neft., Choz. 51, 75-7 (1926). Also in Chimie et Industrie 16, 58 (1926), and Abstr. Chem. Abstr., Vol. 20, 1926, p. 3801.

Pass steam for exactly 10 min. into a 250 c.c. graduated cylinder containing 20 c.c. of H_2O and 100 c.c. of oil, place in a water bath at 55 deg. cent. for 1 hr. and note the amount of H_2O (either clean or milky) of emulsion and of oil, and the H_2O content of the oil. With a given oil the rate of separation of the emulsion may vary, but the final result is constant; the H_2O content of the separated oil cannot always be determined with the desired degree of accuracy; on the whole, the method yields fairly accurate results. Application of the test to turbine oils prepared by treating ordinary machine oil with 1, 2 or 3 per cent of SiO_2 gel showed that the oil was improved and did not give any emulsion. The method is suitable for adoption as a standard test, except that it is unnecessary to determine the H_2O content of the oil, and the height of the emulsified layer is the only important consideration.

SIROZI HATTA. Effects of Tetraethyl Lead Upon Deteriorations of Turbine Oils. J. Soc. Chem. Ind. Japan, Vol. 28, 1346-52 (1925). Abstr. Chem. Abstr., Easton, Vol. 20, 1926, p. 816.

On the assumption that the deterioration of turbine oils is due mainly to the oxidation of the components of the oils by the action of heat and air, Et_4Pb was used as an anti-catalyser of the oxidation. 0.05, 0.1 or 0.2 per cent of Et_4Pb was added to pure oils and kept at 120 deg. cent.;

moist O_2 was passed in at the rate of about 150 bubbles per minute. Samples were taken at definite time intervals for testing color, specific gravity, viscosity, acid and saponification value, amount of sludge and the Herschel di-emulsivity. When an oil of the paraffin series was used, the darkening of the color, the sludge formation and the deterioration of di-emulsive power were distinctly decreased by the presence of Et_4Pb. The specific gravity, viscosity and acid and saponification values of the oil were, however, independent of the presence of Et_4Pb, all increasing gradually.

As to oils of the naphthenic series, the result was of an opposite nature, except that the darkening of the color was retarded; the specific gravity, acid and saponification values and the sludge formation were all distinctly increased by the presence of Et_4Pb.

F. Schwarz. New Method for Preparation of Valuable Mineral Oils, Especially Transformer and Turbine Oils. Petroleum Z22, pp. 576-8, 1926. Abstr. Chem. Abstr., Vol. 21, 1927, p. 1182.

The treatment of distillates, etc., by means of H_2SO_4 is discussed.

1925

Hans Staeger. Indice de Goudrionnification et Specifications Des Huiles Utilisees pour Les Transformateurs Et Les Turbines a Vapeur. (Brown Boveri Cie. Revue, Baden, Annee 12, 1925, pp. 131-135, 150-153.)

This article seeks to show that the tar figure is not a suitable basis for the comparison of transformer oils since it takes into account only the acidity of oil under given conditions and does not indicate the various reaction products resulting from the decomposition of the oil.

A. Salathe. Examination of a Turbine Oil Sludge. Ind. Eng. Chem. 17, 414-15 (1925). Abstr. Chem. Abstr., Vol. 19, 1925, pp. 414-15.

A sludge from Sterling Quality Turbine Oil used in a 25,000-kw. turbine contained 42.5 per cent water and 13.6 per cent acids (aliphatic and naphthenic, calculated on an oil-free basis). Treatment of the water from the sludge with I_2 and warming in the presence of sufficient Na_2CO_3 to produce alkalinity caused precipitation of iodoform, proving presence of acetaldehyde. The high saponification value obtained showed presence of acids, esters and soaps. Oxidation as a cause of sludging is indicated.

1924

Hans Staeger. Ueber den Katalytischen Einfluss von Metallen Auf Mineralöle (Schweizerische Elektrotechnische Verein Bulletin, Zurich, Jahrgang 15, 1924, pp. 93-106. Abstracted in Electrical World, New York, Vol. 83, 1924, p. 1016. Science Abstracts, London, Vol. 27-B, 1924, p. 464. Chemical Abstracts, Easton, Vol. 19, 1925, p. 724.

Bare copper, brass, tin and zinc accelerate sludging of oil considerably. The action depends upon the proportion between the surface of the submerged metal and the volume of oil except in the case of aluminum, tin, nickel, iron—with which metals the oxidation at the zone of immersion is of importance. Lead, copper and zinc are eaten away by the generated asphaltogenous acids. The presence of lead liberates a highly oxidizing product of resinous character. The data are given in curves, tabulations and microphotographs.

T. S. Sligh, Jr. An Oxidation Method for Measuring the Stability of Mineral Oils—A. S. T. M. Proceedings, Philadelphia, Vol. 24, Part II, 1924, pp. 964-972, discussion pp. 973-974.

The oxidation methods proposed in this paper for obtaining knowledge of the sludging characteristics of oils are intended as standardized tests which may be applied to laboratory investigations. The tests consist essentially in distinguishing between various classes of oxidation products and a sludging number is assigned—depending upon the amounts and proportions of products formed.

Evert Norlin. Undersokningar over Transformatorolior Metoder for Bestamning av Transformatorolyors Bestandighet Mot Luftoxidation (Stockholm), 1925, 46 pages. Sweden-Statens Provninganstalt Meddelande 25.

In this paper a report is given on the investigations made for the purpose of elaborating the chief methods of testing the resistance of transformer oils to oxidation by the air, viz., methods of testing tar value, asphalt value, formolite value and iodine value. The results obtained with the Kissling and Brauer tar value tests are compared and a standard method devised. The asphalt value (Michie) test was adopted with slight changes.

National Electric Light Association. Prime Movers Committee—Report 1924. Lubrication (N. E. L. A. Proceedings, New York, 1924, pp. 1426-1438).

Information is given as to methods of making tests for the oxidation, acidification, emulsification and sludging of turbine oils. Laboratory data is presented in graphic form to show the relation of water to acidification, oxidation and sludge formation; the effect of air and water on oxidation and the relation of the amount of water present to emulsibility. A "sludge accelerator" is described and a comparison is made of the results obtained with this device as against the results obtained in actual practice.

Hans Von Der Heyden and Kurt Typke. Einwirkung Verschiedener Seifer auf Transformatorenöl Petroleum, Berlin, Jahrgang 20, 1924, pp. 857-858. Abstr. Chem. Abstr., Easton, Vol. 18, 1925, p. 3474. Soc. of Chem. Ind. Journal, London, Vol. 43, 1924, pB-624.

After heating samples of transformer oil with lead, iron, copper, sodium potassium, magnesium, calcium and aluminum oleates and lead, iron and copper stearates, the following properties were determined: Color, precipitate, viscosity, ash content, acid number and tar number.

Frank Fritz. Beobachtungen über die Ursachen der Veränderung der Schmier und Isolieröle im Gebrauch. Petroleum, Berlin, Jahrgang 20, 1924, pp. 1488-1493. Same, Condensed, in Der Praktische Maschinen Konstrukteur, Berlin, Jahrgang 57, 1924, pp. 579-580. Abstracted in Chemisches Zentralblatt, Berlin, Folge 6, Jahrgang 6, 1924, p. 2626.

Discusses in a general way the function of oil in transformers, the causes of sludging and acid formation, and methods of maintaining dielectric strength.

Four stages in turbine oil decomposition:

1. Oxygen combines with oil and forms acids and secondary decomposition products.
2. Formation of metal salts from these acids.
3. Formation of high molecular weight oxygen addition—compounds of hydrocarbons.
4. Decomposition of high molecular weight compounds into low molecular weight compounds.

In a decomposing oil:

1. The specific gravity and flash point go up.
2. The viscosity increases.
3. The saponification value increases.
4. The tar number increases rapidly and the iodine number decreases.

1923

Hans Staeger. Die Methylalkoholextraktion bei Mineralölen. (Helvetica Chimica Acta, Geneva, Vol. 6, 1923, pp. 893-900.) Abstracted in Soc. of Chem. Ind. Journal, London, Vol. 242, 1923, p. 1117A.

Samples of oils were tested to determine chiefly the nature of sludges formed, and the other products of oxidized oil. Determinations were made and tabulated for acid number, tar number, index of refraction, specific gravity and formolite number.

Ad. Gruen and E. Ulbrich. Zur Oxydation des Paraffins Mittels Luftuerstoff (Zeitschrift fur Angewandte Chemie, Leipzig, Jahrgang 36, 1923, pp. 125-126). Abstr. Chem. Abstr., Easton, Vol. 17, 1923, p. 1782.

The authors found that when paraffins were heated to 170 deg. cent. the acids formed upon oxidation increased with the amount of air and the time of oxidation. Traces of moisture in the air increased the effect, while CO_2 retarded it.

1922

Waters, Campbell, Easter. Sulphur Compounds and Oxidation of Petroleum Oils. (Ind. Eng. Chemistry, Easton, Vol. 14, 1922, pp. 725-727). Abstr. Chem. Abstr., Easton, Vol. 16, 1922, p. 3752.

Mineral oils containing large percentages of sulphur compounds are more easily oxidized than those in which there is less sulphur. The bearing of this fact on the formation of sludge in transformer oils is pointed out.

HANS STAEGER. Huiles de Transformateurs et Modifications de Leurs Proprietes Sous L'action de la Chaleur. (Revue Brown Boveri Cie., Baden, Annee 9, 1922, pp. 159-167). Same in Elektrotechnische Zeitschrift, Berlin, Jahrgang 44, 1923, pp. 73-78. Abstracted in Science Abstracts, London, Vol. 26B, 1923, p. 235, Electrical World, New York, Vol. 80, 1922, p. 948.

A discussion of the sources and characteristics of the oils used in transformers and of the chemical change in the oil under service conditions. The French, German, British and Brown Boveri sludge tests are outlined and a comparison of results on three oils is given. The Brown Boveri test is used to study the effects of air and copper, and the reaction of the oil and copper.

1921

WATERS, CAMPBELL, EASTER. Catalytic Oxidation of Petroleum Oils (Journal Ind. Eng. Chem., Easton, Vol. 13, 1921, pp. 901-903). Abstr. Chem. Abstr., Easton, Vol. 16, 1922, p. 158.

The effects of various metal and metallic oxide catalysts on the oxidation of the two oils is determined.

1916

L. G. RADCLIFFE and G. POLYCHRONIS. Iodine Absorption and Tendency to Sludge. Formation of Some Hydrocarbon Oils. Soc. Chem. Ind. Journal, London, Vol. 35, 1916, pp. 340-343. Abstr. Chem. Abstr., Easton, Vol. 10, 1916, pp. 1708-9.

Shows graphically and in tabulated form the relation between sludge formation and iodine value.

1914

F. SCHWARZ and J. MARCUSSON. Die Untersuchungen der Dampfturbinenöle (Mitteilungen Aus Du Koniglichen Materialprüfungsamt zu Berlin-Lichtenfelde, West Berlin, Jahrgang 32, 1914, pp. 496-502.

Tests to determine the nature of resinous tar and coke impurities and the conditions which bring about the formation of acids and other oxidation products of mineral oils.

TENTATIVE METHOD FOR DETERMINATION OF DISSOLVED OXYGEN IN BOILER FEED WATER—ISSUED APRIL, 1928

Scope

The presence of dissolved oxygen in water used for boiler feed is objectionable, since it increases the corrosive properties of the water. It is essential in steam-station operation that the dissolved oxygen content of the feed water be kept as low as possible. In order to control the dissolved oxygen, tests should be made at frequent intervals.

Application of Test

The application of the Winkler method, herein described in detail, is intended for use on all boiler feed water supplies except raw water.

If organic matter, nitrates or iron salts are present in appreciable amounts the Rideal-Stewart method (appearing in Standard Methods of Water Analysis A. P. H. A., 6th Edition, 1925) should be applied.

After further investigation it may be possible to indicate the permissible amounts of organic matter, nitrites or iron salts under which the method outlined may be employed.

Description of the Winkler Method for Determining Dissolved Oxygen

The Winkler Iodimetric method depends upon the liberation in the solution of an amount of iodine exactly proportional to the amount of oxygen dissolved. Chemically, it amounts to the oxidation of the manganous chloride solution to manganic acid by the oxygen present, and a subsequent reduction of iodide by the manganic acid. The starch indicator indicates the presence of iodine, and the standardized solution of sodium thiosulphate has a definite iodine absorbing value. The calculations by the formula are in terms of oxygen, but the intermediate steps are computed in terms of iodine. The reactions involved are given in Table II.

Reagents

1. **Manganous Chloride**—Dissolve 425.5 grams of crystalline manganous chloride C.P. $(4H_2O)$ in 1000 c.c. of distilled water.

2. **Alkaline Potassium Iodide**—700 grams of potassium hydroxide c.p. and 150 grams of potassium iodide c.p. are dissolved separately in distilled water and the mixture diluted to 1000 c.c.

3. **Sulphuric Acid**—Equal volumes of c.p. concentrated acid (sp. gr. 1.84) and distilled water.

4. **Starch Solution**—Dissolve 5 grams of Litner's Soluble Starch in 50 c.c. of distilled water to make a thin paste, and then pour into 200 c.c. of boiling distilled water and continue boiling for 4 or 5 minutes. When cold add a few drops of chloroform and keep this solution in a dark glass stoppered bottle. Starch solution does not keep well and should be made up fresh every week.

5. **Sodium Thiosulfate: 0.025 N solution**—Dissolve 6.205 grams of chemically pure recrystallized sodium thiosulfate in distilled water and dilute the solution to 1000 c.c. with freshly boiled and cooled distilled water. Each c.c. is equivalent to 0.2 mg. of oxygen, or to 0.1395 c.c. of oxygen at 0 deg. cent. and 760 mm. pressure. Inasmuch as this solution is not permanent, it should be standardized weekly against a 0.025 N solution of Potassium Dichromate or 0.025 N solution of Potassium Permanganate. If special investigations are being made, the thiosulfate should be calibrated daily.

[NOTE: When facilities for the preparation of the above reagents are not available, they can be purchased from any reliable chemical supply house.]

Collection of Sample

Water supplies in excess of 125 deg. fahr. and above atmospheric pressure shall be cooled through

TABLE II

REACTIONS OF WINKLER TEST FOR DISSOLVED OXYGEN

(1)	$MnCl_2$ Manganous Chloride	+	2 KOH Potassium Hydroxide	=	$Mn(OH)_2$ Manganous Hydroxide	+	2 KCl Potassium Chloride		
(2)	2 $Mn(OH)_2$ Manganous Hydroxide	+	O_2 Oxygen	=	2 H_2MnO_3 Manganous Acid				
(3)	2 KCl Potassium Chloride	+	H_2SO_4 Sulfuric Acid	=	K_2SO_4 Potassium Sulfate	+	2 HCl Hydrochloric Acid		
(4)	$Mn(OH)_2$ Manganous Hydroxide	+	H_2SO_4 Sulfuric Acid	=	$MnSO_4$ Manganous Sulfate	+	2 H_2O Water		
(5)	H_2MnO_3 Manganous Acid	+	4 HCl Hydrochloric Acid	=	$MnCl_2$ Manganous Chloride	+	3 H_2O Water	+	Cl_2 Chlorine
(6)	2 KI Potassium Iodide	+	Cl_2 Chlorine	=	2 KCl Potassium Chloride	+	I_2 Iodine		
(7)	2 $Na_2S_2O_3$ Sodium Thiosulfate	+	I_2 Iodine	=	$Na_2S_4O_6$ Sodium Tetrathionate	+	2 NaI Sodium Iodide		

a copper coil condenser, throttled at the discharge end to room temperature.

A narrow-necked glass stoppered bottle of 250 to 300-c.c. capacity is satisfactory. To the end of the sample connection attach, by means of heavy walled rubber hose, a glass tube, which will permit filling the bottle by displacement of the air and water by overflowing. The minimum rate of filling should be 250 c.c. per 30 seconds, and the sample bottle should be permitted to overflow not less than 5 minutes. This procedure insures the complete removal of air in the bottle and subsequent solution in the water of such air. Make certain that the sample line from the source of sampling to the bottle has been freed of air bubbles and deposits by a strong flushing of the line. After the water has been displaced in the specified time, the glass tube admitting the water is removed and the glass stopper quickly inserted in place to prevent exposure of the sample to air. Make certain that no air space is left between the stopper and water. The glass stopper should be ground to a point or cone to eliminate trapping of air.

The next step of adding the reagents should proceed immediately.

Adding Reagents

Remove the stopper from the sample bottle and add immediately 2 c.c. of Manganous Chloride and 2 c.c. of Alkaline Potassium Iodide in the order mentioned and quickly replace the stopper. The pipettes used to deliver these reagents should extend to the bottom of the bottle, and the additions made in sequence with individual pipettes should be rapid. A short length of rubber tubing should be attached to the upper end of the pipettes to reduce the possibility of drawing the solution into the mouth. Do not expel solution by breath.

After the addition of the Alkaline Potassium Iodide replace the stopper, mix by shaking and *permit the precipitate to settle.* Then add 2 cc. of sulphuric acid and mix by shaking.

The procedure to this point must be carried out in the field, but after the acid has been added and the stopper replaced, the rest of the test shall be performed as soon as convenient, preferably within one hour.

Titrating Sample

Measure 250 c.c. of the sample and transfer to a 300 c.c. porcelain casserole. (The entire sample may be conveniently transferred and titrated if the volume of the sample bottles are previously determined).

Titrate the sample with 0.025 N Sodium Thiosulphate until the solution becomes a pale yellow color, then add 3 c.c. of the starch solution and titrate until the first disappearance of the blue color.

If the sample contains oxygen in excess of 0.5 c.c. per liter, the water will have a decided yellow color.

If zero or only traces of oxygen, the water will not appear yellow. The starch solution should then be added, and if any blue color appears thiosulphate should be added until the blue color disappears. The difference between the initial and final readings of the burette will be the number of cubic centimeters of thiosulphate used, which is proportional to the amount of oxygen present.

Calculations

If 250 c.c. of water were titrated, the calculations will be as follows:

$$\frac{1000}{250} \times (\text{c.c. of 0.025 N. Thio.} \times 0.1395) =$$

cubic centimeters of oxygen per liter standard condition (0 deg. cent. and 760 mm.). Express individual results to the second decimal place. Report values below 0.03 c.c. as "trace."

Notes When Making This Determination

(1) When the manganous chloride and alkaline potassium iodide are added a white precipitate will be noticed (manganese hydroxide).

(2) If oxygen is present, a brown colored precipitate will be noticed which is manganous acid, depending upon the amount of oxygen present.

(3) The addition of the sulphuric acid dissolves the brown precipitate and sets free an amount of iodine equivalent to the quantity of oxygen in the sample.

(4) The solution at this time will be yellow in color; the depth of color depending upon the amount of oxygen present.

(5) If oxygen is present and starch is added to the solution at this stage, the color will change to a deep green or blue color, depending upon the amount of iodine (oxygen) present.

Tolerance

With care the above procedure will give reproducible results as low as 0.03 c.c. of oxygen per liter.

References

1. Public Health Bulletin No. 151. (The determination of dissolved oxygen by the Winkler Method.) Emery J. Theriault.

2. "Determination of Dissolved Oxygen in the Presence of Iron Salts." Industrial and Engineering Chemistry, Vol. 15, No. 11, 1923. A. M. Buswell and W. V. Gallagher.

3. Standard Methods of Water Analysis. Sixth Edition, 1925. American Public Health Association.

Apparatus

The illustrations in Fig. 5 to 9 show the apparatus and steps in the operation. Sufficient construction details for making the cooling coil are shown in Fig. 5. An itemized specification of the apparatus follows:

APPARATUS

1. Copper cooling coil.
2. Rubber tubing, heavy wall, ¼ in. bore, ⅛ in. wall.
3. Flint glass bottles, narrow mouth with mushroom glass stopper ground to a point. Capacity, 8 oz. for collecting samples.
4. Flint glass bottles, narrow mouth for rubber stoppers. Capacity, 8 oz. for reagents. (The number of sample bottles required is optional, depending on the number of sampling points in the station.)
5. One bottle dropping TK type, flat glass stopper, 125 ml. capacity, for starch solution.

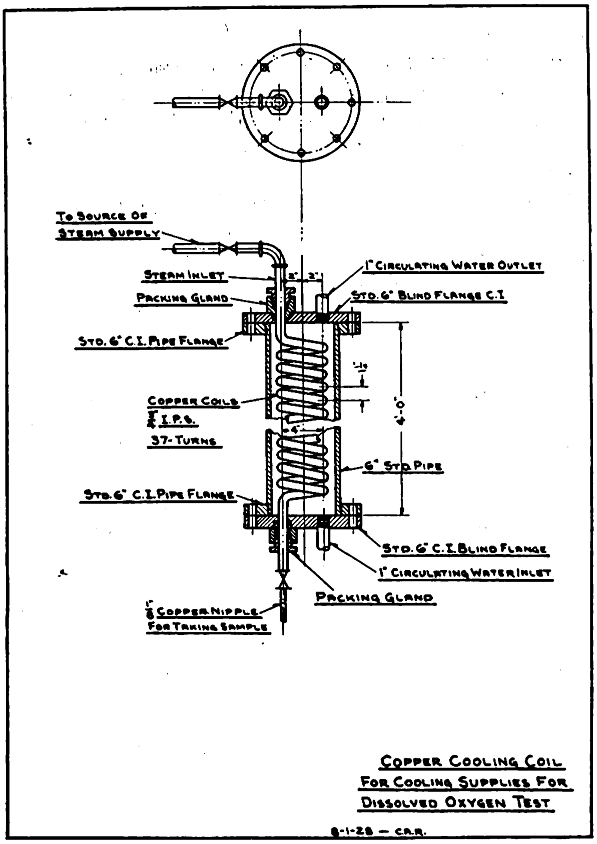
To Source of Steam Supply
Steam Inlet
Packing Gland
Std. 6" C.I. Pipe Flange
Copper Coils
¾ I.P.S.
37-Turns
Std. 6" C.I. Pipe Flange
1/8" Copper Nipple For Taking Sample
1" Circulating Water Outlet
Std. 6" Blind Flange C.I.
2"
2"
4'-0"
6" Std. Pipe
Std. 6" C.I. Blind Flange
1" Circulating Water Inlet
Packing Gland
Copper Cooling Coil For Cooling Supplies For Dissolved Oxygen Test
8-1-28 — C.R.R.

FIG. 5—COPPER COOLING COIL FOR COOLING SUPPLIES FOR DISSOLVED OXYGEN TEST.

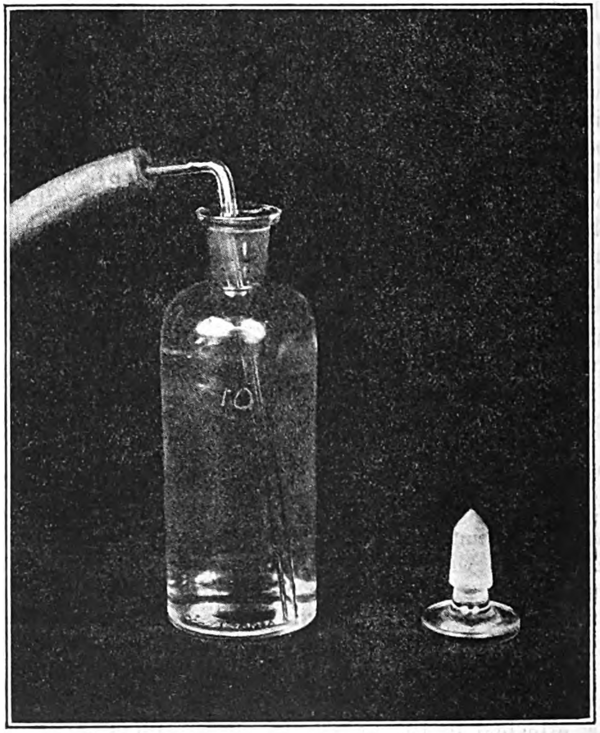

FIG. 6—SAMPLING BOTTLE WITH GLASS STOPPER GROUND TO A POINT. HOSE AND GLASS TUBE FOR CONVEYING WATER TO BOTTOM OF BOTTLE SO THAT AIR IS DISPLACED.

6. One glass cylinder, heavy base and lip for pouring, capacity 250 ml., subdivisions 2 ml.

7. One casserole, porcelain, glazed both sides, flat bottom, pour out, and porcelain handle, capacity 375 ml., size No. 4.

8. One burette with straight glass stop-cock, capacity 10 ml., subdivision 0.05 ml.

9. One apparatus support, rectangular base 4 by 6 in., length of rod 18 in.

10. One Universal burette clamp, rubber covered jaws.

11. Four pipettes, transfer type, bulb in center, graduated to deliver 2 ml. fitted with 2 in. of pure gum rubber tubing.

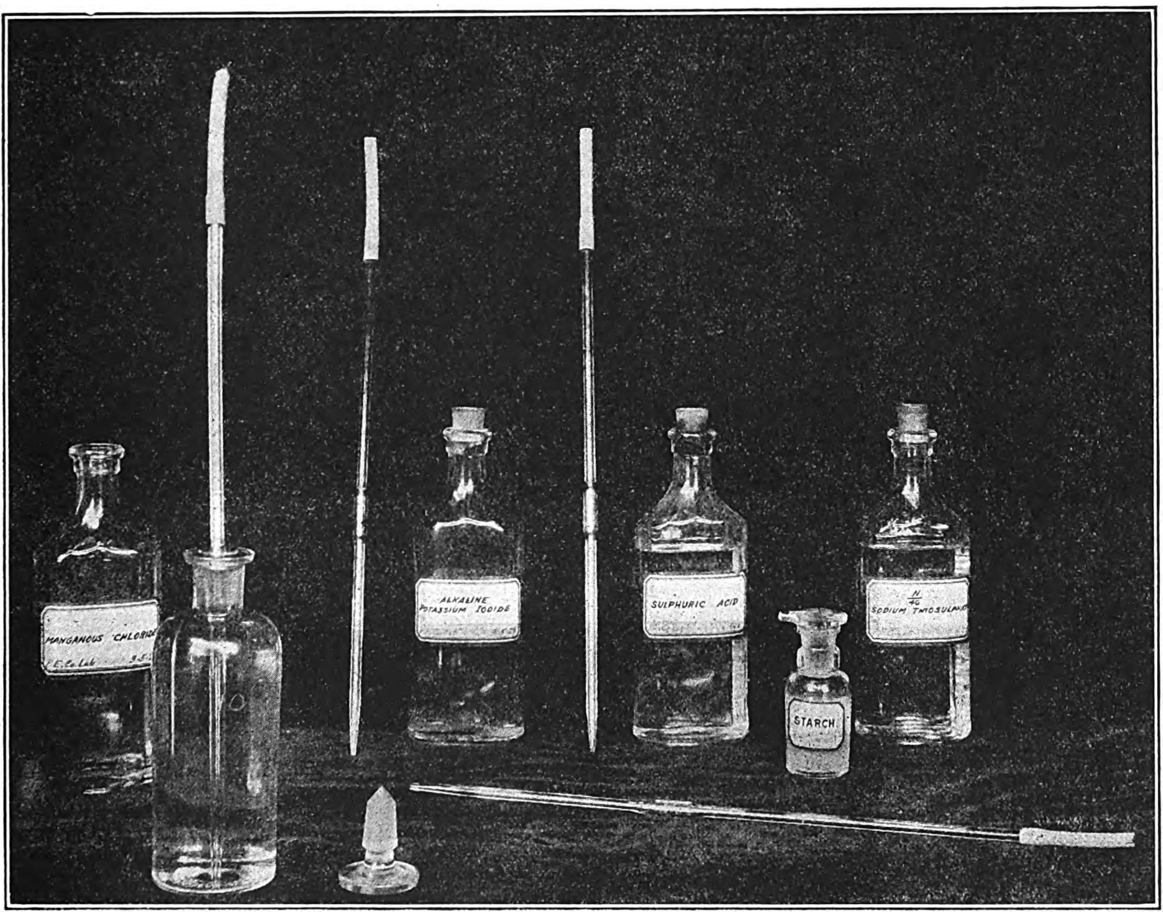
MANGANOUS CHLORID
E. Co. Lab.
ALKALINE POTASSIUM IODIDE
SULPHURIC ACID
N/40 SODIUM THIOSULPH
STARCH

FIG. 7—METHOD OF ADDING REAGENTS TO WATER. PIPETTE EXTENDS TO BOTTOM OF BOTTLE. SET-UP ALSO SHOWS SEPARATE PIPETTE FOR EACH REAGENT.

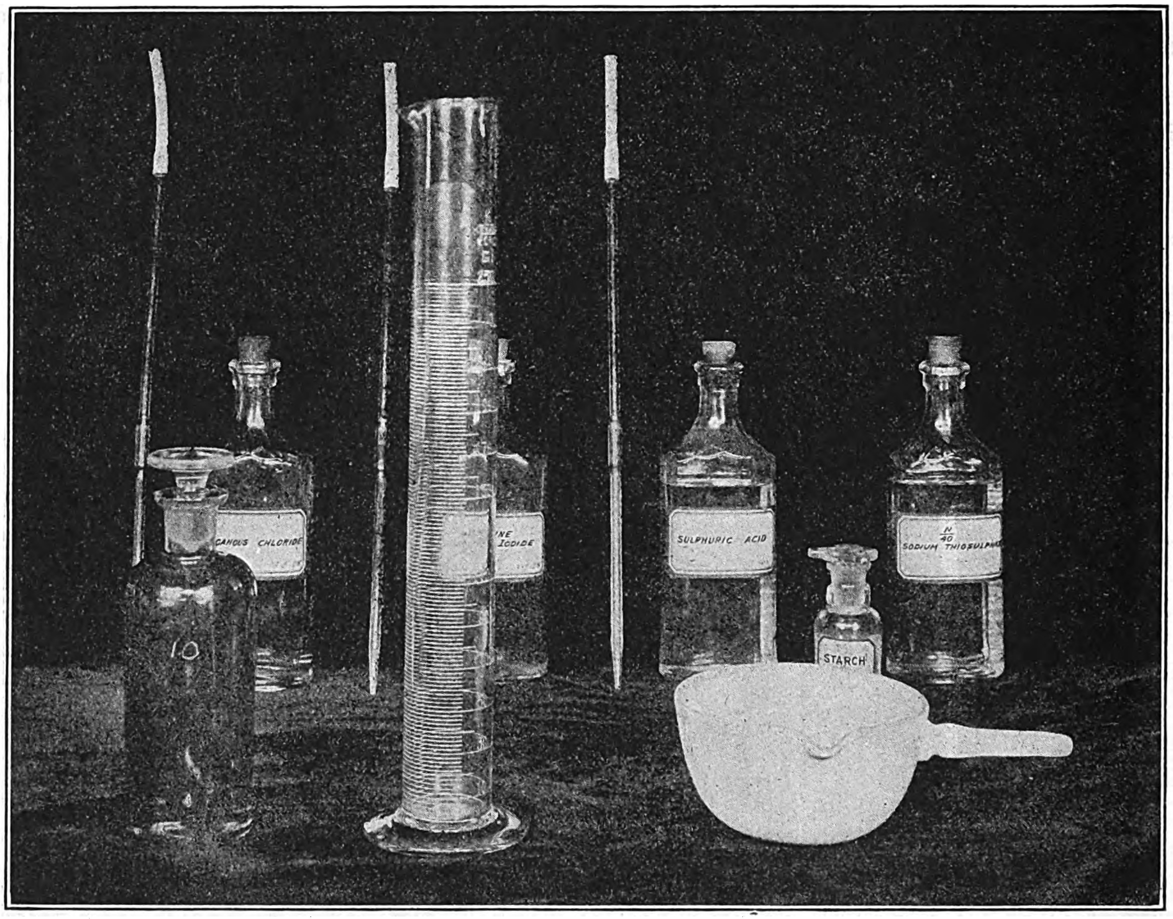
GANOUS CHLORIDE
NE IODIDE
SULPHURIC ACID
N/40 SODIUM THIOSULPHA
STARCH
10

FIG. 8—SAMPLE AFTER ADDITION OF SULPHURIC ACID. 250 C.C. OF SOLUTION IS THEN MEASURED WITH GRADUATED CYLINDER AND TRANSFERRED TO PORCELAIN CASSEROLE.

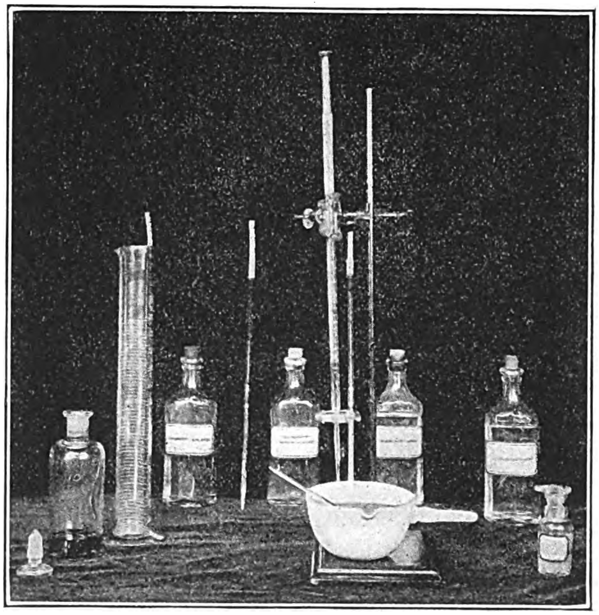

FIG. 9—SET-UP FOR TITRATING SOLUTION.

POWER STATION CHEMISTRY — PART II

Abstract

This report of the Chemists' Subcommittee of the Prime Movers Committee includes a non-technical review of water treatment for steam generation. The committee has adopted as standard procedure the reporting of water analyses in ionic form, and expressed in parts per million by weight. The reactions involved in water treatment calculations are presented in ionic form, and a procedure is included for calculation of water reagent requirements. The presentation of the subject in ionic form departs from previously published methods. Attempts to visualize water composition by the use of hypothetical or so-called probable combinations is made more difficult by the increasing use of arbitrary conventionalities, which have no basis on fundamental data.

A contributed statement discusses a graphic method of controlling the treatment in a Lime Soda system. The committee publishes an individual member statement on a laboratory study of turbine oil, using a Funk sludging machine.

Approved test methods for judging the quality of turbine oils are presented under Recommended Test Procedures. The tests will serve to establish variations in various shipments of the same trade name of turbine oils, and a selected few will serve in a measure to show the rate of alteration an oil undergoes in service. The tests alone are not suitable for determining the comparative desirability of different brands of new oils for turbine lubricating service.

The report emphasizes the desirability of making tests for the Hydrogen Ion Concentration in water supplies as one of the factors to be considered in the corrosiveness of the water, and statements of the significance of the Hydrogen Ion Concentration have been included both as committee and manufacturers statements.

Individual members have submitted statements for plant use, one on the graphical estimation of various alkalinities in water, the other, a plant control test for estimating phosphates in boiler water.

A manufacturer's statement on equipment for the electrometric determination of Hydrogen Ion Concentration and direct reading of the conductance of water concludes the report.

WATER TREATMENT FOR STEAM GENERATION

Committee Statement

Scope

The report discusses the major mechanical and chemical processes for treating water for steam generation. The mechanism of the reactions in the chemical processes is detailed both in molecular and ionic form. The ionic form, adopted by the committee, is used in the water analysis statement and in the treatment calculations.

Processes

The processes in use may be classified as:

A. *Non-chemical*
  1. Sedimentation
  2. Filtration
  3. Evaporation
  4. Deconcentration by blow down
  5. Deaeration

B. *Chemical*
  1. External
    a. Lime-Soda Ash
      Intermittent and Continuous—cold
      Continuous—hot
    b. Lime—Barium
      Intermittent and Continuous—cold
    c. Lime—Sodium Aluminate
      Intermittent and Continuous—cold
      Continuous—hot
    d. Base Exchange (Zeolite)
      Continuous—cold
  2. Internal
    e. Hydroxides and Carbonates
    f. Aluminates
    g. Phosphates
    h. Foam Preventives

Non-Chemical Processes

The non-chemical processes are not discussed because in most instances mechanical construction and operation constitute the major problem. Quite often water receives chemical treatment previous to filtration or evaporation. These cases are similar to those covered under External Chemical Treatment.

The optimum conditions for steam generation are the production of clean steam, free from both entrained solids and gases originating either in the feed water or formed by decomposition of treating reagents in the boiler. Mechanical methods are available for the removal of dissolved oxygen and free carbon dioxide. Partly combined carbon dioxide (HCO_3) requires chemical treatment for its complete removal before the water enters the boiler, since only partial removal is made by mechanical processes, such as deaerators and heaters.

Publication No. 289-114, Serial Report, Prime Movers Committee.

CHEMICAL PROCESSES

External Chemical Treatment

The chemical methods of water treatment involve reagent additions to prevent the formation of scale, and to minimize priming and foaming within the boiler. The formation of scale is prevented by eliminating the scale forming constituents as insoluble solids, prior to admission of the water into the boiler.

The scale-forming ions are calcium and magnesium when present along with either the carbonate, sulphate or silicate radicals. If the carbonates or sulphates can be reduced, or the calcium and magnesium removed, there is less possibility of scale formation. When calcium and magnesium occur in water containing bicarbonates, they are classed as carbonate hardness and may cause carbonate deposits on the metal surfaces. When calcium and sulphate radicals occur and are allowed to enter the boiler, a hard sulphate scale may form. If sufficient silicate is present, a hard silicate scale may form. To treat this type of water, the calcium and magnesium must be reduced.

Lime Soda Treatment

Most external chemical systems use a lime reagent to convert free carbon dioxide and bicarbonate to the normal carbonate. When lime (CaO) or hydrated lime $Ca(OH_2)$ is added to the water, the bicarbonate is converted to the carbonate with the precipitation of calcium as the carbonate, and magnesium as the hydroxide. The molecular reactions illustrating the conversion of the dissolved salts for this and subsequent treatments are given in Table II.

The residual calcium or magnesium in the treated water depends upon the solubility of calcium carbonate and magnesium hydroxide.

When non-carbonate hardness (sulphates, chlorides, silicates and nitrates) is present, soda ash is added to accomplish its removal.

The residual calcium ion depends upon the solubility of the calcium carbonate and the amount of soda ash present.

Treatment with Barium

Where the sulphate concentration is high and elimination is desirable, a barium reagent is used. This results in a decrease in soluble solids going to the boiler. The barium sulphate formed is practically insoluble.

Use of Alum and Sodium Aluminate

In many instances, especially in cold-process work, so-called coagulants are used, which, by the formation of gelatinous substances or "flocs," hasten the sedimentation of the insoluble products of the reactions. Aluminum sulphate (alum), sodium aluminate and ferrous sulphate (copperas), are used. There is considerable uncertainty as to the exact chemical reactions of alum and sodium aluminate when added to alkaline waters. The work of recent investigators indicates that the reactions involved are not cases of simple hydrolysis, as was formerly thought.[1]

Effect of Temperature Changes

The rate of chemical reactions increases with temperature rise. Consequently, where equipment space is limited, hot processes may be desirable.

Zeolite (Base Exchange) Process

The Zeolite (base exchange) Process practically removes the scale-forming calcium and magnesium and introduces sodium, which is not scale-forming.

Zeolite (a hydrous sodium aluminum silicate whose approximate composition is $2\ SiO_2 \cdot Al_2O_3 \cdot Na_2O \cdot 6\ H_2O$) must be regenerated when the available sodium is exhausted. The zeolite is made available for re-use when a salt brine has passed through the zeolite bed, and the sodium has replaced the calcium and magnesium.

The introduction of sodium products in the boiler may be objectionable due to the gradual concentration of the soluble solids and high alkalinities. When high alkalinities result from such treatment of high carbonate waters, pre-treatment may be desirable. However, such cases require special studies. The relative quantity of dissolved solids resulting from treating the same natural water by lime-barium, lime-soda ash and zeolite increase in the order named.

Internal Chemical Treatment

Higher boiler ratings, higher operating pressures and longer operating periods have resulted in directing greater attention to internal treatment. Basic reactions are involved, a complete understanding of which requires data regarding solubilities at higher temperatures. Not all these data are available.

Soda Ash Treatment

Waters containing a low concentration of calcium and magnesium may be advantageously treated without an external system. Soda ash has been widely used in such cases.

The reactions are reversible. Thus an excess of sulphate may cause calcium sulphate scale to form. The completeness of the reaction depends upon the solubility of the various salts, the amounts present and the temperature. At higher temperatures the carbonate decomposes to form hydroxide, liberating carbon dioxide.

Hydroxide will not prevent the formation of sulphate scale; hence sodium carbonate is not always suitable for scale prevention at higher operating pressures. (No specific upper pressure limit may be stated as plant operating condition, boiler design, local water supply and related factors must be considered.) Hydroxide is effective in converting magnesium to the insoluble magnesium hydroxide, a suspension.

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[1] Boiler Feed Water Purification, S. T. Powell, 1927, McGraw-Hill, page 29.

Sodium Aluminate Treatment

Sodium aluminate has been applied in some installations for internal treatment. It increases the alkalinity of the water, and forms a "floc," which assists in sedimentation of suspended solids.

Phosphate Treatment

Experience has shown that at operating pressures above 200 lb. per sq. in., with local conditions considered, phosphate treatment is more effective than soda ash for the prevention of scale because of the chemical stability of the calcium and magnesium phosphate. The phosphate compounds formed remain in suspension in the water and will not produce scale, providing the necessary excess of phosphate reagent is present.

Trisodium phosphate is usually used. In event the raw water contains a high bicarbonate content, hydroxide will be generated in the boiler under imposed temperature conditions. If the hydroxide concentration developed in the boiler is excessive, it may be diminished by using disodium phosphate—Na_2HPO_4; monosodium phosphate—NaH_2PO_4; or phosphoric acid—H_3PO_4.

Silicate, if present in sufficient quantity, may form a hydrous magnesium silicate scale. In the presence of hydroxide alkalinity, the silicate usually forms the soluble sodium silicate and silicate scale does not form.

Phosphate is also an inhibitive for embrittlement, a type of boiler metal failure attributed by some to high caustic soda concentration in the boiler. The experimental work of Professor Parr[2] and F. G. Straub of the University of Illinois has shown that the presence of a comparatively small amount of phosphate will inhibit caustic embrittlement.

Sulphuric acid, sodium sulphate, sodium bisulphate, or aluminum sulphate treatment is generally resorted to for the prevention of embrittlement. The presence of sodium sulphate in the boiler in a definite relationship to methyl-orange alkalinity as sodium carbonate inhibits embrittling action. This relationship varies with the boiler pressure and has been recommended in the A.S.M.E. Boiler Code, 1926.[3]

Working Pressure of Boiler, lb. per sq. in. gage	Relation of Sodium Carbonate Alkalinity	to	Sodium Sulphate
0—150	1		1
150—250	1		2
250 and over	1		3

Deconcentration by Boiler Blow-down

At high boiler ratings the presence of soluble and insoluble solids in the boiler water causes trouble due to "carry-over." To control the concentration of these solids, various types of blow-down apparatus are employed. Some involve the use of continuous blow-down with heat exchangers. This method increases the total make-up. Another method uses a small volume of blow-down to control soluble solids and a recirculation of the hot boiler water through equipment which removes the suspended solids, thus controlling the amount of these solids. Still another method involves the use of a small continuous blow-down and a circulation of the hot water through a modified hot-process external treatment system back to the boiler. Here likewise a control of soluble and insoluble solids is maintained. The mixture of zeolite treated water with untreated water in the boiler, coupled with continuous blow-down and recirculation, is still another method. All of these processes use the principle of removing from the boiler a part of the water to control concentration.

TREATMENT CALCULATIONS

The data required for calculating the quantity of chemical reagents for initiating the treatment of water, or to make comparative studies include: (1) The analysis of water; (2) the selection of the reagents required, and a knowledge of the reactions involved between the dissolved elements and the treating reagents.

Statement of Analysis

The ionic form of stating the dissolved substances in water has been adopted in this report, and was necessary because of erroneous deductions which are drawn from hypothetical, or so-called probable combinations. The mineral substances commonly found in water are present predominantly as ions, rather than as compounds. A condition of 98 per cent dissociation may be shown to exist in water containing dissolved mineral substances under 2000 parts per million. It is evident that the arbitrary union of any two ions or radicals to form a compound is empirical, failing to conform to dissociation data. Fundamental data are not available concerning the solubility of a single compound in the presence of other dissolved compounds under boiler operating conditions.

Among proponents of the hypothetical statement there is no agreement. Some develop combinations to state the quality of water as they suppose it exists in the natural state. Some formulate the combinations in an attempt to state the quality as the water would behave when evaporated. The first mentioned group emphasizes the non-scale forming compounds; the latter favors the scale-forming. Another erroneous deduction is made by attempting to calculate to compounds the radicals found by analysis in boiler scale, and so evaluate the water. The actual state of combination of the radicals in boiler scale may only be correctly determined by a petrographic study of the crystals.

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[2] Embrittlement of Boiler Plate by Samuel W. Parr and Frederick G. Straub, Bulletin No. 177 Engineering Experiment Station, University of Illinois Bulletin, Vol. XXV, No. 4, page 45, June 5, 1928.

[3] Suggested Rules for the Care of Power Boilers, Section VII, A. S. M. E. Boiler Construction Code, 1926, American Society of Mechanical Engineers, par. C A-5, pages 80-81.

The application of hypothetical combinations results in the following difficulties:

a. The analysis is incorrectly used to determine the quality of a water, and to prescribe treatment and processes.
b. The analysis is accepted at its face value by those not familiar with the subject.
c. The analysis cannot be directly compared to other analyses without involved recalculation.

Space prevents a detailed discussion. The interested reader is referred to a complete review of the subject by C. W. Foulk.[4]

The recommended items for the statement of the analysis are shown in Table I.

These data summarize the analytical results in fundamental form. The dissolved substances are stated in ionic form; the interpolated alkalinities and hardness values are shown in the conventional form.

All values are expressed primarily in parts per million (p.p.m.), by weights, except the hydrogen ion concentration, which is expressed as the pH value, and specific conductance expressed as mhos/cm. The use of parts per million simplifies computations, and conformity is established to existing station practice wherein quantity values for water and steam are expressed in pounds.

The milli-equivalent per liter (me) values to which certain parts per million values may be calculated afford a ready visualization of the character of the water. A means is provided to determine the correctness of the analysis.

The milli-equivalent of the ion is the product of the parts per million multiplied by the milli-equivalent factor. The term "milli-equivalent" factor is Stabler's[5] reaction coefficient.

> "The reaction coefficient is measured in more commonly used terms by the ratio of valence to the atomic weight of the radical."

In other words, each ion or radical has a definite combining capacity, and when the weight in parts per million of ions is multiplied by the milli-equivalent factor, the several results are directly comparable. See appendix B for milli-equivalent factors.

Water Treatment Reactions

Calculations for the reagent weights depend upon the reactions and the weight of ions to be treated. The selection of the reagent by the user depends upon the results desired, the process used and costs.

Molecular Reactions

The molecular reactions commonly used are developed in Table II.

Their presentation here differs slightly from previously published form; ionization of the dissolved salt is indicated by the respective electrical charge exponents. The compounds shown without the exponents are either insoluble or undissociated. The only purpose of presenting this deviation in the form of the reactions is to link the reactions with those shown in Table III, Section II, Water Treatment Reactions in Ionic Form.

Ionic Reactions

The ionic reactions are fundamental. Their application to the ions reported in the water analysis is easy. It will be observed that the ion in the water combines with the "active" ion of the reagent, and in some cases, e.g., $BaCO_3$, both ions are "active." To avoid over-treating, such facts must be considered.

Water Treatment Calculations

The calculation factors for water treatment are developed on the basis of ionic analyses and ionic reactions. Factors for seven of the commonly used reagents are presented in Table III, Section III.

Discussion of Table III—Ionic Reactions and Calculation Factors

Section I—Common Reagents for Treatment

The composition of the reagent when in solution is shown in ionic form. Metallic ions (sometimes called bases, positive radicals or cations), possess a positive electrical charge which by convention is shown as a positive exponent ($^+$). The repetition of the exponent is an indication of the combining power (valency) of the ion. Non-metallic ions, (sometimes called acid, negative radicals or anions) possess a negative electrical charge shown by a negative exponent ($^-$).

The data given in Section III are based upon the percentage of composition of the reagents (pure form) and their molecular weights. It must be remembered that after the values in Section III are used, they should be corrected by using the commercial purity values. Complete specifications are given in the Appendix D.

Section II—Water Treatment Reaction in Ionic Form

The ionic reactions developed are fundamental. The application of the reactions is readily made from the ions as reported in the water analysis. The reactions are keyed to the seven commonly used reagents. The user has the choice of reagents, consideration to be given to economic factors and operating conditions.

Section III—Reagent Requirements and Products of Reactions

The development of the numerical data gives for one part per million of the ion in the water to be treated, the weight in parts per million of the selected reagent and the products of reaction.

Application of Molecular and Ionic Reactions

The procedure outlined in the discussion may best be illustrated by applying the reactions to a specific example, as shown in Appendix A.

The water analysis selected at random to show

(a) Variation in composition when reported in hypothetical form
(b) Treatment reactions and calculations

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[4] Industrial Water Supplies, Geological Survey of Ohio, Fourth Series, Bulletin 29, 1925, Ohio State University, Columbus, Ohio.

[5] Stabler—Industrial Applications of Water Analyses, U. S. Geological Survey, Bulletin 274, page 167.

TABLE I

WATER ANALYSIS STATEMENT

Source			
Date			
Temperature, Degrees F.			
Dissolved Mineral Solids			p.p.m.
Dissolved Organic Solids			"
Suspended Mineral Solids			"
Suspended Organic Solids			"
Total Solids			"
Silica, SiO_2			"
Oxides of Iron and Alumina, $Fe_2O_3+Al_2O_3$			"
Dissolved Metallic Ions*			
Aluminum	AL^{+++}	p.p.m.	me.
Calcium	Ca^{++}	"	"
Iron, Ferrous	Fe^{++}	"	"
Iron, Ferric	Fe^{+++}	"	"
Hydrogen	H^{+}	"	"
Magnesium	Mg^{++}	"	"
Sodium	Na^{+}	"	"
Sum of Metallic Milli-equiv		"	"
Dissolved Non-metallic Ions*			
Bicarbonate	HCO_3^{-}	p.p.m.	me.
Carbonate	CO_3^{--}	"	"
Chloride	Cl^{-}	"	"
Hydroxide	OH^{-}	"	"
Phosphate	PO_4^{---}	"	"
Nitrate	NO_3^{-}	"	"
Sulphate	SO_4^{--}	"	"
Sum of Non-metallic Milli-equiv		"	"
Dissolved Oxygen			p.p.m.
Free Carbon Dioxide CO_2			"
Hydrogen Ion Concentration expressed as pH			
Specific Conductance at 25 Deg. Cent. mhos/cm.			
Carbonate $(CO)_3$	Alkalinity as $CaCO_3$		"
Bicarbonate $(HCO)_3$	" " "		"
Hydroxide (OH)	" " "		"
Total	" " "		"
Hydrogen (H) Acidity	" " "		"
Calcium Hardness	" "		"
Magnesium Hardness	" "		"
Carbonate Hardness (a)	" "		"
Non-carbonate Hardness (a)	" "		"
Total Hardness			"

*The order of ions does not imply relative solubility.

(a) Recommended terminology, Standard Methods of Water Analysis, 6th Edition, 1925, page 27.

TABLE II

MOLECULAR REACTIONS FOR WATER TREATMENT

ITEM NO.	DISSOLVED SALT	TREATING REAGENT		REACTION PRODUCTS	
	REACTIONS WITH LIME, HYDRATED, $Ca(OH)_2$				
1	$Ca^{++}(HCO_3)_2^-$	+ $Ca^{++}(OH)_2^-$	$\rightleftharpoons 2(CaCO_3)$	+ $2(H_2O)$	
2	$Mg^{++}(HCO_3)_2^-$	+ $2(Ca^{++}(OH)_2^-)$	$\rightleftharpoons 2(CaCO_3)$	+ $Mg(OH)_2$	+ $2(H_2O)$
3	$2(Na^+(HCO_3)^-)$	+ $Ca^{++}(OH)_2^-$	$\rightleftharpoons CaCO_3$	+ $Na_2^+ CO_3^{--}$	+ $2(H_2O)$
4	$Na_2^+ CO_3^{--}$	+ $Ca^{++}(OH)_2^-$	$\rightleftharpoons CaCO_3$	+ $2(Na^+OH^-)$	
5	$Mg^{++}SO_4^{--}$	+ $Ca^{++}(OH)_2^-$	$\rightleftharpoons Mg(OH)_2$	+ $Ca^{++}SO_4^{--}$	
6	$Mg^{++}Cl_2^-$	+ $Ca^{++}(OH)_2^-$	$\rightleftharpoons Mg(OH)_2$	+ $Ca^{++}Cl_2^-$	
7	CO_2	+ $Ca^{++}(OH)_2^-$	$\rightleftharpoons CaCO_3$	+ H_2O	
	REACTIONS WITH SODA ASH - Na_2CO_3				
8	$Ca^{++}SO_4$	+ $Na_2^+CO_3^{--}$	$\rightleftharpoons CaCO_3$	+ $Na_2^+SO_4^{--}$	
9	$Ca^{++}Cl_2^-$	+ $Na_2^+CO_3^{--}$	$\rightleftharpoons CaCO_3$	+ $2(Na^+Cl^-)$	
10	$Mg^{++}SO_4^{--}$	+ $Na_2^+CO_3^{--}$	$\rightleftharpoons Mg^{++}CO_3^{--}$	+ $Na_2^+SO_4^{--}$	
11	$Mg^{++}Cl_2^-$	+ $Na_2^+CO_3^{--}$	$\rightleftharpoons Mg^{++}CO_3^{--}$	+ $2(Na^+Cl^-)$	
12	$Mg^{++}CO_3^{--}$	+ $Ca^{++}(OH)_2^-$	$\rightleftharpoons Mg(OH)_2$	+ $CaCO_3$	
	REACTIONS WITH BARIUM CARBONATE - $BaCO_3$ - BARIUM HYDROXIDE - $Ba(OH)_2$				
13	$Ca^{++}SO_4^{--}$	+ $Ba^{++}CO_3^{--}$	$\rightleftharpoons CaCO_3$	+ $BaSO_4$	
14	$Ca^{++}SO_4^{--}$	+ $Ba^{++}(OH)_2^-$	$\rightleftharpoons Ca^{++}(OH)_2^-$	+ $BaSO_4$	
15	$Ca^{++}Cl_2^-$	+ $Ba^{++}CO_3^{--}$	$\rightleftharpoons CaCO_3$	+ $Ba^{++}Cl_2^-$	
16	$Ca^{++}Cl_2^-$	+ $Ba^{++}(OH)_2^-$	$\rightleftharpoons Ca^{++}(OH)_2^-$	+ $Ba^{++}Cl_2^-$	
	REACTIONS WITH ZEOLITE - Na_2Z *				
17	$Ca^{++}(HCO_3)_2^-$	+ Na_2Z	$\rightleftharpoons 2(Na^+HCO_3^-)$	+ CaZ **	
18	$Mg^{++}(HCO_3)_2^-$	+ Na_2Z	$\rightleftharpoons 2(Na^+HCO_3^-)$	+ MgZ **	
19	$Ca^{++}SO_4^{--}$	+ Na_2Z	$\rightleftharpoons Na_2^+SO_4^{--}$	+ CaZ	
20	$Mg^{++}SO_4^{--}$	+ Na_2Z	$\rightleftharpoons Na_2^+SO_4^{--}$	+ MgZ	
21	$Ca^{++}Cl_2^-$	+ Na_2Z	$\rightleftharpoons 2(Na^+Cl^-)$	+ CaZ	
22	$Mg^{++}Cl_2^-$	+ Na_2Z	$\rightleftharpoons 2(Na^+Cl^-)$	+ MgZ	
	REGENERATION OF ZEOLITE - BACKWASHING WITH SALT - $NaCl$				
23	CaZ	+ $2(Na^+Cl^-)$	$\rightleftharpoons Na_2Z$	+ $Ca^{++}Cl_2^-$	
24	MgZ	+ $2(Na^+Cl^-)$	$\rightleftharpoons Na_2Z$	+ $Mg^{++}Cl_2^-$	

GENERAL NOTES:

The reactions shown should be considered as probably occurring at temperatures below 210°Fahr.

Items shown without positive or negative charges are in molecular form, and are removed from the reaction by precipitation or gaseous evolution, for example, $CaCO_3$ is precipitated, CO_2 is evolved. Items shown with the charges remain in solution in ionic form.

DETAILED NOTES:

Items 1 to 7.

Calcium sulphate, sodium sulphate, calcium chloride, sodium chloride, silica and oxide of iron and alumina do not react with lime.

Items 8 - 9.

Sodium sulphate, sodium chloride, silica and oxide of iron and alumina do not react with soda. The preliminary lime treatment removes the temporary, or bicarbonate (calcium and magnesium bicarbonate) hardness, and some of the permanent hardness ($MgSO_4$+ $MgCl_2$). The ensuing soda treatment removes the remaining permanent hardness ($CaSO_4$ and $CaCl_2$) originally present in the water and the $CaSO_4$ and $CaCl_2$ formed by the lime treatment.

Items 10 - 11.

Where the water originally has only permanent hardness, preliminary lime treatment is unnecessary, and reactions 10 and 11 take place.

Item 12.

On account of the solubility of magnesium carbonate, a sufficient amount of lime should be added to the water to convert the soluble magnesium carbonate to the insoluble magnesium hydroxide as reaction 12.

Items 13 to 16.

Barium compounds after lime treatment are chiefly used for the removal of excessive sulphate. (Soda treatment does not remove sulphate; if calcium sulphate is present soda removes the calcium but leaves the soluble sodium sulphate). The reactions of barium treatment after lime treatment are 13 to 16.

Items 17 to 24.

Sodium salts, silica and oxide of iron and alumina do not react with zeolite.

* Na_2Z, CaZ, and MgZ are not the true chemical formulae of sodium, calcium and magnesium zeolite. Because of their complicated nature the radicals are represented arbitrarily by Z. The approximate formula of zeolite, which is a sodium aluminum silicate, is, $2\ SiO_2.Al_2O_3,Na_2O.6H_2O$.

** Zeolites are exchange silicates, having the power of exchanging the bases which they contain for other bases brought in contact with them. The sodium of the zeolite is replaced by the calcium and magnesium in the water. In the regeneration with salt solution ("backwashing"), sodium is re-introduced and the calcium and magnesium are removed as the soluble chlorides.

ITEM NO.	DISSOLVED SALT	TREATING REAGENT		REACTION PRODUCTS		
	REACTIONS WITH TRISODIUM PHOSPHATE $Na_3PO_4 - 12H_2O$					
25	$3(Ca^{++}(HCO_3)_2^-)$	$+ 2(Na_3^+PO_4^{---})$		$\rightleftharpoons Ca_3(PO_4)_2$	$+ 6(Na^+HCO_3^-)$	
26	$3(Mg^{++}(HCO_3)_2^-)$	$+ 2(Na_3^+PO_4^{---})$		$\rightleftharpoons Mg_3(PO_4)_2$	$+ 6(Na^+HCO_3^-)$	
27	$3(Ca^{++}SO_4^{--})$	$+ 2(Na_3^+PO_4^{---})$		$\rightleftharpoons Ca_3(PO_4)_2$	$+ 3(Na_2^+SO_4^{--})$	
28	$3(Mg^{++}SO_4^{--})$	$+ 2(Na_3^+PO_4^{---})$		$\rightleftharpoons Mg_3(PO_4)_2$	$+ 3(Na_2^+SO_4^{--})$	
29	$3(Ca^{++}Cl_2^-)$	$+ 2(Na_3^+PO_4^{---})$		$\rightleftharpoons Ca_3(PO_4)_2$	$+ 6(Na^+Cl^-)$	
30	$3(Mg^{++}Cl_2^-)$	$+ 2(Na_3^+PO_4^{---})$		$\rightleftharpoons Mg_3(PO_4)_2$	$+ 6(Na^+Cl^-)$	
	REACTIONS WITH DISODIUM PHOSPHATE - $Na_2HPO_4 - 12H_2O$					
31	$3(Ca^{++}(HCO_3)_2^-)$	$+ 2(Na_2^+HPO_4^{--})$	$+ 2(Na^+(OH)^-)^*$	$\rightleftharpoons Ca_3(PO_4)_2$	$+ 6(Na^+HCO_3^-)^{**}$	$+ 2(H_2O)$
32	$3(Mg^{++}(HCO_3)_2^-)$	$+ 2(Na_2^+HPO_4^{--})$	$+ 2(Na^+(OH)^-)$	$\rightleftharpoons Mg_3(PO_4)_2$	$+ 6(Na^+HCO_3^-)$	$+ 2(H_2O)$
33	$3(Ca^{++}SO_4^{--})$	$+ 2(Na_2^+HPO_4^{--})$	$+ 2(Na^+(OH)^-)$	$\rightleftharpoons Ca_3(PO_4)_2$	$+ 3(Na_2^+SO_4^{--})$	$+ 2(H_2O)$
34	$3(Mg^{++}SO_4^{--})$	$+ 2(Na_2^+HPO_4^{--})$	$+ 2(Na^+(OH)^-)$	$\rightleftharpoons Mg_3(PO_4)_2$	$+ 3(Na_2^+SO_4^{--})$	$+ 2(H_2O)$
35	$3(Ca^{++}Cl_2^-)$	$+ 2(Na_2^+HPO_4^{--})$	$+ 2(Na^+(OH)^-)$	$\rightleftharpoons Ca_3(PO_4)_2$	$+ 6(Na^+Cl^-)$	$+ 2(H_2O)$
36	$3(Mg^{++}Cl_2^-)$	$+ 2(Na_2^+HPO_4^{--})$	$+ 2(Na^+(OH)^-)$	$\rightleftharpoons Mg_3(PO_4)_2$	$+ 6(Na^+Cl^-)$	$+ 2(H_2O)$
	REACTIONS WITH MONOSODIUM PHOSPHATE - $NaH_2PO_4 - H_2O$					
37	$3(Ca^{++}(HCO_3)_2^-)$	$+ 2(Na^+H_2PO_4^-)$	$+ 4(Na^+(OH)^-)^*$	$\rightleftharpoons Ca_3(PO_4)_2$	$+ 6(Na^+HCO_3^-)^{**}$	$+ 4(H_2O)$
38	$3(Mg^{++}(HCO_3)_2^-)$	$+ 2(Na^+H_2PO_4^-)$	$+ 4(Na^+(OH)^-)$	$\rightleftharpoons Mg_3(PO_4)_2$	$+ 6(Na^+HCO_3^-)$	$+ 4(H_2O)$
39	$3(Ca^{++}SO_4^{--})$	$+ 2(Na^+H_2PO_4^-)$	$+ 4(Na^+(OH)^-)$	$\rightleftharpoons Ca_3(PO_4)_2$	$+ 3(Na_2^+SO_4^{--})$	$+ 4(H_2O)$
40	$3(Mg^{++}SO_4^{--})$	$+ 2(Na^+H_2PO_4^-)$	$+ 4(Na^+(OH)^-)$	$\rightleftharpoons Mg_3(PO_4)_2$	$+ 3(Na_2^+SO_4^{--})$	$+ 4(H_2O)$
41	$3(Ca^{++}Cl_2^-)$	$+ 2(Na^+H_2PO_4^-)$	$+ 4(Na^+(OH)^-)$	$\rightleftharpoons Ca_3(PO_4)_2$	$+ 6(Na^+Cl^-)$	$+ 4(H_2O)$
42	$3(Mg^{++}Cl_2^-)$	$+ 2(Na^+H_2PO_4^-)$	$+ 4(Na^+(OH)^-)$	$\rightleftharpoons Mg_3(PO_4)_2$	$+ 6(Na^+Cl^-)$	$+ 4(H_2O)$
43	$Na_2^+CO_3^{--})$	$+ Na^+H_2PO_4^-$		$\rightleftharpoons Na_3^+PO_4^{---}$	$+ CO_2$	$+ H_2O$
	REACTIONS WITH PHOSPHORIC ACID - H_3PO_4					
44	$3(Ca^{++}(HCO_3)_2^-)$	$+ 2(H_3^+PO_4^{---})$	$+ 6(Na^+(OH)^-)$	$\rightleftharpoons Ca_3(PO_4)_2$	$+ 6(Na^+HCO_3^-)$	$+ 6(H_2O)$
45	$3(Mg^{++}(HCO_3)_2^-)$	$+ 2(H_3^+PO_4^{---})$	$+ 6(Na^+(OH)^-)$	$\rightleftharpoons Mg_3(PO_4)_2$	$+ 6(Na^+HCO_3^-)$	$+ 6(H_2O)$
46	$3(Ca^{++}SO_4^{--})$	$+ 2(H_3^+PO_4^{---})$	$+ 6(Na^+(OH)^-)$	$\rightleftharpoons Ca_3(PO_4)_2$	$+ 3(Na_2^+SO_4^{--})$	$+ 6(H_2O)$
47	$3(Mg^{++}SO_4^{--})$	$+ 2(H_3^+PO_4^{---})$	$+ 6(Na^+(OH)^-)$	$\rightleftharpoons Mg_3(PO_4)_2$	$+ 3(Na_2^+SO_4^{--})$	$+ 6(H_2O)$
48	$3(Ca^{++}Cl_2^-)$	$+ 2(H_3^+PO_4^{---})$	$+ 6(Na^+(OH)^-)$	$\rightleftharpoons Ca_3(PO_4)_2$	$+ 6(Na^+Cl^-)$	$+ 6(H_2O)$
49	$3(Mg^{++}Cl_2^-)$	$+ 2(H_3^+PO_4^{---})$	$+ 6(Na^+(OH)^-)$	$\rightleftharpoons Mg_3(PO_4)_2$	$+ 6(Na^+Cl^-)$	$+ 6(H_2O)$
50	$Na_2^+CO_3^{--}$	$+ H_3^+PO_4^{---}$	$+ Na^+(OH)^-$	$\rightleftharpoons Na_3^+PO_4^{---}$	$+ CO_2$	$+ H_2O$
51	$3(Na^+(OH)^-)$	$+ H_3PO_4^{---}$		$\rightleftharpoons Na_3^+PO_4^{---}$	$+ 3H_2O$	
	REACTIONS WITH ALUMINUM SULPHATE - ALUM - $Al_2(SO_4)_3^*$					
52	$3(Ca^{++}(HCO_3)_2^-)$	$+ Al_2^{+++}(SO_4)_3^{--}$		$\rightleftharpoons 3(Ca^{++}SO_4^{--})$	$+ Al_2(OH)_6^{**}$	$+ 6(CO_2)$
53	$3(Mg^{++}(HCO_3)_2^-)$	$+ Al_2^{+++}(SO_4)_3^{--}$		$\rightleftharpoons 3(Mg^{++}SO_4^{--})$	$+ Al_2(OH)_6$	$+ 6(CO_2)$
54	$6(Na^+HCO_3^-)$	$+ Al_2^{+++}(SO_4)_3^{--}$		$\rightleftharpoons 3(Na_2^+SO_4^{--})$	$+ Al_2(OH)_6$	$+ 6(CO_2)$
55	$3(Na_2^+CO_3^{--})$	$+ Al_2^{+++}(SO_4)_3^{--}$	$+ 3(H_2O)$	$\rightleftharpoons 3(Na_2^+(SO_4^-))$	$+ Al_2(OH)_6$	$+ 3(CO_2)$

Items 25 to 30.

Technical trisodium phosphate contains 12 molecules of water of crystallization, but because the water does not enter into the reactions it is not included in the equations.

Sodium bicarbonate, sodium carbonate, sodium sulphate, sodium chloride, silica, and oxide of iron and alumina do not react with trisodium phosphate.

When sodium hydroxide, NaOH, is present in the boiler water in excess (which is frequently the case) the use of disodium phosphate, $Na_2HPO_4 \cdot 12H_2O$ is preferable. These reactions of disodium phosphate are reactions 31 to 36 incl. Monosodium phosphate, $NaH_2PO_4 \cdot 12H_2O$, or phosphoric acid, H_3PO_4, may also be used. The reactions for monosodium phosphate and phosphoric acid are given in reactions 37 to 43 incl., and reactions 44 to 51 incl.

Items 31 to 36.

Technical disodium phosphate usually contains 12 molecules of water of crystallization, but because the water does not enter into the reactions it is not included in the equations.

* Sodium hydroxide is usually present in boiler water.

** In the present of excess hydrate, bicarbonate is converted to carbonate.

Sodium bicarbonate, sodium carbonate, sodium sulphate, sodium chloride, silica and oxide of iron and alumina do not react with disodium phosphate.

Items 37 to 43.

Technical monosodium phosphate usually contains one molecule of water of crystallization, but because the water does not enter into the reactions it is not included in the equations.

* Sodium hydroxide is usually present in boiler water.

** In the presence of excess hydrate, bicarbonate is converted to carbonate.

Sodium sulphate, sodium chloride, silica and oxide of iron and alumina do not react with monosodium phosphate.

Items 44 to 51.

* Usually present in boiler water.

** In the presence of excess hydrate, bicarbonate is converted to carbonate.

Sodium sulphate, sodium chloride, silica, and oxide of iron and alumina do not react with phosphoric acid.

Items 52 to 55.

Calcium sulphate, magnesium sulphate, sodium sulphate, calcium chloride, magnesium chloride, sodium chloride, silica, and oxide of iron and alumina do not react with alum.

* Although not a water softener, alum is used in water treatment to aid coagulation and sedimentation. Alum is also a "neutralizer" and changes the small amount of calcium and magnesium carbonates remaining after lime treatment to calcium sulphate.

** The gelatinous aluminum hydroxide "floc" envelops the finer particles of suspended matter in the water and gathers them into particles of larger size, thus aiding sedimentation. Recent investigation indicates the composition of the alum "floc" in alkaline waters not to be as simple as shown here. Its composition is not definitely known and considered to be highly complex.

Sodium aluminate ($Na_2Al_2O_4$) is also used in conjunction with lime-soda treatment. Like alum, it aids coagulation and sedimentation. There is also considerable uncertainty concerning the reactions involved. With calcium bicarbonate its reaction may be considered as shown below with greater complexity in the aluminum "floc" than is shown. With magnesium bicarbonate its reaction is even more questionable; some investigators have considered that a magnesium aluminate is formed. It appears to have no reaction with calcium sulphate.

$$Ca^{++} + (HCO_3)_2^- + Na_2Al_2O_4 + 4H_2O \rightleftharpoons Al_2(OH)_6^{**} + CaCO_3 + Na_2^+ \; CO_3^{--} + 2H_2O$$

Calcium + bicarbonate + sodium aluminate and water ⇌ aluminum hydroxide ("floc") (precipitated) + calcium + carbonate (precipitated) + sodium + carbonate + water

$$\Updownarrow$$

$$2NaOH + Al_2(OH)_6$$

$$\Updownarrow$$

$$2Na^+ + 2(OH)^-$$

sodium + hydroxide

TABLE

WATER TREATMENT—IONIC

SECTION I—COMMON REAGENT FOR WATER TREATMENT

Chemical Name	Common Name	Formula	Mol.Wt	Metallic Ion		Non-Metallic Ion		Commercial Purity
				Symbol	%	Symbol	%	
Calcium Oxide	Unslaked Lime	CaO	56.1	Ca^{++}	71.47	OH^-	60.65	85% CaO
Calcium Hydroxide	Slaked Lime	$Ca(OH)_2$	74.1	Ca^{++}	54.09	OH^-	45.91	90% $Ca(OH)_2$
Barium Carbonate	Witherite	$BaCO_3$	197.4	Ba^{++}	69.60	CO_3^{--}	30.40	98% $BaCO_3$
Barium Hydroxide	Milk of Barium	$Ba(OH)_2 \cdot 8H_2O$	315.5	Ba^{++}	43.54	OH^-	10.78	50% $Ba(OH)_2$
Sodium Carbonate	Soda Ash	Na_2CO_3	106.0	Na^+	43.39	CO_3^{--}	56.61	98% Na_2CO_3
Sodium Hydroxide	Caustic Soda	$NaOH$	40.0	Na^+	57.48	OH^-	42.52	98% $NaOH$
Tri-Sodium Phosphate		$Na_3PO_4 \cdot 12H_2O$	380.2	Na^+	18.14	PO_4^{---}	24.99	96% $Na_3PO_4 \cdot 12H_2O$
Di-Sodium Phosphate		$Na_2HPO_4 \cdot 12H_2O$	358.2	Na^+	12.84	HPO_4^{--}	26.81	94% $Na_2HPO_4 \cdot 12H_2O$
Sodium Silicate	Water Glass	$Na_2O \cdot SiO_2 \cdot H_2O$			Varies		Varies	
Ferrous Sulfate	Copperas, Sugar of Iron	$FeSO_4 \cdot 7H_2O$	278.0	Fe^{++}	20.09	SO_4^{--}	34.55	98% $FeSO_4 \cdot 7H_2O$
Aluminium Sulfate	Alum	$Al_2(SO_4)_3 \cdot 18H_2O$	666.4	Al^{+++}	8.09	SO_4^{--}	43.39	111% $Al_2(SO_4)_3 \cdot 18H_2O$

Reactions assume temperature below 210°F.
Application. To compute from ionic analysis reagents weights for initiating treatment:
Select desired reactions from Section II. By Key to Section III note soluble products.
Select reaction to treat soluble product (except Na+).
Multiply reagent factor (Section III) by parts per million of ion treated. Total each reagent.
Reaction products similarly calculated.
Weight of Commercial Reagent = Weight of Pure Reagent × 100 ÷ Commercial Purity %.

SECTION III—REAGENT REQUIREMENTS AND PRODUCTS OF REACTION

		A				B				C			
		$BaCO_3$				$Ba(OH)_2 \cdot 8H_2O$				CaO			
	Ion in Water	Reagent p.p.m. Req	Product Insoluble	Product Soluble	Product Soluble	Reagent p.p.m. Req	Product Insoluble	Product Soluble	Product Soluble	Reagent p.p.m. Req	Product Insoluble	Product Soluble	Product Soluble
1	Aluminium	10.98	$Al(OH)_3$ 2.89	CO_2 2.45	Ba^{++} 7.64	17.55	$Al(OH)_3$ 2.89		Ba^{++} 7.64	3.12	$Al(OH)_3$ 2.89		Ca^{++} 2.23
2	Aluminium	21.95	$Al(OH)_3$ 2.89	HCO_3^- 6.79	Ba^{++} 15.28								
3	Bicarbonate					2.59	$BaCO_3$ 1.62	CO_3^{--} 0.49		0.46	$CaCO_3$ 0.82	CO_3^{--} 0.49	
4	Calcium	4.92	$CaCO_3$ 2.50		Ba^{++} 3.43								
5	Carbon Dioxide					3.59		HCO_3^- 1.39	Ba^{++} 1.56	0.64		HCO_3^- 1.39	Ca^{++} 0.46
6	Carbon Dioxide					7.17	$BaCO_3$ 4.48			1.28	$CaCO_3$ 2.27		
7	Carbonate					5.26	$BaCO_3$ 3.29	OH^- 0.57		0.93	$CaCO_3$ 1.67	OH^- 0.57	
8	Hydrogen	194.92		HCO_3^- 60.52	Ba^{++} 135.66	155.69			Ba^{++} 67.79	27.67			Ca^{++} 19.78
9	Hydrogen	97.90		CO_2 21.83	Ba^{++} 68.14								
10	Iron (ic)					8.48	$Fe(OH)_3$ 1.91		Ba^{++} 3.69	1.51	$Fe(OH)_3$ 1.91		Ca^{++} 1.08
11	Iron (ic)												
12	Iron (ous)	3.53	$Fe(OH)_2$ 1.61	CO_2 0.79	Ba^{++} 2.46	5.65	$Fe(OH)_2$ 1.61		Ba^{++} 2.46	1.00	$Fe(OH)_2$ 1.61		Ca^{++} 0.72
13	Iron (ous)	7.07	$Fe(OH)_2$ 1.61	HCO_3^- 2.19	Ba^{++} 4.92								
14	Magnesium					12.98	$Mg(OH)_2$ 2.40		Ba^{++} 5.65	2.31	$Mg(OH)_2$ 2.40		Ca^{++} 1.65
15	Sulfate	2.06	$BaSO_4$ 2.43	CO_3^{--} 0.62		3.28	$BaSO_4$ 2.43	OH^- 0.35					

III

REACTIONS AND CALCULATION FACTORS

SECTION II—WATER TREATMENT REACTIONS IN IONIC FORM

	Ion in Water	Active Ion of Reagent	Reaction Products	Choice of Reagents. Key to Sect III						
				$BaCO_3$	$Ba(OH)_2$	CaO	$Ca(OH)_2$	Na_2CO_3	$NaOH$	Na_3PO_4
a	Al^{+++}	$+ 3OH^-$	$= Al(OH)_3$		1-B	1-C	1-D		1-F	
b	$2Al^{+++}$	$+ 3CO_3^{--} + 3H_2O$	$= 2Al(OH)_3 + 3CO_2$	1-A				1-E		
c	Al^{+++}	$+ 3CO_3^{--} + 3H_2O$	$= Al(OH)_3 + 3HCO_3^-$	2-A				2-E		
d	HCO_3^-	$+ OH^-$	$= CO_3^{--} + H_2O$		3-B	3-C	3-D		3-F	
e	Ca^{++}	$+ CO_3^{--}$	$= CaCO_3$	4-A				4-E		
f	$3Ca^{++}$	$+ 2PO_4^{---}$	$= Ca_3(PO_4)_2$							4-G
g	CO_2	$+ OH^-$	$= HCO_3^-$		5-B	5-C	5-D		5-F	
h	CO_2	$+ 2OH^-$	$= CO_3^{--} + H_2O$		6-B	6-C	6-D		6-F	
i	CO_2	$+ CO_3^{--} + H_2O$	$= 2HCO_3^-$					5-E		
j	CO_3^{--}	$+ Ca^{++}$	$= CaCO_3$			7-C	7-D			
k	CO_3^{--}	$+ Ba^{++}$	$= BaCO_3$		7-B					
l	H^+	$+ OH^-$	$= H_2O$		8-B	8-C	8-D		8-F	
m	H^+	$+ CO_3^{--}$	$= HCO_3^-$	8-A				8-E		
n	$2H^+$	$+ CO_3^{--}$	$= CO_2 + H_2O$	9-A				9-E		
o	Fe^{+++}	$+ 3OH^-$	$= Fe(OH)_3$		10-B	10-C	10-D		10-F	
p	$2Fe^{+++}$	$+ 3CO_3^{--} + 3H_2O$	$= 2Fe(OH)_3 + 3CO_2$					10-E		
q	Fe^{+++}	$+ 3CO_3^{--} + 3H_2O$	$= Fe(OH)_3 + 3HCO_3^-$					11-E		
r	Fe^{++}	$+ 2OH^-$	$= Fe(OH)_2$		12-B	12-C	12-D		12-F	
s	Fe^{++}	$+ CO_3^{--} + H_2O$	$= Fe(OH)_2 + CO_2$	12-A				12-E		
t	Fe^{++}	$+ 2CO_3^{--} + 2H_2O$	$= Fe(OH)_2 + 2HCO_3$	13-A				13-E		
u	Mg^{++}	$+ 2OH^-$	$= Mg(OH)_2$		14-B	14-C	14-D		14-F	
v	$3Mg^{++}$	$+ 2PO_4^{---}$	$= Mg_3(PO_4)_2$							14-G
w	SO_4^{--}	$+ Ba^{++}$	$= BaSO_4$	15-A	15-B					

IN PARTS PER MILLION PER PART PER MILLION OF ION IN WATER

D				E				F				G			
$Ca(OH)_2$				Na_2CO_3				$NaOH$				$Na_3PO_4 \cdot 12H_2O$			
Reagent p.p.m. Req	Product Insoluble	Product Soluble	Product Soluble	Reagent p.p.m. Req	Product Insoluble	Product Soluble	Product Soluble	Reagent p.p.m. Req	Product Insoluble	Product Soluble	Product Soluble	Reagent p.p.m. Req	Product Insoluble	Product Soluble	Product Soluble
4.12	$Al(OH)_3$ 289		Ca^{++} 223	5.90	$Al(OH)_3$ 2.89	CO_2 2.45	Na^+ 2.56	4.45	$Al(OH)_3$ 2.89		Na^+ 2.56				
				11.79	$Al(OH)_3$ 2.89	HCO_3^- 6.79	Na^+ 5.12								
0.61	$CaCO_3$ 0.82	CO_3^{--} 0.49						0.66		CO_3^{--} 0.98	Na^+ 0.38				
				2.64	$CaCO_3$ 2.50		Na^+ 1.15					633	$Ca_3(PO_4)_2$ 2.58		Na^+ 115
0.84		HCO_3^- 1.39	Ca^{++} 0.46	2.41		HCO_3^- 2.77	Na^+ 1.05	0.91		HCO_3^- 1.39	Na^+ 0.52				
1.68	$CaCO_3$ 2.27							1.82		CO_3^{--} 1.36	Na^+ 105				
1.23	$CaCO_3$ 1.67	OH^- 0.57													
36.56			Ca^{++} 19.78	104.67		HCO_3^- 60.52	Na^+ 45.52	39.47			Na^+ 22.69				
				52.57		CO_2 21.83	Na^+ 22.81								
1.99	$Fe(OH)_3$ 1.91		Ca^{++} 1.08	2.85	$Fe(OH)_3$ 1.91	CO_2 1.18	Na^+ 1.24	2.15	$Fe(OH)_3$ 1.91		Na^+ 1.24				
				5.69	$Fe(OH)_3$ 1.91	HCO_3^- 3.28	Na^+ 2.47								
1.33	$Fe(OH)_2$ 1.61		Ca^{++} 0.72	1.90	$Fe(OH)_2$ 1.61	CO_2 0.79	Na^+ 0.82	1.43	$Fe(OH)_2$ 1.61		Na^+ 0.82				
				3.80	$Fe(OH)_2$ 1.61	HCO_3^- 2.19	Na^+ 1.65								
3.05	$Mg(OH)_2$ 2.40		Ca^{++} 1.65					3.29	$Mg(OH)_2$ 2.40		Na^+ 1.89	10.42	$Mg_3(PO_4)_2$ 3.61		Na^+ 1.89

was selected from Bulletin 29 (ibid reference 4) p. 340. The water is from Lake Erie, sampled at Painesville, Ohio; the composition reported in ionic form was:

	p.p.m.
Total solids	196
Total hardness as $CaCO_3$	117
Carbonate hardness as $CaCO_3$	100
Non-carbonate hardness as $CaCO_3$	17
Magnesium	9.7
Calcium	35
Sodium and potassium	10
Iron, ferrous	1.2
Bicarbonate	122
Chloride	14
Nitrate	0.25
Sulphate	15
Silica	12
Free carbon dioxide	2

This analysis is calculated to hypothetical form—See Table IV—using seven widely published procedures, and one procedure privately communicated. In spite of the fact that free carbon dioxide is reported, all the methods except No. 5 show the presence of normal carbonates instead of bicarbonate. To the engineer, the variations are sufficiently divergent to lead him to believe that the analyses represent more than one water supply.

The numerical factors for the molecular reactions (Table II) have not been calculated. These may be derived by stoichiometric methods. The interested reader is referred to the references appended to Table IV and, in addition, to Bulletin 29, Geological Survey of Ohio, Industrial Water Supplies, Foulk, 1925, Chapter XI, pp. 123 to 159, and to Boiler Feed Water Purification, S. T. Powell, Table XVIII, p. 332.

TABLE IV

HYPOTHETICAL COMBINATIONS

Method Source	1	2	3	4	5	6	7	8
Silica	12.0	12.0	12.0	12.0	....	12.0	12.0	12.0
Free CO_2	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Ferrous Iron	....	1.2	1.2	1.2	....	....	1.2	1.2
Calcium Carbonate	87.4	71.8	87.4	71.8	....	73.6	87.4	73.8
Calcium Bicarbonate	....	....	....	....	141.0	....	....	....
Calcium Sulphate	....	21.2	....	21.2	....	18.5	....	18.5
Calcium Nitrate	....	....	....	....	....	0.3	....	....
Magnesium Carbonate	22.0	23.9	10.7	23.9	....	33.6	22.2	33.6
Magnesium Bicarbonate	....	....	....	....	17.3	....	....	....
Magnesium Sulphate	16.6	....	14.4	....	18.7	....	16.4	....
Magnesium Chloride	....	10.8	....	11.0	2.0	....	....	....
Magnesium Silicate	....	....	....	....	10.4	....	....	....
Magnesium Nitrate	....	0.3	....	....	....	....	....	....
Ferrous Carbonate	2.5	....	....	....	1.2	2.5	....	....
Sodium Sulphate	2.6	....	....	....	....	2.9	2.9	2.9
Sodium Chloride	23.1	9.8	23.1	9.6	20.7	23.1	23.1	23.1
Sodium Nitrate	0.3	....	0.3	0.3	0.3	0.3	....	....

Method 1—Mineral Content of Water, University of Illinois, Volume 6, No. 3, Sept. 15, 1908, page 37.
2—Hale—Journal of American Chemical Society, No. 29, 1907, page 1078.
3—French, D. K., Scott's Standard Methods of Chemical Analyses, 3rd edition, Volume 2, page 1440.
4—Yoder, J. D., Finding and Stopping Wastes in Modern Boiler Rooms, Cochrane Corp., 3rd edition, 1928, section 5, Feed Water Heating and Conditioning, page 730.
5—Private Communication from C. W. Rice.
6—Low's Technical Method of Water Analyses, Analysis of Boiler Water, Section 338, page 259.
7—Griffin, R. C., Technical Methods of Analysis, 1st edition 1921, page 519.
8—Lord and Demorest, Metallurgical Analyses, 3rd edition, 1913, page 301.

INDIVIDUAL STATEMENT

The following statement of routine plant control for boiler water conditioning using a lime and soda ash process is contributed by Mr. O. K. Smith, United Light and Power Engineering and Construction Co.

The growing tendency during the past few years toward higher pressures and higher ratings has called for more exacting methods of feed water control. It is obvious that the higher the pressure, and especially the rating carried, the greater will be the tendency toward scale formation. This demands a minimum amount of incrustating solids going to the boilers from whatever treating system is in use, and the blow-downs or deconcentrating equipment carefully regulated.

In using the Lime and Soda Process, it is necessary to give the operation very close attention and to accurately control the reactions in order to reduce to a minimum the total amount of dissolved solids in the water leaving the treating apparatus. At best, there will be left in the water between 17 and 34 parts per million (1 to 2 grains per gallon) of hardness as calcium carbonate, due to the slight solubilities of calcium carbonate and magnesium hydroxide. Water treating apparatus manufacturers[6] have published diagrams designed to give the operator a rapid method of determining the condition of the treated water and an approximate degree of rectitude in the rate of chemical feed. A chart has been designed to permit reducing the total solids in the treated water to a minimum by close control of the excess chemical feed.

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[6] Examples of such charts are published in "Finding and Stopping Waste in Modern Boiler Rooms," Cochrane Corp., 1928, page 735 and 737.

The chart depends upon the relation of carbonate, bicarbonate and hydroxide alkalinity as parts per million of calcium carbonate and the interpolated reagent weights. The tests for the alkalinities are made by neutralizing a 100 c.c. sample of water with N/20 sulfuric acid to both the phenolphthalein (Pht) and methyl-orange (M.O.) end points.

The rate of increase or decrease of lime and soda ash in pounds per 1,000,000 lb. water treated is read directly from the chart so that the alkalinities of the water can be maintained at all times within the area marked "Degree of Tolerance." The Degree of Tolerance has been designed to give approximately 17 parts per million of normal carbonate alkalinity above the solubility of the incrusting carbonates in the water. The area is also located slightly in the zone of hydroxide alkalinity with respect to the addition of lime, or reduction in carbonate hardness. The magnesium should be quite completely removed as the hydroxide, leaving the principal incrusting carbonate as the calcium salt which has a solubility of approximately 20 parts per million. It is understood, of course, that with the addition of soda ash to raw water, the incrusting sulphates are first acted upon, giving partially soluble magnesium carbonate and calcium carbonate as a precipitate. The magnesium being further acted upon by excess lime producing the more insoluble magnesium hydroxide and calcium carbonate, it is readily seen that with a normal carbonate greater than the solubility of calcium carbonate as shown by titration, the complete reduction of non-carbonate hardness is indicated. This is believed to be a more accurate method of controlling the hardness, and practically eliminates the soap test, except possibly as a check, in cases where the normal carbonate test is below the solubility as stated above or in cold processes where reactions are not so complete.

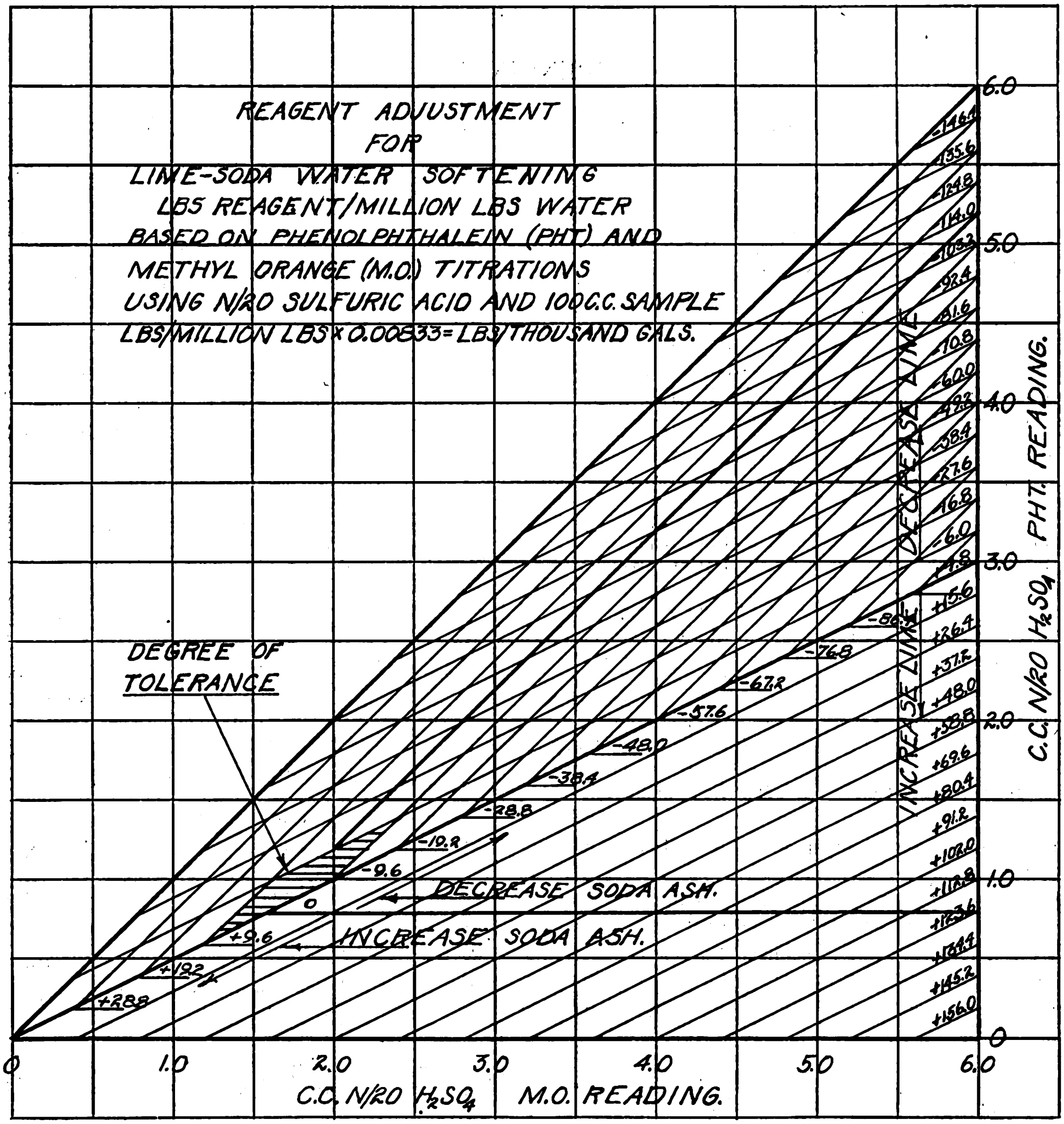

FIG. 1—REAGENT ADJUSTMENT FOR LIME-SODA SOFTENING SYSTEM.

It is necessary to carry a slight alkalinity in order to overcome corrosion and scale formation from small amounts of suspended matter. This point should be kept as low as possible due to the possibility of setting up caustic embrittlement under certain conditions. The chart gives a close approximation of the rate of increase or decrease of chemical feed assuming 70 per cent available calcium hydroxide. For the sake of clarity, the quantitative determination of the bicarbonate, carbonate and hydroxide alkalinity as calcium carbonate are shown in another chart under the section Methods of Testing (see Fig. 4.)

The use of the chart is best understood by applying the following examples:

Example 1. Treated water containing bicarbonate and carbonate alkalinity as $CaCO_3$

Readings obtained on testing 100 c.c. of water gave:
Pht. reading 1.0 c.c. N/20 H_2SO_4
M.O. reading 2.8 c.c. N/20 H_2SO_4

By reference to Fig. 1, the coordinates 1.0 and 2.8 intersect on a 34 deg. diagonal. Follow this diagonal to the right and note an increase of 26.4 lb. of lime is required. From the intercept read horizontally to the left to the heavy 34 deg. diagonal, and note a decrease of 9.6 lb. of soda ash per 1,000,000 lb. of water is required. The adjustments will produce a treated water the quality of which falls within the "degree of tolerance" area.

Example 2. Treated water containing carbonate and hydroxide alkalinity as $CaCO_3$

Readings obtained on testing 100 c.c. of water gave:
Pht. 1.6 c.c. N/20 H_2SO_4
M.O. 2.4 c.c. N/20 H_2SO_4

The coordinates 1.6 and 2.4 intersect on a 34 deg. diagonal. Follow this diagonal to the right and note a decrease of 16.8 lb. of lime per 1,000,000 lb. of water is required. The coordinates also intersect on a 45 deg. diagonal. Follow this diagonal to the left, and note zero change in soda ash is required. The adjustments indicated will produce a treated water, the quality of which falls within the "degree of tolerance" area.

APPENDIX A

CALCULATIONS FOR CONDITIONING REAGENTS BASED ON IONIC ANALYSIS OF WATER

Water analysis in ionic form, parts per million

Carbon dioxide	CO_2	2	Bicarbonate	HCO_3	122
Calcium	Ca	35	Sulphate	SO_4	15
Magnesium	Mg	9.7	Chloride	Cl	14
Sodium	Na	10	Nitrate	NO_3	0.25

The reactions applied and factors used are for:

CO_2 —Reaction h, Section II; Section III, 6-C
Mg —Reaction u, Section II; Section III, 14-C
HCO_3 —Reaction d, Section II; Section III, 3-C
Ca —Reaction e, Section II; Section III, 4-E

Lime CaO requirements, products formed, and soluble ions introduced.

Item*			
1.	$2 CO_2 \times 1.28$ CaO	=	2.6 CaO required
1a.	$2 CO_2 \times 2.27\ CaCO_3$	=	4.5 $CaCO_3$ precipitated product
2.	9.7 Mg $\times$ 2.31 CaO	=	22.4 CaO required
2a.	9.7 Mg $\times$ 2.40 $Mg(OH)_2$	=	23.3 $Mg(OH)_2$ precipitated product
2b.	9.7 Mg $\times$ 1.65 Ca	=	16.0 Ca soluble ion introduced
3.	122 $HCO_3 \times 0.46$ CaO	=	56.1 CaO required
3a.	122 $HCO_3 \times 0.82\ CaCO_3$	=	100.0 $CaCO_3$ precipitated product
3b.	122 $HCO_3 \times 0.49\ CO_3$	=	59.8 CO_3 soluble ion introduced

Soda ash Na_2CO_3 requirements, products formed and soluble ions introduced.

Ca to be conditioned includes 35 p.p.m. in original water plus 16 p.p.m. introduced in item 2b = 51. p.p.m. Ca

4.	51 Ca $\times$ 2.64 Na_2CO_3	=	134.5 Na_2CO_3 required
4a.	51 Ca $\times$ 2.50 $CaCO_3$	=	127.5 $CaCO_3$ precipitated product
4b.	51 Ca $\times$ 1.15 Na	=	59.7 Na soluble ion introduced

Note: It will be noted that in item 3b 59.8 p.p.m. Co_3 ion was introduced, and this amount when calculated to the soda ash equivalent $\frac{106\ Na_2CO_3}{60\ CO_3} = 1.767$ will reduce the amount of Na_2CO_3 required for the conditioning of the Ca ion.

4c.	59.8 $Co_3 \times 1.767$	=	105.7 Na_2CO_3
4d.	134.5 Na_2CO_3 — 105.7 Na_2CO_3	=	28.8 Na_2CO_3 actually required
4e.	58.7 Na — 46.2 Na	=	12.5 Na soluble ion actually introduced

Summarizing

Lime required, pure chemicals = 81.1 p.p.m.
Item 1 + 2 + 3
Soda ash required, pure chemicals = 28.8 p.p.m.
Item 4d

Lime required, commercial chemicals $= 81.1 \times \frac{100}{85} =$ 95.4 lb. per 1,000,000 lb. water

Soda ash required, commercial chemicals $= 28.8 \times \frac{100}{98} =$ 29.4 lb. per 1,000,000 lb. water

Soluble ions found in the conditioned water:

				p.p.m.
Na	— 10	raw water + 12.5 (Item 4e)	=	22.5
SO_4	— 15	raw water	=	15
Cl	— 14	raw water	=	14
NO_3	— 0.25	raw water	=	0.25

Non-soluble precipitated products formed removable by sedimentation and filtration

			p.p.m.
$CaCO_3$	— Items (1a) + (3a) + (4a) 4.5 + 100 + 127.5	=	232.0
$Mg(OH)_2$	— Item (2a)	=	23.3

NOTE: No corrections have been applied in the summary for the solubility of $CaCO_3$ and $Mg(OH)_2$, nor has allowance been made for the arbitrary excess of CaO and Na_2CO_3 weights usually added.

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* The item numbers refer to sequence in calculations, and not to the designation in the table.

APPENDIX B

TABLE V

CONVERSION FACTORS PARTS PER MILLION TO MILLI-EQUIVALENTS

Name of Ion	Molecular or Atomic Weight	Combining Value	Milli-Equivalent Factor Multiply by
Aluminum	26.97	3	0.1107
Barium	137.37	2	0.0146
Bicarbonate	61.008	1	0.0164
Calcium	40.07	2	0.0499
Carbonate	60.0	2	0.0333
Chloride	35.457	1	0.0282
Hydrogen	1.008	1	0.9921
Hydroxide	17.008	1	0.0588
Iron, ferric	55.84	3	0.0537
Iron, ferrous	55.84	2	0.0358
Magnesium	24.32	2	0.0822
Nitrate	62.008	1	0.0161
Phosphate	95.027	3	0.0316
Sodium	22.997	1	0.0435
Sulphate	96.064	2	0.0208

$$\text{Milli Equivalents} = \text{p.p.m. of ion} \times \frac{\text{Combining Value}}{\text{Mol. or At. Wt.}}$$

The formula for determining the correctness of the analysis is:

$$\text{Error} = 100\,\frac{\text{pe} - \text{ne}}{\text{pe} + \text{ne}}$$

pe = sum of metallic ion equivalents
ne = sum of non-metallic ion equivalents

Error need not exceed 5 per cent values for waters containing 100 or more parts per million.

Miscellaneous Factors

Dissolved Oxygen

p.p.m. by weight × 0.6975 = c.c. per liter
c.c. per liter × 1.4337 = p.p.m. by weight

Alkalinities and hardness in terms of calcium carbonate

Bicarbonate ion (HCO_3) p.p.m. × 0.8197 = (HCO_3) alkalinity as $CaCO_3$ p.p.m.

Carbonate ion (CO_3) p.p.m. × 1.667 = CO_3 alkalinity as $CaCO_3$ p.p.m.

Hydroxide ion (OH) p.p.m. × 2.941 = (OH) alkalinity as $CaCO_3$ p.p.m.

Calcium ion (Ca) p.p.m. × 2.497 = (Ca) hardness as $CaCO_3$ p.p.m.

Magnesium ion (Mg) p.p.m. × 4.115 = (Mg) hardness as $CaCO_3$ p.p.m.

Sulphate — alkalinity ratio

Total alkalinity as $CaCO_3$ × 1.06 = alkalinity as sodium carbonate p.p.m.

Sulphate ion (SO_4) × 1.479 = sodium sulphate, p.p.m.

APPENDIX C

CONDUCTANCE CALCULATIONS FROM IONIC ANALYSIS

The primary purpose of this calculation is to show the high degree of ionization of the soluble salts in water. It can also be used to check the accuracy of the analytical procedure.

The specific conductance of a water was measured before analysis and gave a value of 49.6×10^{-4} mhos per cm. at 25 deg. cent. The dissolved solids determined by evaporation was 2,150 p.p.m. After the analysis was completed, the specific conductance of the water was calculated using the equivalent ionic conductance of the various ions.

TABLE VI

Ions by Analysis	Milli-equivalents per million	Equivalent Ionic Conductance mhos per equiv. at 25 deg. cent.	Specific Conductance mhos per cm. × 10^6 at 25 deg. cent.
Hydrogen	—	× (a) 350.	= —
Calcium	1.297	× (a) 60.	= 77.82
Magnesium	0.066	× (b) 53.7	= 3.54
Sodium	33.637	× (a) 50.9	= 1712.12
Carbonate	1.322	× (c) 69.	= 91.22
Hydroxide	5.163	× (a) 192.	= 991.30
Sulphate	13.549	× (a) 79.	= 1070.37
Chloride	14.748	× (a) 75.5	= 1113.47
Phosphate	0.086	× (c) 71.	= 6.11
Nitrate	—	× (b) 70.6	= —
		Sum	5065.95
		Sp. Cond. at 25 deg. cent.	= 50.66×10^{-4}

(a) Values published in Handbook of Chemistry and Physics, Hodgman and Lange, Chemical Rubber Publishing Co., Cleveland, Ohio, 12th edition, 1927, p. 777.
(b) Value published in Electrochemistry by Creighton and Fink, John Wiley & Sons, Vol. 1, Table XXXIV, p. 134. Values calculated from 18 deg. cent. by formula 19, p. 133.
(c) Landolt-Boernstein Tables.

APPENDIX D

SPECIFICATIONS FOR REAGENTS USED IN WATER TREATMENT

Lime (CaO)

Slaking

When lumps of quicklime are immersed in water, they shall readily disintegrate into a suspension of finely divided material.

Chemical Requirements

1—For quicklime the standard of composition shall be a content of 85 per cent available calcium oxide (CaO), but quicklime of less CaO content may be accepted where conditions of service permit and the price of the less pure product is such as to give increased economy considering the additional quantity of both lime and sludge to be handled.

2—For hydrated lime the standard shall be a content of 90 per cent available calcium hydroxide ($Ca(OH)_2$). The magnesium salt content shall be less than 3 per cent.

Bonus and Reduction

Where large quantities of lime are to be purchased it is recommended that the contract be drawn to include a bonus or a reduction of 1.5 per cent in payment for each 1 per cent by which the available CaO or $Ca(OH)_2$ exceeds or falls below the standard percentage. In case of small purchases the contract should permit rejection for failure to reach the standard.

Packing and Shipment

Quicklime may be shipped in bulk, in wooden barrels, in metal drums or in waterproof bags, packages of each kind to be of uniform weight. Hydrated lime is usually shipped in paper bags holding 50 lb. net each.

Soda Ash (Na_2CO_3)

Chemical Requirements

The soda ash shall be that known as 58 per cent light soda ash and shall contain not less than 98 per cent of sodium carbonate (Na_2CO_3). The material shall be in a dry powdered form, shall contain no large lumps or large crystals, and shall be free from chips and other foreign matter.

Caustic Soda (NaOH)

Chemical Requirements

The caustic soda shall be that known as 76 per cent actual test sodium oxide and shall contain not less than 98 per cent sodium hydroxide (NaOH). The dry material is manufactured in three forms, viz. solid, ground and flaked.

Packing and Shipment

Solid caustic soda is customarily shipped in steel drums containing approximately 700 lb. net weight. The ground and flake material is commonly shipped in steel drums or in wooden barrels containing approximately 400 lb.

Barium Carbonate, (Witherite), ($BaCO_3$)

Chemical Requirements

This material shall consist of not less than 98 per cent barium carbonate ($BaCO_3$). The hydrochloric acid insoluble matter shall be less than ½ of 1 per cent.

Packing and Shipment

Barium carbonate may be shipped in bulk, in bags of uniform weight or in barrels of uniform weight.

Barium Hydroxide, ($Ba(OH)_2.8H_2O$)

Chemical Requirements

This substance shall contain at least 50 per cent of barium hydroxide, $Ba(OH)_2$ (anhydrous), shall be readily soluble in warm water and shall contain not more than a trace of iron. Other solid substances should be absent.

Packing and Shipment

Barium hydroxide may be shipped in bulk, in air-tight barrels or kegs of uniform weight.

Trisodium Phosphate, ($Na_3PO_4.12H_2O$)

Chemical Requirements

Trisodium phosphate for water treatment shall contain not less than 24 per cent of available water-soluble PO_4. The water-insoluble matter shall not exceed ½ or 1 per cent.

Packing and Shipment

Trisodium phosphate may be shipped in bulk, in bags of uniform weight or in barrels of uniform weight.

Disodium Phosphate, $Na_2HPO_4 12H_2O$

Chemical Requirements

Disodium phosphate for water treatment shall contain not less than 25 per cent of available water-soluble PO_4. The water-insoluble matter shall not exceed ½ of 1 per cent.

Packing and Shipment

Disodium phosphate may be shipped in bulk, in bags of uniform weight or in barrels of uniform weight.

Sulphate of Alumina ($Al_2(SO_4)_3$ + *Water of Crystallization*)

Chemical Requirements

1. The material shall be basic, shall contain not less than 17 per cent available water-soluble alumina (Al_2O_3) and shall not contain more than 0.75 per cent iron (Fe_2O_3).

Insoluble Matter

1. Sulphate of alumina from which the insoluble material has been removed shall contain not more than 0.5 per cent of material insoluble in distilled water.

2. Sulphate of alumina from which the insoluble material has not been removed shall contain not more than 7.5 per cent of material insoluble in distilled water.

Sizes of Lumps or Grains

1. Lump sulphate of alumina shall range in size from ¾ to 3 in.

2. Ground sulphate of alumina for use in dry-feeding machines shall be of such size that not less than 95 per cent shall pass a woven sieve having 10 meshes per linear in., and 100 per cent shall pass a sieve having 4 meshes per linear in.

Packing and Shipment

1. Sulphate of alumina may be shipped in bulk, in bags of uniform weight or in barrels of uniform weight.

Sulphate of Iron ($FeSO_4.7H_2O$)

Chemical Requirements

1. Sulphate of iron shall be what is commonly known as sugar sulphate of iron theoretical formula, Fe $So_4.7H_2O$.

2. It shall contain not less than 98 per cent of pure ferrous sulphate ($FeSO_4.7H_2O$), not more than 1/15th of 1 per cent of free acid and shall be clean and free from all dirt and particles of foreign matter.

Packing and Shipment

Sulphate of iron may be shipped in bulk in paper-lined, tight box cars, in bags, in barrels or in castors, packages of each kind to be of uniform weight.

Sampling and Testing

1. The composition of the chemicals shall be determined by analyzing samples taken promptly upon the arrival of the material at the point of consumption.

2. When chemicals are shipped in bulk, the sample shall be so taken that it will represent an average of all parts of the shipment from top to bottom, and shall not contain a disproportionate share of the top and bottom layers. It shall weigh at least 10 lb. (in the case of lump lime 100 lb.), and shall be crushed if necessary, mixed thoroughly and "quartered" to provide two 1-lb. samples, one of which shall be kept carefully sealed for use in a possible retest as provided hereinafter.

3. When shipped in packages at least 3 per cent of the number of packages shall be sampled. They shall be taken from various parts of the shipment, dumped, mixed and sampled as in the above paragraph.

4. When sampling quicklime or hydrated lime it is essential that the operation be conducted as expeditiously as possible, in order to avoid undue exposure of the material to the air. The sample to be sent to the laboratory shall immediately be placed in an air-tight container in which the unused portion shall be stored until the shipment has been finally accepted or rejected by the purchaser.

Resampling

1. Notice of dissatisfaction with a shipment based on these specifications must be in the hands of the consignor within 10 days after the receipt of the shipment at the point of destination. If the consignor desires a retest, he shall notify the consignee within 5 days of receipt of the notice of complaint. The duplicate sample shall then be forwarded for a test to some laboratory agreed upon by both parties. This retest shall be made at the expense of the consignor. The results of the retest shall be accepted as final.

LUBRICATION

Committee Statement

Approved test methods for judging the quality of turbine oil are presented under "Recommended Practices" (p. 19) as part of the Committee's activities. Attention is called to the fact that these tests alone are not suitable for determining the comparative desirability of different brands of new oil for turbine lubricating service. They will, however, serve to establish variations in shipments of the same brand of oil and also (especially the Water and Sediment Test, the Steam Emulsion Test, and the Neutralization Number), serve to measure the degree of alteration the oil undergoes in service.

To establish the comparative suitability of various brands of oil an oxidation test of some degree of acceleration should be used. No such test has been included in this group because it has never been approved. Two such tests have received considerable study by some members of the Committee: (1) The Funk Sludge Test and (2) The Rogers Stability Test.

The Committee should consider these two tests with a view to establishing their suitability in selecting oils for turbine service.

Individual Statement

A laboratory study on the sludging of turbine oils has been made by Mr. C. P. Menges, New York Edison Co. This supplements the subcommittee report published in Power Station Chemistry, N. E. L. A. Publication No. 289-28. Mr. Menges reports:

A comparison is made between the data obtained by sludging a sample of turbine oil in a Funk Sludging Machine, and the data obtained by observing the behavior of this oil in a 35,000-kw. G. E. Turbine.

Comparisons are made of the data obtained by sludging heavy and light turbine oils in a Funk Sludging Machine.

From the tests (heavy and light turbine oils) it would not be advisable to draw general conclusions, but it appears that a heavier oil is limited in service to viscosity, while, on the other hand, a lighter oil develops a considerably greater neutralization number and sludge content long before the limiting viscosity is reached. The origin and method of refining of lubricating oils are also important factors.

Data on Oil In Service and Sludged In a Funk Sludging Machine

The oil in No. 12 turbine (35,000 kw.), having an oil reservoir of 1100 gal. capacity, has been in operating service 3757 hr. It had been intended not to add any new oil during the time of test, but owing to work done on the machine, 79 gal. were added to make up for deficiency, after 2726 hr. operation.

Data obtained from the service test and sludging test are presented in tabular form.

At the end of the sludging test, the condition of the oil (assuming an accelerated oxidation of 100:1) was such as would be given by 12,000 hr. of actual service operation. However, after 3757 hr., no sludge developed in the oil, but some sludge and water which did not go into circulation was found in the bottom of the oil reservoir. The probable

TABLE VII

DATA ON TURBINE OIL IN SERVICE

Hr. in Service	Neutralization Number MgKOH	Saybolt Viscosity at 100° F. Seconds	Saponification No. %
110	0.073	240	trace
301	0.098	...	....
431	.....	...	....
544	0.116	239	....
777	0.157	...	....
894	0.190	...	0.29
1111	0.198	...	....
1399	0.210	...	....
1681	0.300	...	....
1914	0.300	...	....
2051	0.300	249	0.40
2139	.....	...	0.40
2600	0.334	...	....
2726	0.390	...	0.82
*3220	0.374	...	....
3460	0.392	...	....
3768	0.460	253	0.78

* 79 gal. new oil added after 2726 hr. service.

OIL SLUDGED IN FUNK'S SLUDGING MACHINE

After sludging 120 hr.......	0.800	260	2.30

reason for no sludge formation was the absence of any appreciable quantity of water and also the more resistant nature of this oil to oxidation or deterioration as shown in the comparison of light and heavy turbine oil study. It was thought advisable to discontinue the plant test, not so much on account of greater increase in acidity or oxidation, but to prevent the oil from attaining a greater viscosity than 255 sec. at 100 deg. fahr. (Saybolt), which is the limiting viscosity of our system oil. By periodic addition of fresh oil to the system of approximately 25,000 gal., no troublesome sludge was produced. This oil has been in continual service for over 15 yr. De Laval separators are being used to separate the water and the small amount of sludge.

The system oil to date shows the following tests:

Neutralization Number, mg KOH per gm oil.......	0.50
Saponification Number, expressed in per cent.......	1.2
Water, per cent....................................	0.8
Sludge, milligrams per 100 c.c......................	10.4
Saybolt viscosity at 100 deg. fahr., sec.............	255

Previous to the use of this oil, an oil of lower viscosity had been in service. After a short time formation of sludge was noticed in the circulating oil, which gradually separated in the pipe lines and clogged the strainers. This oil was subsequently replaced by the oil now in use, which is giving very satisfactory service.

Comparison of Heavy and Light Turbine Oils in Funk Sludging Machine

Comparative data on three turbine oils are shown graphically in Fig. 2.

The samples were tested in the Funk Sludging Machine under similar conditions. Eight and one-half gal. of oil were circulated at a temperature of 200 deg. fahr., passing a 50 per cent mixture of air and oxygen through the oil at a rate of 10 cu. ft. per hr. No additions of new oil were made during the test. A 100 c.c. sample was withdrawn from the machine each 2 hr. The condensate varied from 200 c.c. to 375 c.c. water each 2 hr. This was not returned to the machine but an equivalent quantity of fresh water was added, the condensate samples being reserved for acid tests, etc.

A marked difference was found in these oils. Neutralization number, sludge and emulsion developed in the lighter oils to a much greatest extent. Sample No. 3 emulsified so badly after 90 hr. that it was difficult to continue the test after that time.

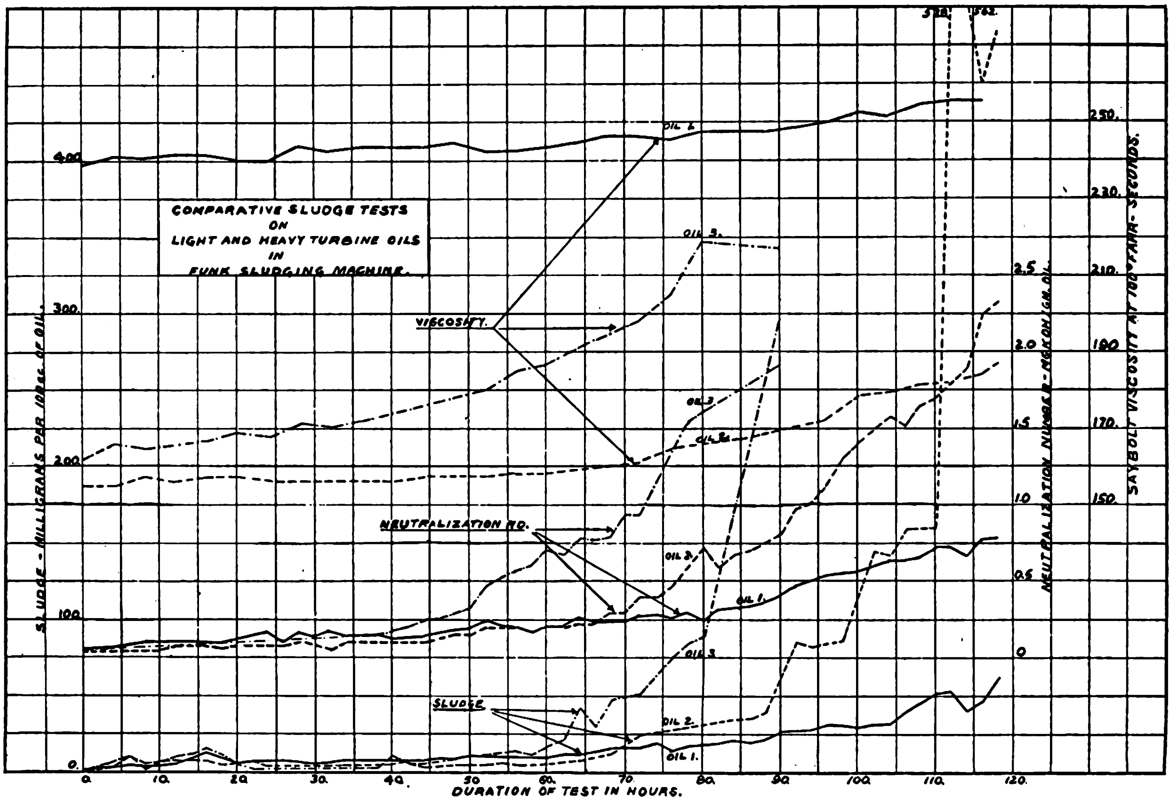

FIG. 2—COMPARATIVE SLUDGE TESTS ON LIGHT AND HEAVY TURBINE OILS IN FUNK SLUDGING MACHINE.

METHODS OF TESTING

Committee Statement

The Committee is assembling recommended test procedures for use in the laboratory and in the field. At a suitable time, the methods will be published in manual form.

Methods of tests for turbine oils have been compiled from various sources. The tests, when applied to new oils to establish variations in quality of various shipments are: Gravity, Flash and Fire, Pour, Viscosity, Steam Emulsion Neutralization Number, Corrosion, Water and Sediment, and Oxidation at High Temperature (Slight Method). Tests, when applied to turbine oils in service to show alteration in quality are: Viscosity, Steam Emulsion, Neutralization Number, Water and Sediment.

The Committee recommends the determination of the hydrogen ion concentration, pH, in the station water supplies. The test is made by either colorimetric or electrometric procedures. Ample operating instructions are furnished by the equipment manufacturers. Powell[7] states:

> The hydrogen ion concentration of a water is a measure of its alkalinity or acidity. This test differs from the ordinary alkalinity or acidity tests because it is not only more delicate, but is indicative of conditions that are not shown by these tests. The test is important in routine practice and is sufficiently simple to be made by plant operators who have no special training in chemistry.
>
> This determination has a specific sphere of usefulness in the control of boiler feed water, since it indicates the active acidity or alkalinity of a water which is not discernible by ordinary titrimetric analyses.
>
> The electrolytic determination of the H-ion concentration consists of measuring a potential difference or electromotive force between two electrodes which form the extremities of a so-called gas chain.
>
> To determine the hydrogen ion concentration by the colorimetric method, 10 c.c. of water to be tested are placed in a test tube and ½ c.c. of a prepared dye (indicator) is added. The treated sample is allowed to stand for 5 min., and the color produced is also allowed to stand for 5 min. and then matched against one of the color standards which have been prepared by the same indicator as used in the test. The number of the standard color tube that matches the treated sample of water is the hydrogen-ion concentration number. The standards are numbered from 0 to 14.0. The tubes above 7.0 may be considered within the alkaline range, and those below 7.0 within the acid range.
>
> The foregoing test is less accurate than the electrometric method. The latter method is also desirable in many instances, since a permanent record may be obtained by the use of recording devices.

The change of the pH in water with rising temperature is shown graphically in Fig. 3. This curve was prepared by Mr. C. H. Fellows, Detroit Edison Co.

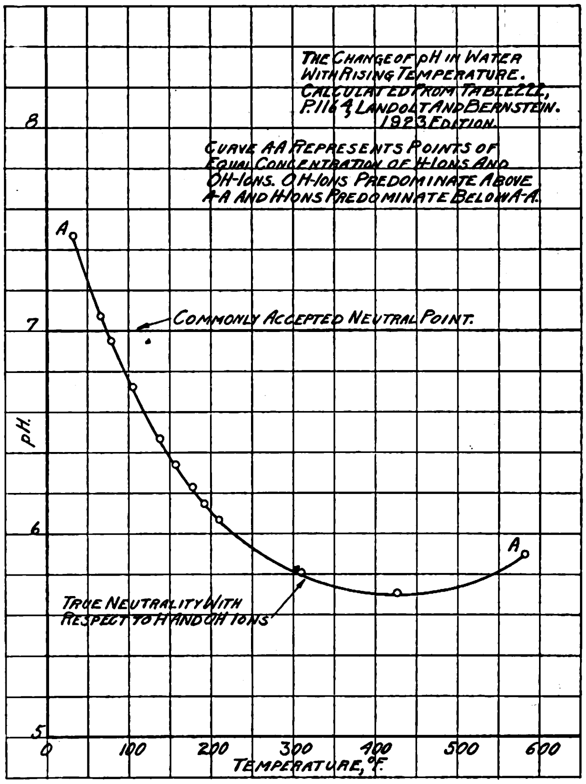

FIG. 3—THE CHANGE OF pH IN WATER WITH RISING TEMPERATURE.

PLANT METHOD FOR THE READY ESTIMATION OF THE VARIOUS ALKALINITIES IN WATER

Individual Statement

Mr. O. K. Smith, United Light & Power Engineering & Construction Co., Davenport, Iowa, presents the following plant method for the ready estimation of the various alkalinities in raw, treated and boiler water.

Method of Test

Measure 100 cc. of the water to be tested in a volumetric flask, and empty into a 200 cc. casserole. Add four or five drops of phenolphthalein (Pht) indicator and titrate the sample with N/20 sulphuric acid until the pink color just disappears.

The number of cc. used is the Pht. reading. Next add two or three drops of methyl-orange (M.O.) indicator to the same sample and continue the titration until the color changes from yellow to orange. The first definite tinge of orange which does not fade on stirring is the end point. The total number of cc. of acid used starting from the beginning of the Pht. titration to the end of the methyl-orange titration is the M.O. reading.

The various alkalinities may be read directly from a chart, eliminating calculations.

The chart is divided into two areas by three datum lines: the x-axis along which the carbonate alkalinity is zero, a heavy 34 deg. diagonal along which bicarbonate and hydroxide alkalinities are zero, and a heavy 45 deg. diagonal along which carbonate alkalinity is zero. (All alkalinities are expressed in parts per million of calcium carbonate).

The area included between the x-axis and the heavy 34 deg. diagonal denotes amounts of carbonate and bicarbonate alkalinity, carbonate alkalinity being indicated by lines parallel to the x-axis, and the bicarbonate alkalinity being indicated by lines parallel to the 34 deg. diagonal.

The area included between the heavy 34 deg. diagonal and the heavy 45 deg. diagonal denotes various amounts of carbonate and hydroxide alkalinities, carbonate alkalinity being indicated by lines parallel to the heavy 45 deg. diagonal, and hydroxide alkalinity being indicated by lines parallel to the heavy 34 deg. diagonal.

Use of Chart

The readings obtained on a sample of water were:

$$a \begin{cases} \text{Pht reading } 1.0 \text{ cc. N/20 } H_2SO_4 \\ \text{M.O reading } 2.8 \text{ cc. N/20 } H_2SO_4 \end{cases}$$

and on another water

$$b \begin{cases} \text{Pht reading } 1.6 \text{ cc. N/20 } H_2SO_4 \\ \text{M.O reading } 2.4 \text{ cc. N/20 } H_2SO_4 \end{cases}$$

By reference to Fig. 2 using the results of test a: the coordinates 1.0 and 2.8 intersect in the area of bicarbonate and carbonate alkalinities, on the horizontal line (read right) showing 50 p.p.m. carbonate alkalinity and on a 34 deg. diagonal, (read obliquely left) showing 20 p.p.m. bicarbonate alkalinity. Using the results of test b: the coordinates 1.6 and 2.4 intersect in the area of carbonate and hydroxide alkalinity; on a 34 deg. diagonal (read obliquely left) showing 20 p.p.m. hydroxide alkalinity, and on a 45 deg. diagonal (read obliquely right) showing 40 p.p.m. carbonate alkalinity.

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[7] Note—Part of Powell's discussion is presented in Boiler Feed Water Purification by S. T. Powell, McGraw-Hill Book Co., 1927, page 314.

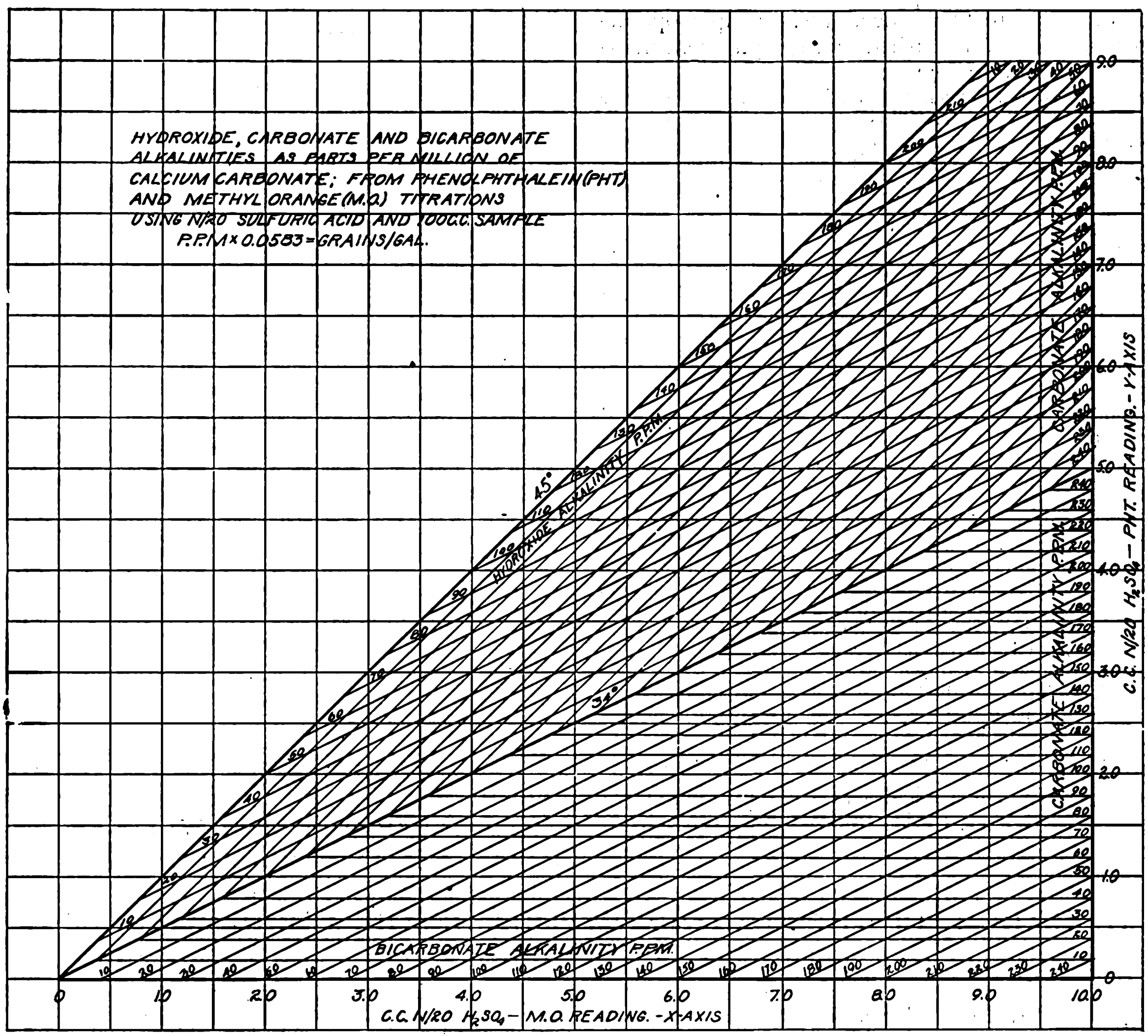

FIG. 4—Ready Estimation of Alkalinities from Titration Values.

TENTATIVE METHODS FOR DETERMINATION OF PHOSPHATE IN BOILER WATER

Scope

In boiler water treatment it is often advisable to use phosphate for treating the water. In order to control the use of phosphate, it is also advisable to be able to determine rapidly and with a fair degree of accuracy, the soluble phosphate in the boiler water at frequent intervals.

Application of Test

The application of this method is intended for use on boiler water samples. If organic matter is present in sufficient amounts to cause a marked coloration of the water, this method cannot be used.

Description of Method of Testing for Phosphate

The test is dependent upon the fact that molybdenum present as phospholybdic acid may be reduced in the presence of an excess of molybdic acid. The reducing agent used is Hydroquinone. If hydroquinone is added to an acid solution of molybdic acid, no phosphate being present, the solution will be colorless when treated with alkaline sulphite; but if phosphate is present, phospholybdic acid is formed and reduced giving a blue color. As small an amount as 5 p.p.m. of phosphate gives a distinct blue color in this test.

Apparatus

1. Glass funnels and filter paper.
2. 250 c.c. volumetric flasks.
3. 10 c.c., 5 c.c. pipettes.
4. 50 c.c. graduated cylinder.

Solutions

Molybdic Acid Solution

125 grams of pure ammonium molybdate are dissolved without heat in about 2 liters of phosphate-free distilled water. 75 c.c. of conc. H_2SO_4 are

slowly added and the volume made up to 2½ liters (roughly). A slight blue coloration does not hinder the use of this solution.

Hydroquinone Solution

50 grams of pure hydroquinone are dissolved in about 2½ liters of phosphate-free distilled water and 3 c.c. of conc. H_2SO_4 added.

Carbonate-Sulphite Solution

To 6 liters of distilled water add 1500 grams of commercial soda ash. Dissolve 225 grams of sodium sulphite in 1500 c.c. of water and add to the above solution.

Stock Solution of Phosphate

Pure mono-potassium phosphate is finely ground, dried at 105 deg. cent. for three hours, cooled and kept in desiccator. Of this salt 0.1432 grams are dissolved in distilled water, 5 c.c. of concentrated H_2SO_4 added and made up to one liter in a volumetric flask with distilled water. One c.c. of this solution contains one-tenth of a milligram of PO_4.

Sulphuric Acid Solution

300 c.c. of concentrated H_2SO_4 are added to about 2200 c.c. of distilled water. This is labeled H_2SO_4.

Determination of Phosphate

Three 250 c.c. volumetric flasks are required. Into the first, measure 50 c.c. of the filtered sample of boiler water. 10 c.c. of the standard phosphate solution are delivered by a pipette into the second flask, and 20 c.c. of the phosphate solution are delivered into the third flask. Add to each flask in succession, 10 c.c. sulfuric acid, 5 c.c. of molybdic acid and 5 c.c. of hydroquinone solution. Allow the reactions to proceed for five minutes. Add to each flask 15 c.c. of the carbonate sulphite solution. Agitate each flask to mix the reagents. Fill each flask to the 250 c.c mark with distilled water.

Place the flask containing the sample of boiler water between the two flasks containing the standard solutions and compare colors. If the color is lighter than the flask containing the 10 c.c., it is less than 20 p.p.m. of PO_4. If it is between the one containing the 10 c.c. and the one containing 20 c.c., it is between 20 and 40 p.p.m. If it is darker than the one containing 20 c.c., it is over 40 p.p.m.

Different maximum and minimum values may be established by changing the amount of standard phosphate solution used.

This method gives the PO_4 content with a possible error of about 10 per cent.

RECOMMENDED PRACTICES

Tests for Turbine Oils—Gravity

Signficance of Test

Gravity used in connection with other properties of the oil may serve as an index of uniformity of shipments. Gravity is of little significance as an index of the quality of the oil. The gravity of a petroleum oil is a numerical value which is an index of a measured volume of the product.

Method of Test

TENTATIVE METHOD OF TEST FOR GRAVITY BY MEANS OF THE HYDROMETER

Abstracted from A. S. T. M. Tentative Specification Serial Designation: D 287—28 T

ISSUED, 1928

DEFINITIONS

2. (*a*) *Specific Gravity.*—The specific gravity of a petroleum oil and of mixtures of petroleum products with other substances is the ratio of the weight of a given volume of the material at a temperature of 60 deg. fahr. (15.56 deg. cent.) to the weight of an equal volume of distilled water at the same temperature, both weights being corrected for the buoyancy of air.

(*b*) *A.P.I. Gravity.*—The A.P.I. gravity scale is an arbitrary one which is related to the specific gravity of a petroleum oil in accordance with the formula:

$$\text{Degrees A. P. I.} = \frac{141.5}{\text{sp. gr. } 60°/60° \text{ F.}} - 131.5$$

Table VIII showing the equivalent specific gravity, pounds per gallon and gallons per pound at 60 deg. fahr. for each degree A.P.I. from 0 to 100 deg. A.P.I. is given in the Appendix to this method.

APPARATUS

There are two kinds of hydrometers in common use, the plain type and the combined thermometer and hydrometer, known as a thermo-hydrometer. Although the thermo-hydrometer type of instrument is sufficiently satisfactory for routine use, the thermometer incorporated in it possesses certain inherent defects of design which render it unfit for use when results of unquestioned accuracy are desired. Therefore, in all referee tests the temperature of the sample being tested must be determined by means of a separate thermometer.

3. *Hydrometer Calibrations.*—The hydrometer may be calibrated either in terms of specific gravity or degree A.P.I. It shall be of glass of the conventional constant mass and variable displacement type, with a paper hand-written scale. The range may be any suitable portion of the interval between 0 and 100 deg. A.P.I. (1.0760 to 0.6112 sp. gr.) and it shall be so divided that 0.1 deg. A.P.I. or 0.0005 of a unit of specific gravity shall not be less than 1 mm. (0.039 in.) in width. The value of the smallest sub-divisions shall be 0.1 deg. A.P.I. when the instrument is calibrated in degrees A.P.I. or 0.0005 of a unit of specific gravity when it is calibrated in the specific gravity scale. The accuracy of calibration of the hydrometer shall be such that the error at any point of the scale shall not exceed the value of one smallest scale division. Each fifth smallest sub-division on the scale shall be denoted by a longer line. The graduations shall be numbered at each multiple of 1 deg. A.P.I. or at each multiple of 0.01 of a unit of specific gravity, in accordance with the type of calibration used. The paper scale, or an extension thereof, of the hydrometer shall have plainly printed on it the name of the manufacturer, a serial number and the definition of the scale.

NOTE.—In the case of A.P.I. hydrometers the scale is defined by the expression:

$$\text{Degrees A.P.I.} = \frac{141.5}{\text{sp. gr. } 60°/60° \text{ F.}} - 131.5$$

In the case of specific gravity hydrometers the inscription "Sp. gr. 60°/60° fahr., Petroleum" is sufficient to denote that the hydrometer is intended to determine specific gravities at 60 deg. fahr. relative to water at 60 deg. fahr. when the readings are taken at 60 deg. fahr.

The long axis of the hydrometer shall assume a vertical position when the instrument is floating freely in the sample. Any solid material, such as shot, paper, etc., used in the weighing of the hydrometer shall be firmly secured in place by the use of a suitable cement, the softening point of which lies well above 195 deg. fahr. When mercury is used for weighting, it shall be placed in a small bulb below the main bulb of the hydrometer and completely separated from the bulb by means of a glass partition.

4. (*a*) *Separate Thermometer.*—These specifications cover a total immersion thermometer graduated in either centigrade or fahrenheit degrees as specified, the ranges being — 20 + 102 deg. cent. or — 5 to + 215 deg. fahr. respectively.

Type: Etched stem, glass.

Liquid: Mercury.

Range and Subdivision: — 20 to + 102 deg. cent. in 0.2 deg. cent. or — 5 to + 215 deg. fahr. in 0.5 deg. fahr.

Total Length: 403 to 409 mm. (15.87 to 16.10 in.).

Stem: Plain front, enamel back, suitable thermometer tubing. Diameter 7 to 8 mm. (0.276 to 0.315 in.).

Bulb: Corning normal or equally suitable thermometer glass, heavy wall. Length 14 to 19 mm. (0.55 to 0.75 in.). Diameter 6 to 7 mm. (0.236 to 0.275 in.).

Distance to — 20 deg. cent. or — 5 deg fahr. Line from Bottom of Bulb: 32 to 51 mm. (1.26 to 2.00 in.).

Distance to + 102 deg. cent. or + 215 deg. fahr. Line from Top of Stem: 25 to 45 mm. (0.98 to 1.77 in.).

Filling Above Mercury: Nitrogen gas.

Top Finish: Glass ring.

Graduation: All lines, figures and letters clear cut and distinct. Each whole degree centigrade or fahrenheit line to be longer than the remaining lines. Graduations to be numbered at each multiple of 2 deg. cent. or 5 deg. fahr.

Immersion: Total.

Special Marking: "A. S. T. M. gr.," a serial number and the manufacturer's name or trade mark shall be etched on the stem.

Scale Error: The error at any point of the scale when the thermometer is standardized as provided below shall not exceed 0.1 deg. cent. or 0.25 deg. fahr.

Standardization: The thermometer shall be standardized immersed in the testing bath to the top of the mercury column, at the ice point and at temperature intervals of from 15 to 20 deg. cent. or 30 to 40 deg. fahr.

Case: The thermometer shall be supplied in a suitable case on which shall appear the marking: "A. S. T. M. gr. — 20 to + 102 deg. cent." or "A. S. T. M. gr — 5 to + 215 deg. fahr." according to the type of thermometer.

NOTE.—For the purpose of interpreting these specifications the following definitions apply:

The total length is the over-all length of the finished instrument.

The diameter is that measured with a ring gage.

The length of the bulb is the distance from the bottom of the bulb to the beginning of the enamel backing.

The top of the thermometer is the top of the finished instrument.

(*b*) *Thermometer for Thermo-hydrometer.*—The thermometer incorporated in the thermo-hydrometer type of instrument shall be of the paper scale type (scale to be placed in either the bulb or stem of the hydrometer) having a range of from 20 to 130 deg. fahr. or 60 to 220 deg. fahr. depending upon the range of the hydrometer. The paper scale shall be graduated in 2 deg. fahr. divisions accurate to ± 1 deg. fahr. (Note) and shall be printed in red ink to avoid any possibility of its being confused with the black gravity scale.

NOTE.—This approximates the limit of accuracy which it is possible to obtain in this type of thermometer. It becomes at once obvious, therefore, in view of the following facts, that a high degree of accuracy in the determination of the gravity of an oil cannot be expected when this type of thermometer is used for the determination of the temperature of the sample undergoing test.

Between 10 and 11 deg. A.P.I., 1 deg. A.P.I. is equivalent to 0.0070 of a unit of specific gravity. Between 90 and 91 deg. A.P.I., 1 deg. A.P.I. is equivalent to only 0.0028 of a unit of specific gravity. In correcting the observed gravity of an oil of 10 deg. A.P.I. for temperature, an error of ± 2 deg. fahr. in the determination of the temperature of the oil will introduce maximum error of only 0.1 deg. A.P.I. (0.0007 sp. gr.) in the gravity. In correcting the observed gravity of an oil of 90 deg. A.P.I. for temperature, an error of 1 deg. fahr. in the determination of the temperature of the oil will introduce a maximum error of 0.3 deg. A.P.I. (0.00084 sp. gr.) in the gravity. For convenience, the following table is given which shows the errors at each tenth degree A.P.I. from 10 to 100 deg. A.P.I. which may be introduced into a corrected gravity as the result of an error of ± 1 deg. fahr. in the determination of the observed temperature:

Observed Gravity, deg. A.P.I.	Resultant Maximum Error in Corrected Gravity, deg. A.P.I. per ± 1 °F. Error in Observed Temperature
10-11	0.1
20-21	0.1
30-31	0.1
40-41	0.1
50-51	0.2
60-61	0.2
70-71	0.2
80-81	0.2
90-91	0.3
At 99	0.3

5. *Hydrometer Cylinder.*—The hydrometer cylinder in which the sample for the gravity test is confined shall be made of clear glass and shall be cylindrical in shape. For convenience in pouring it may have a lip on the rim. The inside diameter of the cylinder shall be at least 2.54 cm. (1.0 in.) greater than the outside diameter of the hydrometer used in it. The height of the cylinder shall be such that the length of the column of sample it contains is greater by at least 2.54 cm. 1.0 in.) than the portion of the hydrometer which is immersed beneath the surface of the sample after a state of equilibrium has been reached.

PROCEDURE

6. (*a*) The determination of the gravity of crude petroleum or its products may be made at any suitable temperature between 0 and 195 deg. fahr. in accordance with the procedure described in Section 7. The observed gravity at the observed temperature shall be corrected to the gravity at 60 deg. fahr. as described in Section 8.

(*b*) The gravity of mixtures of petroleum products with other substances shall be determined at a temperature of 60 deg. fahr. in accordance with the procedure described in Section 7, since there are no nationally recognized tables giving the coefficients of expansion of such mixtures.

7. The sample to be tested for gravity shall be poured into the clean hydrometer cylinder without splashing, so as to avoid the formation of air bubbles and to reduce to a minimum the evaporation of the lower boiling constituents of the lighter oils. If air bubbles are formed they shall be removed after they have collected on the surface by touching them with a piece of clean blotting paper or filter paper before the hydrometer is placed in the sample. If the sample to be tested is easily volatile both the hydrometer and hydrometer cylinder shall be cooled before use to a temperature below that of the sample.

The cylinder containing the prepared sample shall be placed in a vertical position in a place free from air currents. The hydrometer shall be carefully lowered into the sample to a level, two smallest scale divisions below that at which it will float and shall then be released. When the hydrometer has come to rest, floating freely away from the walls of the cylinder, the gravity shall be read as the point at which the surface of the sample apparently cuts the hydrometer scale. In the case of samples sufficiently transparent this point shall be determined by placing the eye slightly below the level of the liquid and slowly raising it until the surface of the sample first seen as a distorted ellipse seems to become a straight line cutting the hydrometer scale. In the case of non-transparent samples where this procedure cannot be followed, the point on the hydrometer scale to which the sample rises above the main surface of the liquid shall be read with the eye placed slightly above the plane of the surface of the sample. This reading shall then be corrected by subtracting in the case of A.P.I. hydrometers or adding in the case of specific-gravity hydrometers, an amount equal to the height which the sample rises on the hydrometer stem above the main liquid surface. This height will vary for different oils and different hydrometers, and the amount of correction necessary will depend upon the width of the hydrometer scale graduations. The necessary correction factor shall be determined, therefore, for the particular hydrometer in use by observing the height above the main surface of the liquid to which the oil rises on the hydrometer scale when the hydrometer in question is immersed in a transparent oil having a surface tension similar to that of the sample under test.

The temperature of the sample shall be determined from the reading of the separate thermometer placed in the sample or from that of the thermometer contained in the hydrometer when the thermo-hydrometer type of instrument is used (see Note).

NOTE.—Precautions should, of course, be taken to prevent the temperature of the sample from changing appreciably during the time necessary to complete the test. This may be done when testing non-viscous oils by choosing a temperature of test only slightly different from the room temperature. When testing viscous oils which must be heated before testing it will be necessary to surround the test cylinder with a bath maintained at a constant desired temperature during the time of test.

Although it is usually satisfactory to determine the temperature of the sample immediately after reading the hydrometer, it is recommended that in all referee tests this temperature be determined both before and after the hydrometer is read.

CALCULATION

8. In the case of crude petroleum and petroleum products the determinations made in Section 7 are commonly referred to as "observed gravity and observed temperature." These observations shall be corrected to the gravity at 60 deg. fahr. by the use of Tables 1 and 3 of the "National Standard Petroleum Oil Tables" as published in the U. S. Bureau of Standards *Circular No.* 154. Table 1 shall be employed if the observed gravity is in degress A.P.I. and Table 3 if expressed as specific gravity.

Interpolations in Table 1 shall be made as follows: When the observed gravity ends in 1, 2, 3, 4 or 5 tenths of a degree A.P.I., find the degrees A.P.I. at 60 deg. fahr. corresponding to the observed gravity, disregarding the tenths of a degree. To this value add tenths of a degree dropped from the observed gravity to obtain the corrected value of the gravity in degrees A.P.I. at 60 deg. fahr. When the observed gravity ends in 6, 7, 8 or 9 tenths find the degrees A.P.I. and 60 deg. fahr. corresponding to the next larger value of observed gravity in the table. Correct this figure by subtracting a number of tenths equal to the difference between the observed value and the next larger value.

ACCURACY

9. Duplicate determinations shall agree within 0.1 deg. A.P.I. or the equivalent thereof in units of specific gravity at the particular gravity being determined when the same hydrometer and thermometer are used in the tests.

Separate laboratories using different hydrometers and thermometers should obtain duplicate results agreeing within 0.5 deg. A.P.I. or the equivalent thereof in units of specific gravity at the particular gravity being determined.

APPENDIX·

Table VIII is primarily an abridgement of Table 5 of the "National Standard Petroleum Oil Tables" as published in the U. S. Bureau of Standards *Circular No.* 154, which contains similar data for each 0.1 deg. A.P.I. from 10 to 100 deg A.P.I., inclusive. The data for gravities from 0 to 9 deg. A.P.I., inclusive, have been added in order to extend the use of the A.P.I. gravity scale to petroleum oils having a specific gravity slightly greater than unity.

Flash and Fire Test

Significance of Test

The Flash point of a product may be defined as the temperature to which it must be heated in order to give off sufficient vapor to form an inflammable mixture with air.

The Fire point may be defined as the temperature to which a product be heated in order to burn continuously after the inflammable air-vapor mixture is once ignited.

The Flash point of the oil may serve as a rough indication of its tendency to vaporize; it is an index of fire hazard but is more generally employed for identification and classification of the oil.

Method of Test

STANDARD METHOD OF TEST FOR FLASH AND FIRE POINTS BY MEANS OF OPEN CUP

Abstracted from A. S. T. M. Specification Serial Designation: D 92—24

Scope

1. The open cup flash and fire test on all products except fuel oils and those having an open cup flash below 175 deg. fahr. shall be determined in the Cleveland Open Cup.

APPARATUS

2. The cup, Fig. 5, shall be supported by a metal plate ¼ in. (0.635 cm.) in thickness and 6 in. (15.24 cm.) in width, Fig. 6. The plate shall be of brass, cast iron, wrought iron or steel. In the center of the plate there shall be a plane depression 1/32 in. (0.079 cm.) in depth, and of just sufficient diameter to fit the cup. There shall be a circular opening 2 3/16 in. (5.50 cm.) in diameter, cut through the plate, centering with the center of the above-mentioned depression. The plate shall be covered with a sheet of hard asbestos board ¼ in. in thickness, and of the same shape as the metal plate. There shall be cut in the center of the asbestos board a circular hole just fitting the cup. Heat may be supplied from any convenient source. The use of a gas burner, electric heater, or alcohol lamp is permitted, but under no circumstances are products of combustion or free flame allowed to come up around the cup. The source of heat shall be centered under the opening in the plate and shall be of a type that will not produce local superheating. If a flame heater is used, it may be protected from drafts or excessive radiation by any suitable type of shield, that does not project above the level of the upper surface of the asbestos board.

3. The thermometer shall conform to the following requirements. These specifications cover a special thermometer graduated in either Centigrade or Fahrenheit degrees as specified, the ranges being — 6 to + 400 deg. cent., or + 20 to + 760 deg. fahr. respectively.

Type: Etched stem, glass.

Liquid: Mercury.

Range and subdivision: — 6 to + 400 deg. cent. in 2 deg. cent. or + 20 to + 760 deg. fahr. in 5 deg. fahr.

Total length: 303 to 307 mm. (11.92 to 12.08 in.).

Stem: Plain front, enamel back, suitable thermometer tubing. Diameter, 6.0 to 7.0 mm. (0.24 to 0.28 in.).

Bulb: Corning normal or equally suitable thermometric glass. Length, not over 13 mm. (0.51 in.). Diameter, not greater than stem.

Distance to — 6 deg cent. or 20 deg. fahr. line from bottom of bulb: 40 to 50 mm. (1.57 to 1.97 in.).

Distance to 400 deg. cent. or 760 deg. fahr. line from top of thermometer: 30 to 45 mm. (1.18 to 1.77 in.).

Filling above mercury: Nitrogen gas.

Top finish: Red glass ring.

TABLE VIII

SHOWING SPECIFIC GRAVITIES, POUNDS PER GALLON, AND GALLONS PER POUND AT 60 °F., CORRESPONDING TO DEGREES A. P. I.

Degrees A. P. I.	Specific Gravity at 60°/60° F.	Pounds per Gallon at 60° F.*	Gallons per Pound at 60° F.*	Degrees A. P. I.	Specific Gravity at 60°/60° F.	Pounds per Gallon at 60° F.*	Gallons per Pound at 60° F.*
0	1.0760	8.962	0.1116	50	0.7796	6.490	0.1541
1	1.0679	8.895	0.1124	51	0.7753	6.455	0.1549
2	1.0599	8.828	0.1133	52	0.7711	6.420	0.1558
3	1.0520	8.762	0.1141	53	0.7669	6.385	0.1566
4	1.0443	8.698	0.1150	54	0.7628	6.350	0.1575
5	1.0366	8.634	0.1158	55	0.7587	6.316	0.1583
6	1.0291	8.571	0.1167	56	0.7547	6.283	0.1592
7	1.0217	8.509	0.1175	57	0.7507	6.249	0.1600
8	1.0143	8.448	0.1184	58	0.7467	6.216	0.1609
9	1.0071	8.388	0.1192	59	0.7428	6.184	0.1617
10	1.0000	8.328	0.1201	60	6.7389	6.151	0.1626
11	0.9930	8.270	0.1209	61	0.7351	6.119	0.1634
12	0.9861	8.212	0.1218	62	0.7313	6.087	0.1643
13	0.9792	8.155	0.1226	63	0.7275	6.056	0.1651
14	0.9725	8.099	0.1235	64	0.7238	6.025	0.1660
15	0.9659	8.044	0.1243	65	0.7201	5.994	0.1668
16	0.9593	7.989	0.1252	66	0.7165	5.964	0.1677
17	0.9529	7.935	0.1260	67	0.7128	5.934	0.1685
18	0.9465	7.882	0.1269	68	0.7093	5.904	0.1694
19	0.9402	7.830	0.1277	69	0.7057	5.874	0.1702
20	0.9340	7.778	0.1286	70	0.7022	5.845	0.1711
21	0.9279	7.727	0.1294	71	0.6988	5.817	0.1719
22	0.9218	7.676	0.1303	72	0.6953	5.788	0.1728
23	0.9159	7.627	0.1311	73	0.6919	5.759	0.1736
24	0.9100	7.578	0.1320	74	0.6886	5.731	0.1745
25	0.9042	7.529	0.1328	75	0.6852	5.703	0.1753
26	0.8984	7.481	0.1337	76	0.6819	5.676	0.1762
27	0.8927	7.434	0.1345	77	0.6787	5.649	0.1770
28	0.8871	7.387	0.1354	78	0.6754	5.622	0.1779
29	0.8816	7.341	0.1362	79	0.6722	5.595	0.1787
30	0.8762	7.296	0.1371	80	0.6690	5.568	0.1796
31	0.8708	7.251	0.1379	81	0.6659	5.542	0.1804
32	0.8654	7.206	0.1388	82	0.6628	5.516	0.1813
33	0.8602	7.163	0.1396	83	0.6597	5.491	0.1821
34	0.8550	7.119	0.1405	84	0.6566	5.465	0.1830
35	0.8498	7.076	0.1413	85	0.6536	5.440	0.1838
36	0.8448	7.034	0.1422	86	0.6506	5.415	0.1847
37	0.8398	6.993	0.1430	87	0.6476	5.390	0.1855
38	0.8348	6.951	0.1439	88	0.6446	5.365	0.1864
39	0.8299	6.910	0.1447	89	0.6417	5.341	0.1872
40	0.8251	6.870	0.1456	90	0.6388	5.316	0.1881
41	0.8203	6.830	0.1464	91	0.6360	5.293	0.1889
42	0.8155	6.790	0.1473	92	0.6331	5.269	0.1898
43	0.8109	6.752	0.1481	93	0.6303	5.246	0.1906
44	0.8063	6.713	0.1490	94	0.6275	5.222	0.1915
45	0.8017	6.675	0.1498	95	0.6247	5.199	0.1924
46	0.7972	6.637	0.1507	96	0.6220	5.176	0.1932
47	0.7927	6.600	0.1515	97	0.6193	5.154	0.1940
48	0.7883	6.563	0.1524	98	0.6166	5.131	0.1949
49	0.7839	6.526	0.1 32	99	0.6139	5.109	0.1957
				100	0.6112	5.086	0.1966

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* The data in this column are based upon apparent weights in air, the weight of one gallon of water at 60° F. in air being assumed to be 8.3282 lb. Consequently, a correction for the buoyancy of air is required in computing these figures from the specific gravities in the second column.

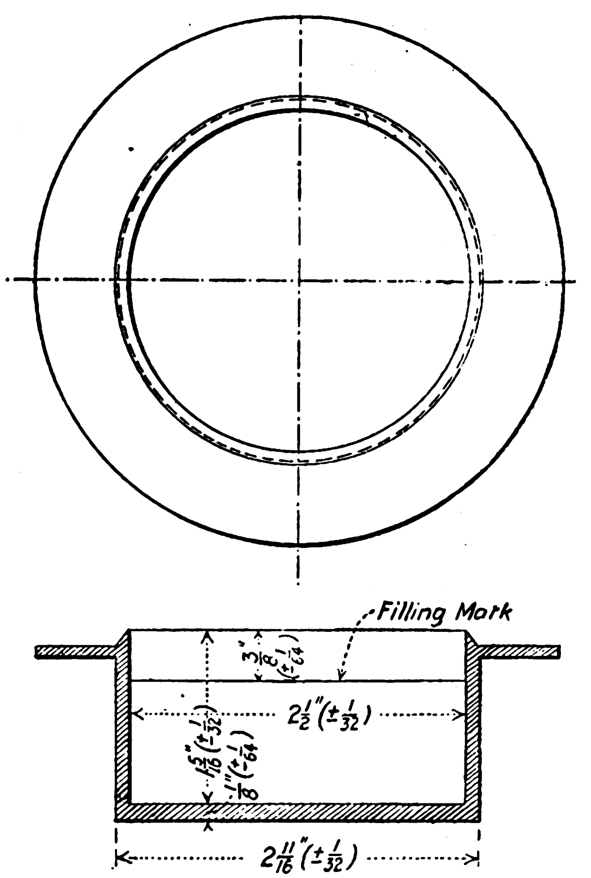

FIG. 5—CLEVELAND OPEN CUP, A.S.T.M.

Graduation: All lines, figures, and letters clear cut and distinct. The first and each succeeding 10 deg. fahr. line to be longer than the intermediate lines. Graduations to be numbered at each multiple of 20 deg.

Immersion: 25 mm. or one inch. The words "1-in. immersion" on Fahrenheit thermometers or "25 mm. immersion" on Centigrade thermometers and a line around the stem 25.4 mm. or 1.00 in. above the bottom of the bulb shall be etched on the thermometer.

Special marking: "A.S.T.M. Open Flash" a serial number and the manufacturer's name or trade mark shall be etched on the stem.

Scale error: The error at any point of the scale when the thermometer is standardized as provided below shall not exceed 1 deg. cent. up to 372 deg. cent. or 2½ deg. fahr. up to 700 deg. fahr.

Standardization: The thermometer shall be standardized at the ice point and at intervals of approximately 100 deg. fahr. for 25-mm. or 1-in. immersion and for the following temperatures of the emergent mercury column:

Thermometer Reading		Average Temperature of Emergent Mercury Column	
100° C.	200° F.	44° C.	110° F.
150° C.	300° F.	54° C.	129° F.
200° C.	400° F.	64° C.	150° F.
250° C.	500° F.	77° C.	175° F.
300° C.	600° F.	91° C.	205° F.
350° C.	700° F.	108° C.	240° F.

Test for permanency of range: After being subjected to a temperature between 360 to 370 deg. cent. or 680 to 700 deg. fahr. for 24 hours, the accuracy shall be within the limit specified.

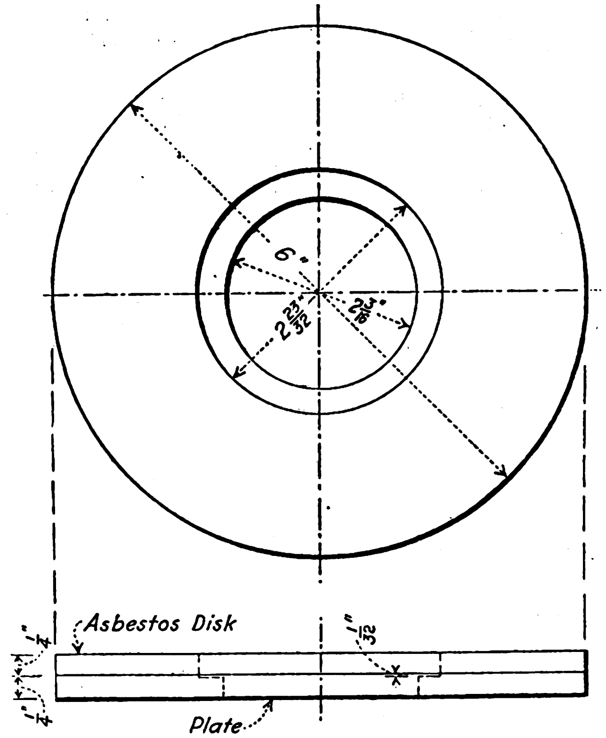

FIG. 6—HEATING PAD FOR CLEVELAND OPEN CUP, A.S.T.M.

Case: The thermometer shall be supplied in a suitable case on which shall appear the marking: "A.S.T.M. Open Flash, — 6 to + 400 deg. cent." or "A.S.T.M. Open Flash, + 20 to + 760 deg. fahr.," according to the type of thermometer.

NOTE.—For the purpose of interpreting these specifications the following definitions apply:
The total length is the over-all length of the finished instrument.
The diameter is that measured with a ring gage.
The length of the bulb is the distance from the bottom of the bulb to the beginning of the enamel backing.
The top of the thermometer is the top of the finished instrument.

PROCEDURE

4. (*a*) The thermometer shall be suspended or held in a vertical position by any suitable device. The bottom of the bulb shall be ¼ in. (0.635 cm.)[1] from the bottom of the cup, and above a point half way between the center and back of the cup.

(*b*) The cup shall be filled with the oil to be tested in such a manner that the top of the meniscus is exactly at the filling line at room temperature. The surface of the oil shall be free from bubbles. There shall be no oil above the filling line or on the outside of the apparatus.

(*c*) The test flame shall be approximately 5/32 in. (0.397 cm.) in diameter.

NOTE: For purposes of comparison it is recommended that a bead of suitable light colored material be mounted in a convenient position so that the size of the test flame can be determined. The device for applying the flame may be of any suitable type, but it is suggested that the tip be approximately 1/16 in. (0.159 cm.) in diameter at the end, and that the orifice be 1/32 in. (0.079 cm.) in diameter. If the device for operating the test flame be mounted in such a manner as to permit automatic duplication of the sweep of the test flame the radius of swing shall be not less than 6 in.

(*d*) The test flame shall be applied as the temperature read on the thermometer reaches each successive 5 deg. fahr. mark. The flame shall pass in a straight line (or on the circumference of a circle having a radius of at least 6 in.) across the center of the cup and at right angles to the diameter passing through the thermometer. The test flame shall, while passing across the surface of the oil, be in the plane of the upper edge of the cup. The time for the passage of the test flame across the cup shall be approximately one second.

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[1] The immersion line engraved on the thermometer stem will be 1/16 in. (0.159 cm.) below the level of the rim of the cup.

(*e*) The oil shall be heated at a rate not exceeding 30 deg. fahr. per minute temperature rise, till a point is reached approximately 100 deg. fahr. below the probable flash point of the oil. Thereafter the rate of heating shall be decreased and for at least the last 50 deg. fahr. before the flash point is reached, the rate shall be not less than 9 nor more than 11 deg. fahr. per minute.

Flash Point

5. The flash point shall be taken as the temperature read on the thermometer when a flash appears at any point on the surface of the oil. The true flash must not be confused with a bluish halo that sometimes surrounds the test flame.

Fire Point

6. After determining the flash point, the heating shall be continued at the specified rate of 9 to 11 deg. fahr. per minute, and application of the test flame shall be made at the specified intervals until the oil ignites and continues to burn for a period of at least 5 seconds. The method of application of the flame shall be the same or for flash point. The temperature read at the time of the flame application which causes burning for a period of 5 seconds or more shall be recorded as the fire point.

Precautions

7. The flash point and fire point tests shall be made in a room or compartment free from air drafts. The operator shall avoid breathing over the surface of the oil. It is desirable that the room or compartment be darkened sufficiently so that the flash may be readily discernible.

Pour Point

Significance of Test

The pour point of a petroleum oil is the lowest temperature at which the oil will pour or flow when it is chilled without disturbance under certain definite specified conditions.

The pour point gives an indication of the temperature below which it may not be possible to pour or remove an oil from its container, or below which it might be dangerous to use the oil in gravity lubricating system, where the head tending to produce flow is small.

Method of Test

The Committee has deleted the procedure for cloud point as described in the A. S. T. M. Method D-97-28.

STANDARD METHOD OF TEST FOR POUR POINTS OF PETROLEUM PRODUCTS

Abstracted from A. S. T. M. Specification Serial Designation: D 97—28

Pour Point

1. The Pour Point of a petroleum oil is the lowest temperature at which this oil will pour or flow when it is chilled without disturbance under certain definite specified conditions.

2. The test for pour point shall be used for all other petroleum oils and may be used for oils on which the test for cloud point is permitted.

APPARATUS

Test Jar

3. The test jar, *a*, shall be of clear glass, cylindrical form, flat bottom, approximately 1 3/16 to 1 5/16 in. in inside diameter and 4½ to 5 in. high. An ordinary 4-oz. oil sample bottle may be used if it is within the above specifications, and no test jar is available.

4. The thermometer, *b*, shall conform to the requirements of one of the following specifications:

(*a*) These specifications cover a special thermometer graduated in either Centigrade or Fahrenheit degrees as specified, the ranges being — 38 to + 50 deg. cent. or — 36 to + 120 deg. fahr., respectively.

Type: Etched stem, glass.

Liquid: Mercury.

Range and Subdivision: — 38 to + 50 deg. cent. in 1 deg. cent. or — 36 to + 120 deg. fahr. in 2 deg. fahr.

Total Length: 220 to 224 mm. (8.69 to 8.81 in.).

Stem: Plain front, enamel back, suitable thermometer tubing. Diameter, 7.0 to 8.0 mm. (0.28 to 0.31 in.).

Bulb: Corning normal or equally suitable thermometric glass. Length, not over 9.5 mm. (0.37 in.). Diameter, not greater than stem.

Distance to — 38 deg. cent. or — 36 deg. fahr. Line from Bottom of Bulb: 120 to 130 mm. (4.73 to 5.12 in.).

Distance to + 49 deg. cent. or + 120 deg. fahr. Line from Top of Thermometer: 19 to 25 mm. (0.75 to 0.98 in.).

Expansion Chamber: To permit heating to 100 deg. cent. or 212 deg. fahr.

Filling Above Mercury: Nitrogen gas.

Top Finish: Plain.

Graduation: All lines, figures and letters clear cut and distinct. Lines at multiples of 5 deg. cent. or 10 deg. fahr. to be longer than the remaining lines. Graduations to be numbered at each multiple of 10 deg. cent. or 20 deg. fahr.

Immersion: 108 mm. or 4¼ in. The words "108-mm. immersion" on Centigrade thermometers or "4¼-in. immersion" on Fahrenheit thermometers and a line around the stem 108.0 mm. or 4.25 in. above the bottom of the bulb shall be etched on the thermometer.

Special Marking: "A.S.T.M. Cloud and Pour," a serial number and the manufacturer's name or trade mark shall be etched on the stem.

Scale Error: The error at any point of the scale, when the thermometer is standardized as provided below, shall not exceed 0.5 deg. cent. or 1 deg. fahr.

Standardization: The thermometer shall be standardized at the ice point and at intervals of approximately 20 deg. cent. or 40 deg. fahr. for 108-mm. or 4¼-in. immersion and for an average temperature of 21 deg. cent. or 70 deg. fahr. for the emergent mercury column.

Case: The thermometer shall be supplied in a suitable case on which shall appear the marking: "A.S.T.M. Cloud and Pour, — 38 to + 50 deg. cent." or "A.S.T.M. Cloud and Pour, — 36 to + 120 deg. fahr." according to the type of thermometer.

NOTE: For the purpose of interpreting these specifications the following definitions apply:
The total length is the over-all length of the finished instrument.
The diameter is that measured with a ring gage.
The length of the bulb is the distance from the bottom of the bulb to the beginning of the enamel backing.
The top of the thermometer is the top of the finished instrument.

(*b*) These specifications cover a special low cloud and pour test thermometer graduated in either centigrade or Fahrenheit degrees as specified, the ranges being — 60 to + 20 deg. cent. or — 70 to + 70 deg. fahr.

Type: Etched stem, glass.

Liquid: Toluene or other suitable liquid colored red with a permanent dye.

Range and Subdivision: — 60 to + 20 deg. cent. in 1 deg. cent. or — 70 to + 70 deg. fahr. in 2 deg. fahr.

Total Length: 227 to 231 mm. (8.92 to 9.08 in.).

Stem: Plain front, enamel back, suitable thermometer tubing. Diameter 7.0 to 8.0 mm. (0.28 to 0.31 in.).

Bulb: Corning normal or equally suitable thermometric glass. Length, 8.0 to 9.5 mm. (0.31 to 0.37 in.). Diameter, 5.0 to 6.5 mm. (0.22 to 0.26 in.).

Distance to — 57 deg. cent. or — 70 deg. fahr. Line from Bottom of Bulb: 120 to 130 mm. (4.73 to 5.12 in.).

Distance to + 20 deg. cent. or + 68 deg. fahr. Line from Top of Thermometer: 35 to 45 mm. (1.38 to 1.77 in.).

Expansion Chamber: To permit heating to + 60 deg. cent. or + 140 deg. fahr.

Filling above Liquid: Gas under pressure.

Top Finish: Plain.

Graduation: All lines, figures and letters clear cut and distinct, lines at multiples of 5 deg. cent. or 10 deg. fahr. to be longer than the remaining lines. Graduations to be numbered at each multiple of 10 deg. cent. or 20 deg. fahr.

Immersion: 108 mm. (4¼ in.). The words "108-mm. immersion" on centigrade thermometers, or "4¼-in. immersion" on fahrenheit thermometers and a line around the stem 108 mm. (4.25 in.) above the bottom of the bulb, shall be etched on the thermometer.

Special Marking: "A.S.T.M. Low Cloud and Pour" a serial number and the manufacturer's name or trademark shall be etched on, the thermometer.

Scale Error: The error at any point of the scale when the thermometer is standardized as provided below, shall not exceed 1 deg. cent. or 2 deg. fahr.

Standardization: The thermometer shall be standardized at the ice point and at intervals of approximately 20 deg. cent. or 35 deg. fahr. for 108-mm. or 4¼-in. immersion, and for an average temperature of 21 deg. cent or 70 deg. fahr. for the emergent liquid column.

Case: The thermometer shall be supplied in a suitable case on which shall appear the marking "A.S.T.M. Low Cloud and Pour, — 60 to + 20 deg. cent. or "A.S.T.M. Low Cloud and Pour, — 70 to + 70 deg. fahr.", according to the type of thermometer.

NOTE: For the purpose of interpreting these specifications, the following definitions apply:

The total length is the over-all length of the finished instrument.
The diameter is that measured with a ring gage.
The length of the bulb is the distance from the bottom of the bulb to the beginning of the enamel backing.
The top of the thermometer is the top of the finished instrument.

Cork

5. The cork, *c*, shall fit the test jar, and shall be bored centrally to take the test thermometer.

Jacket

6. The jacket, *d*, shall be of glass or metal, shall be water tight, of cylindrical form, flat bottom, about 4½ in. deep, with inside diameter ⅜ to ½ in. greater than outside diameter of the test jar.

Cork Disk

7. A disk of cork or felt, *e*, ¼ in. thick and of the same diameter as the inside of the jacket will be required.

Gasket

8. The ring gasket, *f*, shall be about 3/16 in. thick, and made to fit snugly around the outside of the test jar and loosely inside the jacket. This gasket may be made of cork, felt or other suitable material, elastic enough to cling to the test jar and hard enough to hold its shape. The purpose of the ring gasket is to prevent the test jar from touching the jacket.

9. The cooling bath, *g*, shall be of a type suitable for obtaining the required temperatures. The size and shape of the bath are optional but a support, suitable for holding the jacket firmly in a vertical position, is essential. For determination of very low pour points, a smaller insulated cooling bath may be used and the test jar placed directly in it. The required bath temperatures may be maintained by refrigeration if available, otherwise by suitable freezing mixtures.

NOTE.—The freezing mixtures commonly used are as follows:

For temperatures down to 50 deg. fahr., ice and water.
For temperatures down to 10 deg. fahr., crushed ice and sodium chloride.
For temperatures down to — 15 deg. fahr., crushed ice and calcium chloride crystals.
For temperatures down to — 70 deg. fahr., solid carbon dioxide and acetone or gasoline.

The last named mixtures may be made as follows: In a covered metal beaker chill a suitable amount of acetone or gasoline to 10 deg. fahr., or lower, by means of an ice-salt mixture. Invert a cylinder of liquid carbon dioxide and draw off carefully in a chamois skin bag the desired amount of carbon dioxide, which through rapid evaporation will quickly become solid. Then add to the chilled acetone or gasoline enough of the solid carbon dioxide to give the desired temperature.

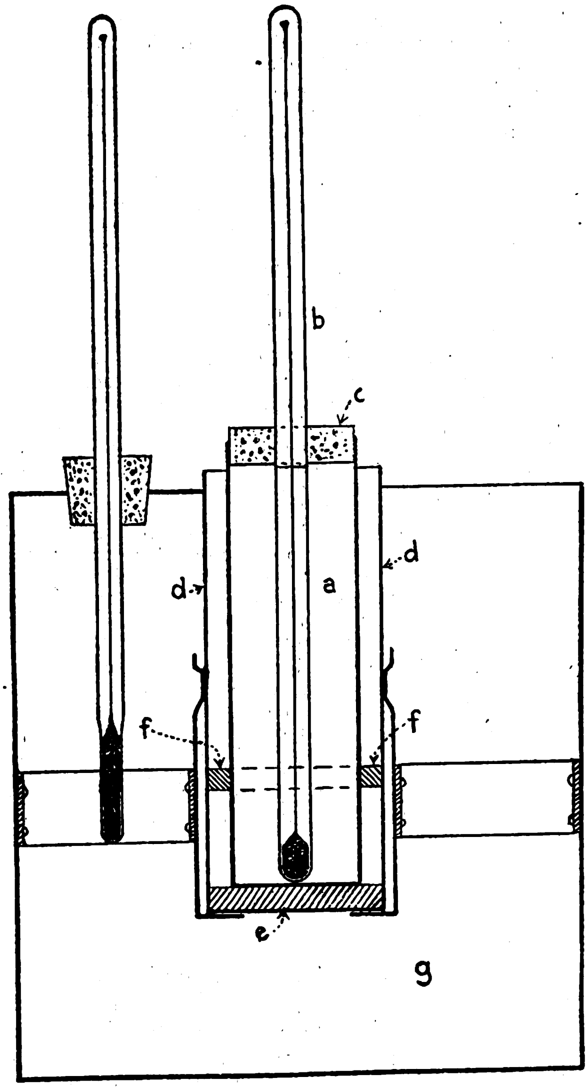

FIG. 7—APPARATUS FOR POUR TEST, A.S.T.M.

PROCEDURE FOR POUR POINT

10. The oil shall be poured into the test jar, *a*, to a height of not less than 2 nor more than 2¼ in. The jar may be marked to indicate the proper level. When necessary, the oil shall be heated in a water bath just sufficiently for pouring into the test jar.

The test jar shall be tightly closed by the cork, *c*, carrying the test thermometer, *b*, in a vertical position in the center of the jar with the thermometer bulb immersed so that the beginning of the capillary shall be ⅛ in. below the surface of the oil.

Heat without stirring to a temperature of 115 deg. fahr. in a bath maintained at not higher than 118 deg. fahr. The oil shall then be cooled to 90 deg. fahr. in air or in a water bath approximately 77 deg. fahr. in temperature. Oils with which the low cloud and pour test thermometer can be used from the beginning of the test shall be cooled to 60 deg. fahr. in any convenient manner before the thermometer is placed in position.

The disk, *e*, shall be placed in the bottom of the jacket, *d*, and the test jar, with the ring gasket, *f*, 1 in. above the bottom, shall be inserted into the jacket. The disk, gasket and inside of jacket shall be clean and dry.

After the oil has cooled enough to allow the formation of paraffin wax crystals, great care shall be taken not to disturb the mass of the oil nor to permit the thermometer to shift in the oil. Any disturbance of the spongy network of wax crystals will lead to low and fictitious results.

The temperature of the cooling bath, *g*, shall be adjusted so that it is below the pour point of the oil by not less than 15 nor more than 30 deg. fahr. and this temperature shall be maintained throughout the test. The jacket, containing the test jar, shall be supported firmly in a vertical position in the cooling bath so that not more than 1 in. of the jacket projects out of the cooling medium.

Beginning at a temperature 20 deg. fahr. before the expected pour point, at each test thermometer reading which is a multiple of 5 deg. fahr., the test jar shall be removed from the jacket carefully and shall be tilted just enough to ascertain whether there is a movement of the oil in the test jar. The complete operation of removal and replacement shall require not more than three seconds. As soon as the oil in the test jar does not flow when the jar is tilted, the test jar shall be held in a horizontal position for exactly five seconds, as noted by a stop watch or other accurate timing device and observed carefully. If the oil shows any movement under these conditions, the test jar shall be immediately replaced in the jacket and the same precedure repeated at the next temperature reading 5 deg. fahr. lower.

The test shall be continued in this manner until a point is reached at which the oil in the test jar shows no movement when the test jar is held in a horizontal position for exactly five seconds. Certain lubricating oils tend to move as a whole and should be very closely observed. The reading of the test thermometer at this temperature, corrected for error if necessary, shall be recorded. The pour point shall be taken as the temperature 5 deg. fahr. above this solid point.

Viscosity

Signficance of Test

Viscosity is the most important single property of a turbine oil. In a bearing operating properly, with a fluid film separating the surfaces, the viscosity of the oil at the operating temperature is the property which determines the bearing friction, heat generation and the rate of flow under given conditions of load, speed and bearing design. The oil should be viscous enough to maintain a fluid film between the bearing surfaces, in spite of the pressure tending to squeeze it out. While a reasonable factor of safety is essential, excessive viscosity means unnecessary friction and heat generation.

Viscosity is the measure of resistance to flow. In scientific work, viscosity is measured in terms of a unit of force designated as the "poise," while in most commercial work, an expression involving the time required for a measured volume of oil to flow, under specified conditions, through a carefully standardized tube, is known as the viscosity of the oil. To distinguish between these two methods of reporting results, the expression "absolute viscosity" is applied to an observation expressed in poises, while that expressed in terms of time of flow (Saybolt seconds by the above method) is designated as "viscosity" at a prescribed temperature.

[NOTE: The committee has deleted all references to the Saybolt Furol Viscosimeter which is included in the A.S.T.M. Standard Method D-88-26.]

Method of Test

STANDARD METHODS OF TEST FOR VISCOSITY OF PETROLEUM LUBRICANTS

Abstracted from A.S.T.M. Specification Serial Designation: D 88—26

Choice of Instrument

1. (*a*) Viscosity shall be determined by means of the Saybolt Universal Viscosimeter.

(*b*) In general, the Saybolt Universal Viscosimeter shall be used for lubricants.

TABLE IX—DIMENSIONS OF OIL TUBE

Dimensions	Saybolt Universal Viscosimeter		
	Minimum, cm.	Normal, cm.	Maximum, cm.
Inside diameter of outlet tube	0.1750	0.1765	0.1780
Outside diameter of outlet tube at lower end	0.28	0.30	0.32
Length of outlet tube	1.215	1.225	1.235
Height of overflow rim above bottom of outlet tube	12.40	12.50	12.60
Outside diameter of overflow rim, at the top[b]	[a]	......	3.30
Diameter of container	2.955	2.975	2.995
Depth of cylindrical part of container	8.8	......	......
Diameter of container between bottom of cylindrical part of container and top of outlet tube	0.9	......	......

[a] The minimum value shall preferably be not less than 3.2 cm.

[b] The section of overflow rim shall be bounded by straight lines, except that a fillet is permissible at the junction with the bottom of the gallery.

(*c*) The Saybolt Universal Viscosimeter shall not be used for times of flow less than 32 seconds.

I. APPARATUS

Viscosimeters

2. (*a*) The Saybolt viscosimeters (see Fig. 8) are made entirely of metal. The oil tube, *A*, is fitted at the top with an overflow cup, *B*, and the tube is surrounded by a bath. At the bottom of the oil tube is a small outlet tube through which the oil to be tested flows into a receiving flask, Fig. 9, whose capacity at 20 deg. cent. (68 deg. fahr.) to a mark on its neck is 60, ± 0.15, c.c. The outlet tube is of hard and non-corrosive metal such as stainless steel, monel metal, etc. The inside diameter of neck of flask, at the level where the graduation mark is placed, is 0.8 to 1.1 cm. The lower end of the outlet tube is enclosed by a larger tube, which when stoppered by a cork, *C*, acts as a closed air chamber and prevents the flow of oil through the outlet tube until the cork is removed and the test started. A looped string may be attached to the lower end of the cork as an aid to its rapid removal. The temperatures in the oil tube and in the bath are shown by thermometers. The bath may be heated by any suitable means. The oil tube shall be thoroughly cleaned, and all oil entering the oil tube shall be strained through a 100-mesh wire strainer. A stop watch shall be used for taking the time of flow of the oil and a pipette shall be used for draining the overflow cup.

Oil Tube

(*b*) The oil tubes, which may be standardized by the U. S. Bureau of Standards, shall conform to the dimensions given in Table IX. The time of flow shall be within ± 1 per cent of the time as obtained with the Bureau of Standards' master tube.[1]

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[1] This tube represents the average mechanically perfect tube, based on the A. S. T. M. specifications, and has been approved by the American Petroleum Institute Committee on Viscosity Standards.

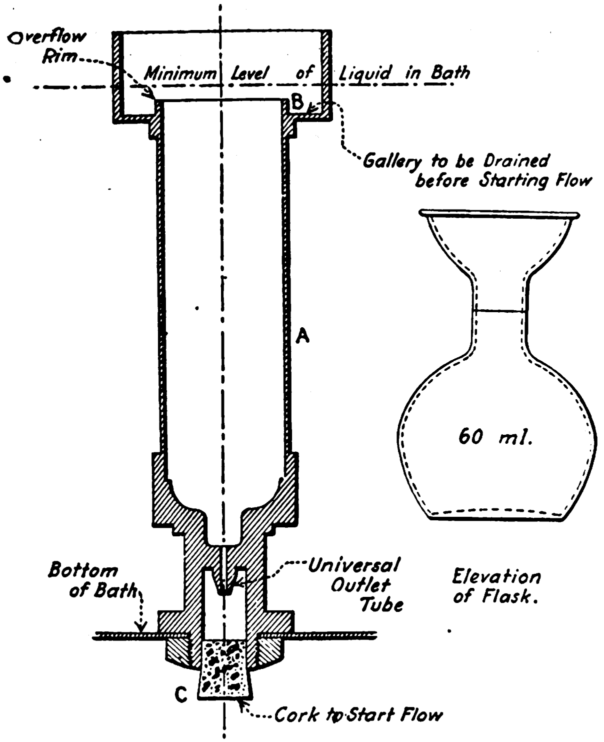

FIG. 8—Sectional View of Saybolt Standard Oil Tube, A.S.T.M.
FIG. 9—Saybolt Oil Receiving Flask, A.S.T.M.

Thermometers

(*c*) The bath and oil tube thermometers shall conform to the following requirements. They cover two sets of 4 thermometers each, one set being graduated in fahrenheit degrees and the other set in centigrade degrees, the ranges being chosen to include the temperatures commonly used in testing.

Type: Etched stem, glass.
Liquid: Mercury.
Ranges and Subdivisions:

Range 94-108° F., subdivision in 0.2° F. for tests at 100° F.
Range 204-218° F., subdivision in 0.2° F. for tests at 210° F.

or

Range 34- 42° C., subdivision in 0.1° C. for tests at 40° C.
Range 95-103° C., subdivision in 0.1° C. for tests at 100° C.

Total Length: 252 to 256 mm. (9.92 to 10.08 in.).

Stem: Plain front, enamel back, suitable thermometer tubing. Diameter, 6 to 7 mm. (0.236 to 0.275 in.). The stem shall preferably be made with an enlargement not less than 4 nor more than 7 mm. (0.16 to 0.28 in.) in length, having a diameter 2 to 3 mm. (0.08 to 0.12 in.) greater than that of the stem, the bottom of the enlargement being 114 mm. (4.5 in.) above the bottom of the bulb.

Bulb: Corning normal or equally suitable thermometric glass.

Length, 25 to 35 mm. (1.0 to 1.4 in.).

Diameter, not less than 5 mm. (0.197 in.) and not greater than that of stem.

Distance to Lowest Specified Graduation from Bottom of Bulb: 135 to 150 mm. (5.3 to 5.9 in.).

Distance to Highest Specified Graduation from Top of Stem: 20 to 35 mm. (0.8 to 1.4 in.).

Contraction Chamber: To be of long narrow type, top to be not more than 60 mm. (2.36 in.) above bottom of bulb, mercury to stand in contraction chamber at 32 deg. fahr. (0 deg. cent.).

Expansion Chamber: To permit heating the thermometer 90 deg. fahr. (50 deg. cent.) above highest temperature on scale, and in all cases to permit heating to 212 deg. fahr. (100 deg. cent.).

Filling above Mercury: Nitrogen gas.

Top Finish: Glass ring.

Graduation: All lines, figures and letters clear cut and distinct. The first and each succeeding 1 deg. fahr. or 0.5 deg. cent. line to be longer than the remaining lines. Graduations to be numbered at each multiple of 2 deg. fahr. or 1 deg. cent.

Immersion: Total.

Special Marking: "A.S.T.M." Viscosity test points to be numbered in full figures and in red, other graduations and figures in black. A serial number and the manufacturer's name or trademark shall be etched on the stem.

Scale Error: The error at any point of the scale shall not exceed 0.2 deg. fahr. (0.1 cent.).

Standardization: The thermometers are to be standardized for the condition of total immersion. Correction for emergent stem shall not be applied.

Case: Each thermometer shall be supplied in a suitable case on which shall appear the marking, "A.S.T.M. Saybolt Viscosimeter Thermometer" and the range.

II. TEMPERATURE OF TESTING

3. (*a*) With the Saybolt Universal viscosimeter, determinations shall be made at 100 deg. fahr. (37.8 deg. cent.), and 210 deg. fahr. (98.9 deg. cent.).

(*b*) Viscosities shall be expressed as ...... seconds, Saybolt Universal, being the time in seconds for the delivery of 60 c.c. of oil.

III. PROCEDURE

4. In tests at 100 deg. fahr. (37.8 deg. cent.) the bath temperature throughout the test shall not vary more than ± 0.1 deg. fahr (0.06 deg. cent.) from the predetermined temperature which will maintain thermal equilibrium as long as the oil is well stirred with the thermometer. In tests at 210 deg. fahr. (98.9 deg. cent.) a variation of ± 0.2 deg. fahr. (0.11 deg. cent.) is permitted.

Any construction of bath may be employed provided the bath temperature necessary to maintain thermal equilibrium (while the oil in the oil tube is well stirred by the oil tube thermometer) is not in excess of 100.25 and 212.00 deg. fahr. (37.9 and 100.00 deg. cent.), respectively, for the standard temperatures previously mentioned. The level of the bath liquid shall not be lower than 0.5 cm. above the overflow rim of the oil tube. In tests at 210 deg. fahr. (98.9 deg. cent.) the water bath shall be vigorously stirred, and may be heated by the direct injection of steam near the bottom of the bath. A bath of other suitable liquid may be used provided it is properly heated and stirred.[1] The heating and stirring of the bath may be accomplished by any suitable means, provided the source of heat is not less than the following distances from any part of the oil tube: 2 in. (5 cm.) with an external heater, 1¼ in. (3 cm.) with an immersion heater. Viscosity determinations shall be made in a room free from daughts and from rapid changes in temperature. The room temperature shall be between 68 and 86 deg. fahr. (20 and 30 deg. cent.).[2]

All oil introduced into the oil tube, either for cleaning or for test, shall first be passed through the strainer.

To make the test, heat the oil to the necessary temperature and clean out the oil tube. Pour some of the oil to be tested through the cleaned tube. Insert the cork stopper into the lower end of the air chamber at the bottom of the oil tube, sufficiently to prevent the escape of air, but not to touch the small outlet tube.

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[1] For example, the bath liquid may be water, to which glycerin or salt has been added. In ordinary routine testing it is frequently desirable to employ oil as a bath medium. This is allowable provided the temperature of the oil bath is adjusted so that the necessary condition of thermal equilibrium is maintained. It is usually necessary to maintain the oil bath at slightly higher temperatures than are necessary when water is the bath medium. Oil bath temperatures will need to be from 0.1 to 0.2° F. (0.06 to 0.11° C.) higher for tests at 100° F. (37.8° C.) and 1.5 to 2.0° F. (0.85 to 1.11° C.) higher for tests at 210° F. (98.9° C.) than the corresponding water bath temperatures.

[2] These limits are necessary for extreme accuracy in standardization and referee tests, but for routine purposes the use of higher temperatures up to 100° F. (37.8° C.) will not ordinarily cause an error of more than 1 per cent.

Heat the oil to be tested, outside the viscosimeter, to slightly but not more than 3 deg. fahr. (1.7 deg. cent.) above the temperature at which the viscosity is to be determined, and pour it into the oil tube until it ceases to overflow into the overflow cup. By means of the oil tube thermometer, keep the oil in the oil tube well stirred, and also stir well the liquid in the bath. It is extremely important that the temperature of the bath be maintained constant during the entire time consumed in making the test. After the temperature of the bath and of the oil in the oil tube have been constant for one minute at the desired temperatures, withdraw the oil tube thermometer, quickly remove the surplus oil from the overflow cup by means of a pipette[3] so that the level of the oil in the overflow cup is below the level of the oil in the oil tube proper; place the 60-c.c. flask, Fig. 9, in position so that the stream of oil from the outlet tube will strike the neck of the flask so as to avoid foam. Snap the cork from its position, and at the same instant start the stop-watch. Stir the liquid in the bath during the run and carefully maintain it at the previously determined proper temperature. Stop the watch when the bottom of the meniscus of the oil reaches the mark on the neck of the receiving flask.

The time in seconds for the delivery of 60 c.c. of oil is the Saybolt Universal viscosity of the oil at the temperature at which the test is made.

With proper attention to details of methods of procedure, duplicate results should not differ from each other by more than 1 per cent.

Steam Emulsion

Significance of Test

When oil and water are mixed in any manner, standing causes them to separate more or less rapidly. The presence of small amounts of certain other materials decreases the rate of separation and may prevent any separation whatever. This physical condition is known as an emulsion, and the phenomenon is known as emulsification.

The A. S. T. M. Standard Method of Test for Steam Emulsion of Lubricating Oils, D-157-28, is designed for use in oils whenever a knowledge of the tendency to separate from water is required.

For forced-feed circulating lubrication systems where the oil is likely to come in contact with water or steam, the steam emulsion test is of great importance. This is particularly true of steam-turbine lubricating systems. For oils intended for this type of service the use of a test of this kind is thoroughly established. Next to viscosity, it is considered the most important test for steam turbine oils, since rapid separation from water is an essential characteristic.

For the lubrication of steam turbines, it is very essential that any emulsion which may be formed separate rapidly and completely. Accordingly a knowledge of the rapidity with which the constituents of an emulsion of oil and water will separate is of considerable value. Since it is not possible to duplicate service conditions in the laboratory, it is necessary to measure the rapidity of separation under some arbitrarily selected set of conditions. This is expressed in some numerical form which serves as an index of the emulsifying characteristics of the oil.

Steam is passed into the oil under specified conditions and the time in seconds required for complete separation of the oil and condensed steam is recorded as the Steam Emulsion Number (S. E. Number) of the oil.

Method of Test

STANDARD METHOD OF TEST FOR STEAM EMULSION OF LUBRICATING OILS

Abstracted from A. S. T. M. Specification Serial Designation: D 157—28

Scope

1. This method shall be used on all oils when an emulsion, demulsibility or emulsification test is required.[1] This method is commonly used for turbine oils and may be used for other lubricating oils.

Description

2. The Steam Emulsion Number (A.S.T.M.S.E.) is the number of seconds required for an oil to separate when emulsified and separated under definitely prescribed conditions.

APPARATUS

Steam Generator

3. The steam generator shall be made of either metal or glass of at least one-liter capacity, capable of withstanding the heat necessary for continued use in the production of steam. It shall be fitted with three outlets with suitable connections for rubber tubing. In case of a metal generator, a large opening for filling and a suitable water gage shall be a necessary part of the apparatus.

Baths

4. The baths shall be of glass with a capacity of 3 to 3½ liters and a depth of 7½ to 9 in. A good quality battery jar or beaker is entirely satisfactory.

Source of Heat

5. Heat for the steam generator shall be supplied by a suitable gas burner or electric hot plate. The separating bath may be heated by any convenient means, including an auxiliary steam line as shown in Fig. 10.

Oil Container

6. The oil container shall be a 25 by 200-mm. test tube graduated from zero or from 10 to 50 c.c. in cubic centimeters, each even 5-c.c. line to encircle the tube.

Steam Piping

7. The steam piping or the steam delivery tube shall consist of a piece of thin-wall glass tubing, not less than 2.3 nor more than 2.7 mm. in inside diameter and 12 in. in length. The steam pipe shall be cut off diagonally at an angle of 30 deg. with the axis of the tube at the discharge orifice and shall be bent at right angles 10 in. from the discharge orifice.

Accessories

8. Accessories shall consist of:

(*a*) Suitable wooden or metal frames or holders for holding all containers in a vertical position in the baths;

(*b*) Thermometers for the separating and emulsifying baths (floating type thermometers of suitable range);

(*c*) Thermometers for the oil container tube (engraved-stem type, of suitable range, graduated in 1 deg. fahr., 5 to 7 mm. in diameter);

(*d*) Corks, rubber tubing and screw pinch-cocks.

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[3] It is recommended that the tip of the pipette should be about 2 mm. inside, and about 3 mm. outside diameter, and great care should be exercised to avoid touching the overflow rim while draining the overflow cup.

[1] Methods for sampling are covered in the Tentative Methods of Sampling Petroleum and Petroleum Products (Serial Designation: D 270-27 T) of the American Society for Testing Materials, see 1928 Book of A.S.T.M. Tentative Standards. The following paragraphs, which are particularly important for protection of samples for the steam emulsion test, are quoted from these methods:

"34. (*a*) Corks for bottles shall be clean, free from holes and loose bits of cork.

(*b*) Sealing wax, or paraffin, shall *not* be poured over corks after cooling."

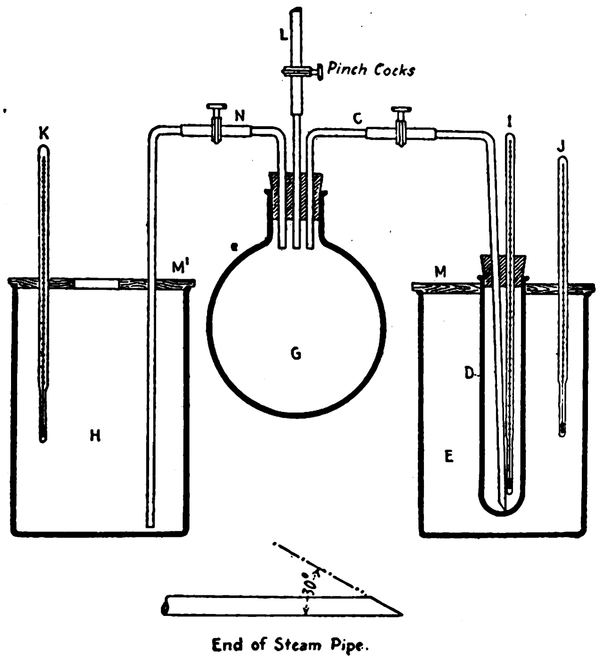

FIG. 10—APPARATUS FOR STEAM EMULSION TEST, A.S.T.M.

PROCEDURE

Preparation

9. The apparatus shall be assembled as shown in Fig. 1. The steam generator shall be filled one-half full of water and heat applied. The baths shall be filled with 3 liters ± 60 c.c. of water. The temperature in the separating bath shall be raised to and maintained at 200 to 203 deg. fahr.

NOTE: Care must be taken if glass battery jars are used, as direct heating by flame or electric heater may cause breakage.

The temperature of the emulsifying bath shall be brought to not less than 67 deg. fahr., nor more than 78 deg. fahr. at the start of the test, and is not controlled thereafter. Twenty cubic centimeters of the oil to be tested shall be measured in the oil container at room temperature and the latter placed in the holder of the emulsifying bath. The steam pipe, or delivery tube, shall be connected to the steam generator with suitable rubber tubing, and screw pinch-cocks placed as shown in Fig. 10.

Care should be taken to see that the apparatus particularly the oil container, oil container thermometer and the steam delivery tube are *chemically clean* before using. Care shall also be taken to prevent any foreign materials from entering the steam generator as any contamination of the steam renders the test valueless.

Emulsification

10. The steam delivery tube line shall be steamed out until all condensation disappears. A cork having two openings, with the thermometer in one, shall be placed in the mouth of the oil container. The thermometer shall be adjusted so that the bottom of the bulb is ¾ to 1 in. from the bottom of the oil container. The steam delivery tube shall be inserted through the second opening in the cork (Note.—This fitting shall be loose.) so that the end of the steam delivery tube shall touch the center of the bottom of the oil container. Steam shall be admitted at a rate that will maintain the temperature of the oil, as shown on the thermometer in the oil container, between 190 and 195 deg. fahr.

NOTE: The usual time necessary for the temperature of the oil to come to this point is 45 to 75 seconds, depending on its character.

This control shall be effected by manipulation of the pinch-cocks on the steam delivery line and steam exhaust line from the steam generator. The steam supply shall be sufficient at all times to cause a generous discharge from the exhaust line. Steaming shall be continued until the volume of condensed steam and oil in the oil container tube is 40 c.c. ±3 c.c. The time required for this operation shall be 4 to 6.5 minutes, depending on the quality of the oil, altitude, etc. If condensed water amounts to 20 c.c. in less than 4 minutes, it shall be taken as an indication of wet steam or incomplete steaming out of the line and the test shall be re-run.

NOTE: The apparent volume in the tube near the end of the steaming operation is approximately 12 to 15 cc. greater than the actual volume due to displacement caused by steam, thermometer and steam delivery tube.

Separation

11. The steam delivery tube shall be withdrawn as soon as the required volume is obtained. The oil container shall be transferred immediately to the separating bath which shall be maintained at 200 to 203 deg. fahr. It is extremely important that the temperature of the separating bath be maintained within the given limits. A stop-watch shall be started at the instant of withdrawal of the steam delivery tube. The cork containing the thermometer shall be removed after the oil container and contents have been placed in the separating bath. The contents of the oil container shall be examined at least every 30 seconds, and the volume of the separated oil layer shall be recorded. When this reading operation has continued until 20 c.c. of oil have separated, the elapsed time in seconds shall be reported as the Steam Emulsion Number (S.E. No. ....). No differentiation shall be made between clear and turbid oil. This examination shall be made without withdrawing the oil container and its contents from the separating bath, and reading the volumes.

In cases where the interface between more-or-less clear oil and the emulsion is not a clear, straight horizontal line, the position of such a line should be carefully estimated to the nearest 0.5 c.c.

If 20 c.c. of oil do not separate, the test shall be discontinued.

Interpretation

12. In interpreting results, the assumption shall be made that the rate of emulsion separation is directly proportional to the resistance to emulsification of the tested oil.

NOTE: The expansion of the oil at the higher temperature is disregarded, so when the separation of the oil is complete, as regards the interface between the oil and emulsion layers, the volume of separated oil will always be more than 20 cc. This in no way interferes with the reproducibility of results, and the time shall be recorded when 20 cc.—and not necessarily all—of the oil have separated, when this occurs in less than 20 minutes.

A.S.T.M. S.E. Number

13. Results shall be reported, to the nearest second, of the time necessary for 20-c.c. oil separation. The time in seconds shall be reported as the Steam Emulsion Number, A.S.T.M. Method (S.E. No.....). In cases where the required volume shall not have separated in 20 minutes, the oil shall be reported as having an S. E. Number, A.S.T.M. Method, of 1200 plus. If a duplicate determination varies by more than 10 per cent, a third test shall be made and the average of the three tests reported.

NOTE: Oils which emulsify separate into three layers without exception: top, clear or turbid oil; middle, lacy or creamy emulsion; bottom, clear or milky water. The S.E. Number is derived from the top layer.

Neutralization Number

Significance of Test

The Neutralization Number of an oil is defined as the weight in milligrams of potassium hydroxide required to neutralize one gram of oil. It represents the sum of the quantities of mineral and so-called organic acids present in the oil or the difference between the organic acidity and the alkali present in the oil. If, as is usually the case, no mineral acid or alkali is present in the oil, the neutralization number is directly proportional to "organic acidity."

The "Alkali Neutralization Number" is defined as the weight in milligrams of potassium hydroxide equivalent to the acid required to neutralize one gram of oil.

The "Mineral Acid Neutralization Number" is defined as the milligrams of potassium hydroxide required to neutralize the mineral acid content in one gram of oil.

The effect of alkali or mineral acid in turbine oil is deleterious.

Organic acids normally present in properly refined turbine oils are low in amount and are not considered harmful from a corrosive standpoint.

Method of Test

[NOTE: The Committee has deleted references to compounded oils, as published in A.S.T.M. Serial designation D-188-27T.]

TENTATIVE METHOD OF TEST FOR NEUTRALIZATION NUMBER OF LUBRICANTS

Abstracted from A.S.T.M. Specifications Serial Designation: D-188-27T

Scope

1. The methods described herein are designed to indicate in lubricants the presence of organic constituents having acid characteristics and the contamination by alkalies and mineral acids.

Definitions

2. (*a*) The Neutralization Number is the weight in milligrams of potassium hydroxide required to neutralize one gram of oil.

NOTE: The Neutralization Number expresses the total amount of the mineral acid, and of the organic constituents having acid characteristics.

(*b*) The Alkali Neutralization Number is defined as the weight of acid required to neutralize one gram of oil, expressed in equivalent milligrams of potassium hydroxide.

(*c*) The Mineral Acid Neutralization Number is the number of milligrams of potassium hydroxide required to neutralize the mineral acid content in one gram of oil.

SOLUTIONS REQUIRED

3. (*a*) *Aqueous Potassium Hydroxide* (1 c.c. = 5 mg. KOH).— Dissolve 5.1 g. of potassium hydroxide, c.p., in one liter of freshly boiled and cooled distilled water. Add a very small amount of barium hydroxide, sufficient to precipitate any potassium carbonate present. Standardize this solution against Bureau of Standards certified benzoic acid, using phenolphthalein as an indicator according to the relation:

$$\frac{5\text{ mg. KOH}}{x\text{ mg. benzoic acid}} = \frac{56.104\text{ g. KOH}}{122.048\text{ g. benzoic acid}}$$

$$1\text{ cc. of KOH} = 10.88\text{ mg. benzoic acid.}$$

This weight of benzoic acid is required for standardization. Make necessary adjustments so that the value of potassium hydroxide equals 5 mg. KOH per 1 cc.

NOTE: Fit the solution bottle with a guard tube of soda lime to prevent access of carbon dioxide. The solution should be standardized at necessary intervals.

The weight of benzoic acid should be dissolved in 50 cc. of 95-per cent alcohol and titrated cold. For blank, use same amount of alcohol and correct the titration.

(*b*) *Sulfuric Acid Solution* (1 cc. = 5 mg. KOH).—Match a sulfuric acid solution so that 1 cc. of the acid will be required to neutralize 1 cc. of the KOH, using phenolphthalein as an indicator, titrating in boiling solution.

(*c*) *Neutralized 95-per-cent Alcohol.*—Add a few drops of phenolphthalein and neutralize carefully the alcohol to a very faint pink end point with some of the above prepared alkali solution.

(*d*) *Phenolphthalein Indicator.*—Dissolve 10 g. of the indicator in 1 liter of 95-per-cent alcohol, preferably ethyl. Use 1 cc. of this strength for titration.

(*e*) *Methyl Orange Indicator.*—Dissolve 1 g. of the indicator in 1 liter of distilled water. Use 0.1 cc. of this strength for titration.

METHODS

4. *Method A.—Neutralization Number of Petroleum Products.*

Weight of Oil: Approximately 20 g. weighed to 0.1 g.

Volume of Solvent: 100 cc. of a mixture of 1:1 neutralized alcohol and distilled water.

Procedure: Agitate oil and solvent thoroughly and heat to boiling. Add 1 cc. of phenolphthalein indicator and titrate rapidly, with vigorous agitation, to a sharp pink end point. The titration must be completed in a hot solution, reheating same if found necessary.

The color change is noted in the alcohol water layer.

Calculation:

$$\frac{(\text{Cubic centimeters of KOH}) \times 5}{\text{Weight of oil taken}} = \text{mg. KOH per 1 g. of oil.}$$

5. *Method B.*[1]*—Alkali or Mineral Acid Neutralization Number in Petroleum Products.*

Weight of Oil: 25 to 50 g. weighed to 0.1 g.

Volume of Solvent: Boiling distilled water, 200 cc.

Procedure: Introduce into a 250-cc. separatory funnel 25 to 50 g. of oil weighed to 0.1 g., and add 100 cc. of boiling distilled water. Shake vigorously, and after oil and water have separated, drain the water layer into a 500-cc. casserole. Wash the oil in the separatory funnel twice by vigorously shaking with 50-cc. portions of boiling distilled water and after separation, drain into the casserole. To the accumulated 200 cc. of water add 1 drop of 1-per-cent phenolphthalein solution. Boil. If solution turns pink, add 1 cc. of the indicator and titrate with the sulfuric acid solution until the extraction is colorless.

If the addition of 1 drop of phenolphthalein causes no change in color, add 0.1 cc. of methyl orange. If color changes to red or pink, titrate with the KOH solution until the red color is just discharged.

An equal volume of distilled water shall be titrated with the standard solution used, and the amount of alkali or acid required shall be subtracted from the titration for blank correction.

Calculation: If the acid solution was required to discharge the phenolphthalein end point, the alkali neutralization number equals:

$$\frac{(\text{Cubic centimeters of acid}) \times 5}{\text{Weight of oil}}$$

If the alkali solution was required to discharge the methyl orange end point, the mineral acid neutralization number equals:

$$\frac{(\text{Cubic centimeters of alkali}) \times 5}{\text{Weight of oil}}$$

Corrosion Test

Significance of Test

Since turbine oils are used in contact with metals, it is essential that the metal shall not be corroded. Sulphur and corrosive compounds are sometimes present in turbine oils and in order to determine the corrosive nature of such oils a corrosion test is employed, which consists of immersing a piece of copper in the oil and maintaining the oil at a temperature of 212 deg. fahr. for three hours. Darkening of the copper after this treatment indicates the presence of corrosive compounds.

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[1] When the oil is acid, the acidity shall not be reported as sulfuric or hydrochloric acid unless the presence of these acids shall have been confirmed by tests.

The above test (while only qualitative) affords the proper degree of protection to the user without imposing an unnecessary hardship on the manufacturer.

Method of Test

Copper strip.

Method 530,31 Bureau of Mines Technical Paper No. 323-B, 1927, p. 97.

Place a clean strip of mechanically polished pure sheet copper about 0.5 in. wide and 3 in. long in a clean test tube. Add enough of the sample to be tested completely to cover the strip. Close the tube with a vented stopper and maintain for 3 hr. at 212 deg. fahr. Rinse the copper strip with sulphur-free acetone and compare it with a similar strip of freshly polished copper. Discoloration or pitting indicates corrosion.

Water and Sediment Test

Significance of Test

This test when applied to new oil receipts gives a volumetric indication of water and of foreign materials such as rust from containers. This test when applied to serviced turbine oil permits the volumetric estimation of water and sediment (sludge) in suspension in the circulating oil.

Method of Test

STANDARD METHOD OF TEST FOR WATER AND SEDIMENT IN PETROLEUM PRODUCTS, BY MEANS OF CENTRIFUGE

Abstracted from A.S.T.M. Specification Serial Designation: D 96—28

Scope

1. This method may be used for crude mineral oils and fuel oils. A centrifuge method for "Water and Sediment" is not entirely satisfactory because the amount of water obtained is nearly always lower than the actual water content. Nevertheless, on account of the wide use of the centrifuge for this purpose, it is desirable that the method of making the determination be standardized as far as possible. It must be clearly understood that the reading of the centrifuge tube includes both the sediment and the precipitated water.

Sample

2. The sample shall be thoroughly representative of the material in question and the portion used for the test shall be thoroughly representative of the sample itself. Deviation from this rule shall not be permitted. The difficulties in obtaining representative samples for this determination are unusually great; hence, the importance of sampling cannot be too strongly emphasized.

APPARATUS

Centrifuge

3. The centrifuge shall be capable of whirling at the required speed at least two 100-cc. centrifuge tubes filled with water. It shall be of sound design and rugged construction so that it may be operated without danger. The tube carriers shall be so designed that the glass centrifuge tubes may be cushioned with water, rubber or other suitable material. The tube holders shall be surrounded during the operation by a suitable metal shield or case, strong enough to eliminate danger if any breakage occurs.

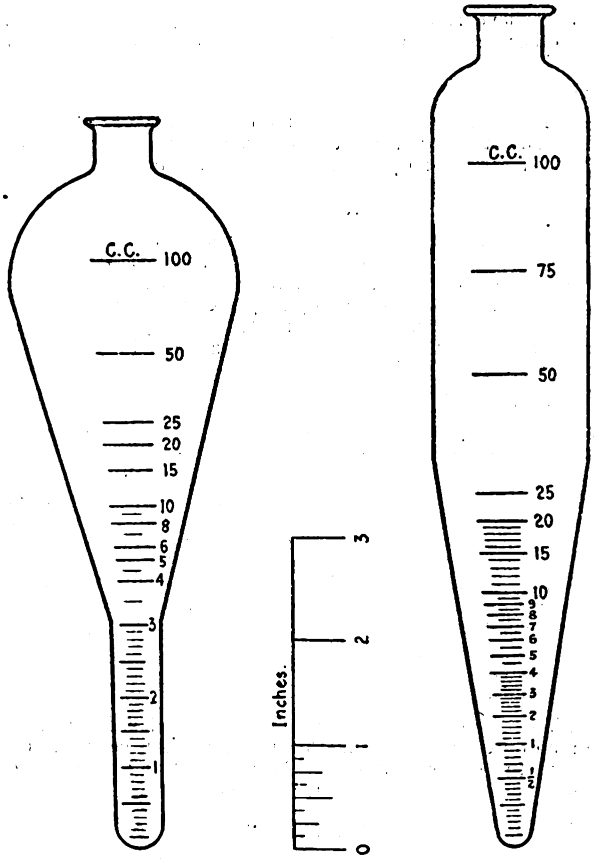

FIG. 11—CENTRIFUGAL TUBES, A.S.T.M.

The preferred form of centrifuge shall have a diameter of swing (tip to tip of whirling tubes) of 15 to 17 in. and a speed of at least 1500 r.p.m. or the equivalent. If the available centrifuge has a diameter of swing varying from these limits, it shall be run at the proper speed to give the same centrifugal force at the tips of the tubes as that obtained with the preferred form of centrifuge. The proper speed shall be calculated from the following formula in which d represents diameter of swing (tip to tip of whirling tubes) of the centrifuge used:

$$\text{R.p.m.} = 1500\sqrt{\frac{16}{d}}$$

Centrifuge Tubes

4. The centrifuge tubes, A.S.T.M. type shall be made of suitable glass and thoroughly annealed. The total capacity shall be about 125 cc. and the mouth shall be suitably constricted for closing with a cork. The graduations shall be clear and distinct, reading upward from the bottom of the tube. The value of the divisions for each range shall not be greater than shown in the following tabulation:

Range.	Scale Divisions.	Limit of Error.	Numbered.
0 - 3 cc.	0.1 cc.	0.05 cc.	1, 2, 3 cc.
3 - 5 "	0.5 "	0.2 "	4, 5 "
5 - 10 "	1.0 "	0.5 "	6, 8, 10 "
10 - 25 "	5.0 "	1.0 "	15, 20, 25 "
50 - 100 "	50.0 "	1.0 "	50, 100 "

The shape is optional provided it does not conflict with the other requirements. Satisfactory types are shown in Fig. 11.

Bath

5. The water or oil bath shall be of sufficient depth for immersing the centrifuge tubes in a vertical position to the 100-cc. mark. Means shall be provided for heating this bath to 120 deg. fahr.

PROCEDURE

6. (*a*) Exactly 50 cc. of 90-per-cent benzol shall be measured into each of two centrifuge tubes and exactly 50 cc. of the oil to be tested shall then be added to each. The centrifuge tubes shall be tightly stoppered and shall be shaken vigorously until the contents are thoroughly mixed. The temperature of the bath shall be maintained at 120 deg. fahr. and the centrifuge tubes shall be immersed therein to the 100-cc. mark for 10 minutes.

(*b*) The two centrifuge tubes shall then be placed in the centrifuge on opposite sides and shall be whirled at a rate of 1400 to 1500 r.p.m. or the equivalent for 10 minutes. The combined volume of water and sediment at the bottom of each tube shall be read and recorded, estimating to 0.1 cc. if necessary. The centrifuge tubes shall then be replaced in the centrifuge, again whirled for 10 minutes, and removed for reading the volume of water and sediment as before. This operation shall be repeated until the combined volume of water and sediment in each tube remains constant for three consecutive readings. In general, not more than four whirlings will be required.

Water and Sediment

7. The combined total volume of water and sediment shall be read on each tube, estimating to 0.1 cc. if necessary. The sum of the two readings shall be recorded as percentage of water and sediment, centrifuge method.

ACCURACY

8. With care and proper attention to details, duplicate determinations of water and sediment by this method should not differ by more than 0.2 cc. provided the centrifuge tubes are accurate and readable to this degree.

Oxidation at High Temperatures

Note: This Method Must Not Be Applied to Used Oils Owing to the Danger of Explosion Due to Moisture or Water Present in the Oil.

Signficance of Test

When petroleum oils deteriorate in service, this deterioration is generally accompanied by oxidation and the formation of oxidation products. In some types of service the possibility of oxidation is not considerable, but in others, such as the lubrication of steam turbines, the ability of the oil to resist chemical change is of prime importance. Accordingly, a method of test that will measure this characteristic is desirable.

The "Sligh Method" consists of subjecting a definite amount of oil to a temperature of 200 deg. cent. in a special flask, from which the air has been displaced and oxygen substituted, for a period of 2.5 hr. The material precipitated from the oxidized oil by petroleum naphtha is a measure of the deterioration of the sample under test.

Oils that have been subjected to oxidizing conditions are usually acidic in nature (organic acids) and if water is brought in contact with such oils, and agitated, undesirable emulsions will be formed.

The steam turbine lubricating system provides opportunity for these conditions to occur when oils are employed which are easily oxidized.

In the selection of oil for steam turbine lubrication a knowledge of the Oxidation Number and the Steam Emulsion Number (providing the viscosity is suitable) furnishes valuable information with regard to possible performance and freedom from sludge formation.

Method of Test

The oxidation value of turbine oils shall be determined by the "Sligh Method" developed at the Bureau of Standards and published in A.S.T.M. Proceedings, Vol. 27, Part 1, 1927, Appendix, p. 461.

PROPOSED OXIDATION TEST FOR MINERAL OILS (SLIGH METHOD)

This method of measuring the resistance of mineral oils to oxidation was developed in the oil laboratory of the U. S. Bureau of Standards. It is the outcome of several years of experimentation with the object of developing an oxidation test which would yield consistent results, which could be precisely specified so that agreement between different laboratories would be possible, and which would not make extraordinary demands upon the operator's time or patience.

It has been taken for granted that the mass of residue precipitated from a petroleum naptha solution of an oxidized oil is a comparative measure of the degree of oxidation of the oil. With this as a basis, various methods of subjecting the oils to definite oxidizing influences have been investigated with this method as the result.

1. The procedure for this method shall be as follows:

(a) Weigh into a clean standard oxidation flask[1] a sample of 10 g. ± O.1.g. of the oil. Displace the air in the flask by oxygen under atmospheric conditions (760 mm. of mercury and 25 deg. cent.) and clamp the slightly greased ground stopper carrying the connection plug into place.

[NOTE: This joint should be gas tight as leakage of oxygen during the test will produce low results.]

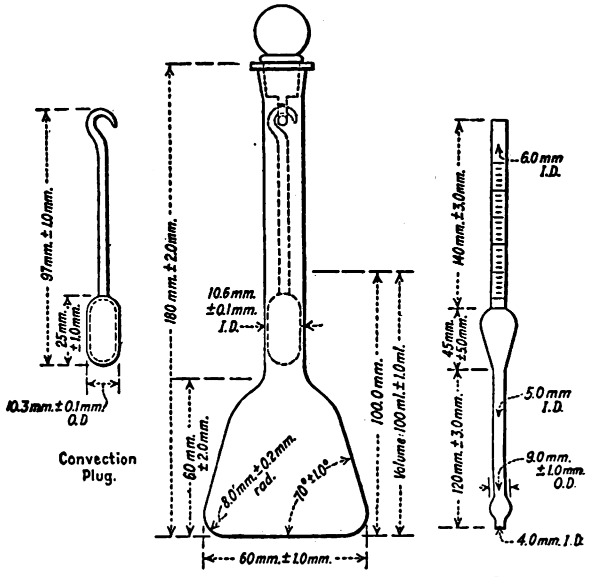

FIG. 12—OXIDATION FLASK AND OIL PIPETTE, A.S.T.M.

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[1] Standard oxidation flasks and oil pipettes as shown in Fig. 12, are manufactured in Pyrex glass and may be obtained through dealers in laboratory supplies.

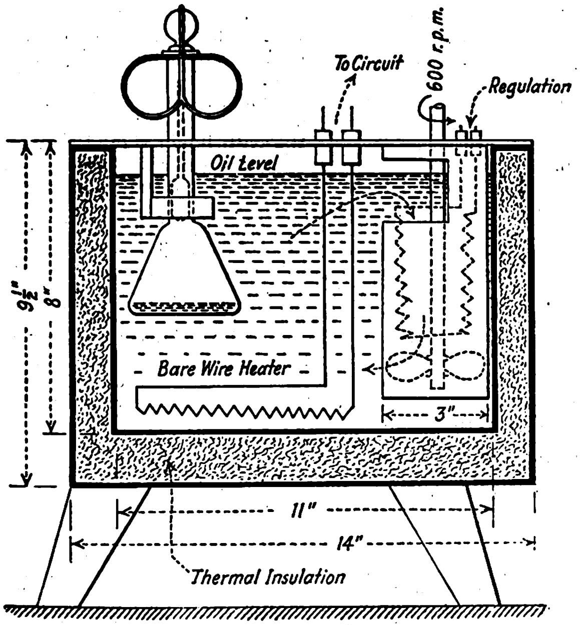

FIG. 13—OXIDATION OIL BATH, A.S.T.M.

(b) Immerse the flask and sample vertically in a well stirred oil bath, Fig. 13, maintained at 200 deg. cent. (392 deg. fahr.) to a point about 1 in. above the body of the flask. Remove after 2.5 hr. at this temperature.

(c) When cool, dilute the oxidized oil to a total volume of 100 cc. with petroleum naphtha. Shake to dissolve the oxidized oil and allow to stand for one hour at a temperature of 25 deg. cent. with a variation of ± 2.0 deg. cent.

[NOTE: The naphtha used should have an end point below 120 deg. cent (248 deg. fahr.), and should be free from unsaturated and cyclic compounds. The naphtha specified in the Tentative Method of Test for Precipitation Number of Lubricating Oils (D 91-21 T)[2] should be used as standard, though any suitable naphtha may be used for the comparative rating of a given series of oils. In general, the amount of precipitates obtained from a given sample of oxidized oil increases with the volatility of the naphtha used.]

(d) Filter and weigh the precipitate. The weight of this precipitate expressed as a percentage of the weight of the sample of oil used and multiplied by 100 is the oxidation number of that sample. Thus, a precipitate of 0.0205 g. (20.5 mg.) from a 10.0 g. sample would be expressed as an oxidation number of 20.5.

The above procedure is thought to be sufficient if followed precisely to insure consistent results. However, the specific procedure followed in the oil laboratory of the U. S. Bureau of Standards is described in detail below as it may serve to call attention to some desirable precautions and conveniences.

APPARATUS

2. (a) *Oxidation Bath*—An oil bath equipped for heating and circulating the oil shall conform to the dimensions shown in Fig. 13. It shall be maintained at a temperature of 200 deg. cent. ± 1 deg. cent. and the circulation should be such that temperature gradients in the bath are negligible. A propeller 2.75 in. in diameter mounted in a 3-in. tube and driven about 600 r.p.m. will give adequate circulation. The bath shall be of sufficient size to accommodate at least six oxidation flasks. A bath 8 in. deep having a capacity of about 3 gal. is suggested. If of a circular form the diameter would be 10 to 11 in. Clamps or supports to hold the flasks in a vertical position shall be provided and a well-fitted cover should be used to reduce the rate of deterioration of the bath fluid and to protect the greased seals on the flasks from overheating. In very warm weather it may be necessary to direct a blast of air, as from an electric fan, across the top of the bath to keep these seals cool. Leakage of oxygen almost invariably results if the stop-cock grease becomes hot enough to flow.

(b) The oil used in the bath should, for safety, have a high flash point and should also have a high resistance to oxidation.

(c) A bath having the construction shown in Fig. 13 should require an input of from 200 to 300 watts to maintain a temperature of 200 deg. cent. Manual or automatic temperature control may be used as desired.

3. *Drying Oven*—The drying oven shall be an air oven in which a temperature of about 105 deg. cent. (230 deg. fahr.) is maintained.

4. *Balance*—The analytical balance shall be sensitive to 0.0001 g. For rough weighing to 0.01 g. it is convenient to reduce the sensitivity and period by attaching a small (2 g.) weight on the pointer. A sensitivity of 1 division on the scale for 0.01 g. permits very rapid weighing of oil samples. The full sensitivity shall, of course, be used in obtaining the weight of precipitates.

5. (a) *Oxidation Flasks*—The oxidation flasks shall be special long-necked Erlenmeyer flasks with the ground glass stoppers and convection plugs conforming to the dimensions shown in Fig. 12. The convection plugs shall be interchangeable in the flasks and serve to render the temperature in the flask independent of the temperature of the room. Convection up and down the neck is also suppressed by their use.

(b) It is essential that the stoppers shall be a good fit in the neck. This may be tested by seating the stopper with a drop of naphtha on the grinding. Under this condition the stopper should seat firmly without shake which may be readily detected by the motion of the thin film of naphtha between the surfaces when a lateral force is applied to the top of the stopper. The stopper clamps (see Fig. 14) shall be bent to shape from the phosphor-bronze spring wire 0.057 in. in diameter (No. 15 B. and S. gage). The half-rings which encircle the flask neck just below the bead shall be cushioned with a wrapping of thread on a short length of soft tubing such as rubber or varnished cambric to avoid localized pressure which might cause breakage of the flasks.

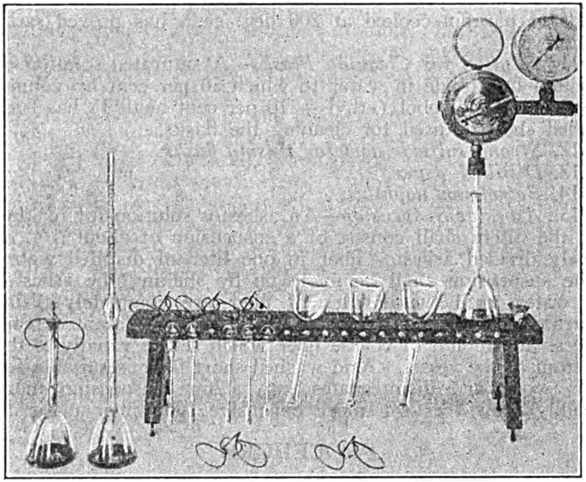

FIG. 14—MISCELLANEOUS EQUIPMENT FOR OXIDATION TEST, A.S.T.M.

[NOTE: This cushioning material is not shown on the clamps in Fig. 14 but should be used. The clamps should exert a total force of about 2 lb. on the stoppers.]

6. *Gooch Crucibles*—Gooch crucibles of the ordinary variety, size No. 3 (25 cc.) of porcelain with perforated bottoms shall be used. These may be marked for identification (see Fig. 15) with chromium oxide and a small amount of borax made up to a creamy paste with water and burned in. The marking may be made on the crucible with a steel pen, allowed to dry in air, and burned in at a temperature of about 1000 deg. cent. with a blow torch or in a furnace.

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[2] Proceedings, A. S. T. M., Vol. 21, p. 648, (1921); also 1926 Book of A. S. T. M. Tentative Standards, p. 457.

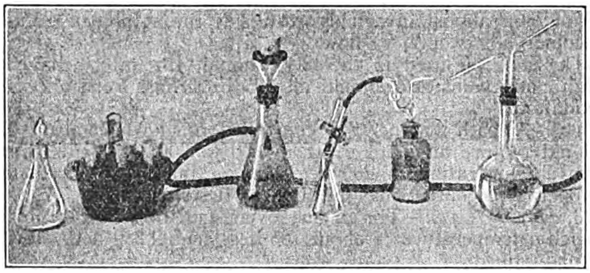

FIG. 15—FILTER SET-UP.

7. *Suction Flask and Accessories*—Fig. 15 shows a convenient filtration outfit. The suction flask "A" shall be connected to the suction system by a rubber tube to which a three-way valve "V" is connected by a glass tee. This valve shall connect to a 300 cc. drexel-form gas wash bottle "B," as shown, which shall be filled with mercury to a depth of about 8 cm. The other valve connection opens to the atmosphere.

8. *Oil Pipettes*—The oil pipettes shall conform to the dimensions shown in Fig. 12 and shall be used in weighing the samples of oil into the oxidation flasks to permit easy adjustment to the desired weight and to prevent soiling of the sides and neck of the flask.

9. *Erlenmeyer Flasks*—Erlenmeyer flasks from ordinary stock should be roughly calibrated and marked for a volume of 100 cc.

10. *Stop-Cock Grease*—Stop-cock grease shall be of medium or hard grade as required to maintain the seal under the operating conditions. A grease made of 72 per cent of petrolatum, 16 per cent of rubber (pure gum), and 12 per cent of paraffin cooked at 200 deg. cent. has proved satisfactory.

11. *Solution for Cleaning Flasks*—A saturated solution of sodium hydroxide in water to which 50 per cent by volume of denatured alcohol (ethyl + 10 per cent methyl) has been added shall be used for cleaning the flasks.

12. *Strong sulfuric acid for rinsing flasks.*

13. *Distilled water.*

14. *Petroleum naphtha.*

15. *Asbestos Suspension*—An asbestos solution for making up the filters shall consist of a suspension of about 6 g. of finely divided asbestos fiber in one liter of distilled water. The suspension shall be made up by shaking the asbestos in water until the bundles of fiber are completely disintegrated. The fine suspension should then be decanted from the small amount of coarse fiber which settles rapidly to the bottom of the vessel. Acid-washed short fiber is suitable for this work and disintegrates into a fine suspension more readily than does the more expensive long fiber material.

PROCEDURE

16. (a) *Weighing of Oil Sample*—The weight of the clean empty flask shall be obtained. A card bearing these weights and the approximate weights of the crucibles posted near the balance will prove a great convenience. Approximately 12 cc. of oil shall be drawn into the oil pipette, the tip of the pipette wiped and the oil transferred to the weighed flask, allowing the oil to drain to a definite point, say till 10 oil drops have been formed. A 10-g. weight shall be placed on the weight pan and a rough balance obtained. The weight of sample is, say, 9.82 g. The pipette shall be replaced in the flask and 3 drops (about 0.05 g. per drop) allowed to drain in. An exact balance should now show 9.95 g., which is within the specified limits (10 g. ± 0.1 g.).

(b) *Filling with Oxygen*—The stoppers of the flasks shall now be slightly greased and the convection plugs attached. A flask shall be brought up over a vertical glass tube through which oxygen (commercial purity as supplied in drums) is issuing downward at the rate of about 2 liters per min. The flask shall be held in this position for about 30 sec. (see Fig. 14) and then removed and the stopper carrying the connection plug quickly put in place, seated and clamped.

(c) The increase in pressure upon heating is largely due to the expansion of the oxygen, as the vapor pressure of lubricating oils is low even at 200 deg. cent., so that with the small necks used a light clamp exerting a total pressure of about 2 lb. should be sufficient.

(d) The flasks shall now be placed in their clips in the bath, which has already been brought to a temperature of 200 deg. cent. The level of the bath liquid should be about 1 in. above the body of the flasks and sufficient space should be left between the flasks and the bottom and sides of the bath for free oil circulation.

(e) After 2.5 hr. at 200 deg. cent. the flasks shall be removed and allowed to cool, and the bath oil washed off in a vessel of gasoline or gasoline-benzol mixture kept for this purpose. The flasks shall then be opened and about 50 cc. of petroleum naphtha added to dissolve the oxidized oil. This solution shall be transferred to a 100 cc. short-necked Erlenmeyer flask, the rinsing from the oxidation flask added, and the solution made up to a total volume of 100 cc. The precipitation flasks shall be corked and set aside to precipitate at a temperature of about 25 deg. cent. for 1 hr.

[NOTE: This precipitation is an equilibrium process and the final state depends upon the temperature as well as upon the nature of the solution. The temperature coefficient of solubility of these oil naphtha solutions is such that, in general, the mass of precipitate is increased by about 1 mg. for each 5 deg. cent. decrease in the temperature of precipitation. Except in precision work, it is not ordinarily necessary to take special precautions to insure the proper precipitation temperature. However, it is customary in the laboratory of the U. S. Bureau of Standards to set the precipitation flasks in a large vessel of water at room temperature and to observe and record the temperature of this water at the time filtration is made. This permits an approximate correction to 25 deg. cent., and guards against rapid changes in temperature.]

After the oxidized oil is transferred to the precipitation flasks the oxidation flasks shall be thoroughly cleaned as described in Section 19.

17. (a) *Preparation of Filters*—The desired number of Gooch crucibles shall be set on a rack above a pan or drain, Fig. 15, and into each shall be poured about 20 c.c. of the asbestos water suspension. This shall be allowed to drain for a few minutes to permit the formation of a thin mat on the bottom of the Gooch crucible and each crucible then sucked dry over the suction flask. The suction valve may be opened wide and the by-pass valve "V" closed to give rapid action. The filter may be washed through with denatured alcohol (90 per cent ethyl + 10 per cent methyl) to hasten the drying, if desired.

(b) The filters shall then be heated in the drying oven for from 30 min. to 1 hr. as required, and allowed to cool in a dessicator, from which they are taken to be weighed when needed.

[NOTE: If the crucibles are slightly warm or if they have become electrified, due to wiping before weighing, erratic weighings will result. No difficulty will be encountered due to atmospheric moisture as neither the filter nor the filtrate takes up moisture readily. Weighings of filters should be taken to the nearest 0.0001 g.]

18. (a) *Filtration*—The weighed filter shall be placed on the suction flask, well seated, and the suction valve set to give a slight bubbling through the mercury by-pass "B," Fig. 15, which should be set to release at a suction of about 8 cm. of mercury.

(b) The clear solution above the precipitate shall now be poured on the filter. A small metal spreader may be used if the filter pad shows a tendency to wash aside. When the precipitate begins to appear, the pouring shall be stopped, the neck of the precipitation flask rinsed into the filter with a stream of petroleum naphtha from the wash bottle.

(c) The oil on the sides of the filter shall now be washed down with a stream of petroleum naphtha and the precipitate carefully poured on. Care should be taken to rinse all precipitate out of the precipitation flasks using a stiff bristle brush to loosen up adherent precipitate. Finally, the precipitate and the filter shall be thoroughly washed with naphtha to remove traces of oil, sucked dry and placed in the drying oven for 15 to 30 min., and when dry removed to cool in the dessicator and the second weighing taken.

19. (a) *Cleaning Flasks*—The oxidation flasks after use shall be filled with a solution of alcoholic caustic-soda and allowed to stand over night or heated for 30 min. in a vessel of water at about 50 deg. cent. and allowed to stand for several hours.

(b) The solution shall then be poured back into its container, the flasks shaken out with clean, coarse washing sand to remove the deposit which the cleaning solution has loosened but not dissolved. After rinsing with tap water, sulfuric acid shall be used to neutralize traces of soda which are active in promoting oxidation. The acid shall then be thoroughly rinsed out with tap water and after a final rinsing with distilled water the flasks set slantwise in rack, not on pegs, to drain and dry; see Fig. 14.

(c) These narrow-necked flasks dry slowly but the process may be hastened, if desired, by heating in the drying oven and inverting the warm flask over a tube through which air is drawn by suction.

(d) This thorough cleaning is essential and shall be performed each time a test is run as traces of oxidized oil remaining in the flask may produce erroneous results in the succeeding test.

The precipitation flasks often show a slight brownish stain which is partially removed upon rinsing into the filter. The mass of this adherent film is negligible as compared to the total mass of the residue.

Precipitation flasks shall be cleaned by rinsing with benzol or carbon tetrachloride followed by petroleum naphtha.

Gooch Crucibles—After the final weighings the filter pads shall be taken out and any stain wiped off with a cloth moistened in benzol or carbon tetrachloride. The crucibles shall be rinsed with petroleum naphtha and may then be made up for the next test.

SOURCES OF ERROR

19. *Oxygen Loss*—A large part of the trouble reported from a number of laboratories regarding this test seem to be attributable to loss of oxygen from the flask during the test. This may be due to a poor fit of the stopper in the neck or the overheating of this point due to inadequate insulation of the top of the oxidation bath.

20. *Breakage of Flask*—Some breakages of the flask at the grinding have been reported. These may be due to poor fit of the stopper, grit on the grinding or more probably to localized pressure of the clamp on the neck or bead.

Erratic results may also be due to imperfect cleaning of the flasks or accidental contamination after cleaning.

DISCUSSION

This oxidation test was designed primarily for the examination of internal-combustion engine lubricants and the conditions of test were chosen with special reference to simplification, reproducibility and acceleration of the tests. Thus, 200 deg. cent. seems to be the highest temperature at which reproducible results may be readily obtained, though a lower temperature may be found more suitable for certain classes of oils.

The use of the mass of asphaltene precipitated from a definite solution of the oxidized oil in petroleum naphtha as a measure of the deterioration of the sample under test seems justified because this precipitate is the product which is largely responsible for the formation of troublesome deposits and "sludges" in service. In addition, the evaluation of this precipitate is fairly simple and has long been in use in oil laboratories.

However, this precipitate is only one of the products of oxidation and it may well be that other products in addition, acidity for instance, may be found to have great influence upon the utility of the oil for certain classes of service.

The test, however, appears to have certain general advantages regardless of the specific conditions of test and the method of evaluation of results which may be found to be useful in particular cases. These advantages may be summed up as follows:

The conditions of test are definitely reproducible and may be varied independently, thus permitting a study of the effects of each factor.

The effects of catalyzers such as metallic oxides or the effects of the oxidation products upon materials with which the oil is in contact in service may be investigated.

The reaction takes place in a closed system and so effects of different atmospheres, air, ammonia and the like, upon the reaction may be noted.

Further, all of the reaction products are available for evaluation and study, and it may thus be possible to work out a complete reaction balance for a given set of conditions. It has been noted that in oxidation substances are formed which have higher molecular weights than the original oil; acids, carbon dioxide and water vapor are also formed.

The quantitative evaluation of these products for particular oils should yield information regarding the effects of methods of refining and treatment upon the stability of the oil.

MANUFACTURERS' STATEMENTS

STATEMENT BY LAMOTTE CHEMICAL PRODUCTS COMPANY

Non-Technical Definition of the "pH" (Hydrogen-Ion) Scale

The principle of making pH measurements by the colorimetric method is based on the fact that various indicators change in color when they are acted upon by solutions of different acidities or alkalinities. Litmus paper is probably the simplest and best known example of an indicator. If litmus paper is dipped into an acid solution, it turns red. If it turns only slightly red, the solution is said to be "slightly" acid. If it turns deep red, however, the solution is said to be "strongly" acid. Similarly, if the paper turns blue the solution is said to be "slightly" or "strongly" alkaline. These are very vague and indefinite terms and their meaning varies enormously, depending largely on the opinion of the worker.

In making pH measurements, definite pH values such as 3.0, 7.4, 9.6, etc., are substituted for the indefinite terms "strongly" and "slightly" acid and alkaline. These pH values can be recorded and can be duplicated at any time.

The degree of acidity or alkalinity of a solution is expressed by the Hydrogen Ion Scale. Instead of being called degrees, as in the case of the thermometer, the units on this scale are called pH values. It is apparent that it is not necessary to know the derivation of the term "degree fahrenheit" in order to determine the temperature of a solution. It is equally true that the worker need not know the meaning of the term "pH" in order to use this method for measuring acidity and alkalinity. On the Hydrogen Ion Scale, a value of pH 7.0 represents neutrality. This means that if the material being tested has a pH of 7.0 it is neither acid nor alkaline.

Thus, any values higher than pH 7.0 denotes alkalinity, the degree of alkalinity increasing as the numbers increase. Analogously, any values lower than pH 7.0 denote acidity, the degree of acidity increasing as the numbers decrease.

It is apparent that if a solution has a pH of 7.6 it is alkaline. If another has a pH of 8.2 it is more alkaline than the one of pH 7.6. It is also clear that acid must be added to a solution of pH 7.6 to bring it to the neutral point of pH 7.0, and that larger quantities must be added to bring it to an acidity of 6.8, 6.0, etc. Similarly, if a solution has a pH of 6.0, it is acid, and it is necessary to add alkali to it in order to bring it to the neutral point pH 7.0, or to an alkaline value such as pH 8.0.

In order that the worker may have some idea of the degree of acidity corresponding to various pH values, it may be stated that a solution which has a pH value of 5.0 is ten times as acid as one with a pH of 6.0. Analogously, a solution of pH 4.0 is ten times as acid as one of pH 5.0. Thps, pH 4.0 indicates an acidity 100 times as great as one of pH 6.0. A similar relationship holds on the alkaline side of the scale. That is, a solution which has a pH of 9.0 is ten times as alkaline as one which has a pH value of 8.0, etc.

As previously stated, litmus is very insensitive partly because it covers such a wide range. In order to make accurate pH determinations it is, therefore, necessary to employ indicators with short ranges, so that the color changes are more distinct.

This means that a number of indicators are necessary to cover the entire pH range 1.2 to 12.6. A complete set of indicators developed to cover this range is shown in the following table:

Name	pH Range	Color Change
Meta Cresol—Purple.	1.2— 2.8	Red—yellow
Bromphenol—Blue ..	3.0— 4.6	Yellow—blue
Bromcresol—Green ..	4.0— 5.6	Yellow—blue
Chlorphenol—Red ...	5.2— 6.2	Yellow—red
Bromthymol—Blue ..	6.0— 7.6	Yellow—blue
Phenol—Red	6.8— 8.4	Yellow—red
Cresol—Red	7.2— 8.8	Yellow—red
Thymol—Blue	8.0— 9.6	Yellow—blue
Nitro—Yellow	10.0—11.6	Colorless—deep yellow
Sulfo—Orange	11.0—12.6	Pale Yellow—deep orange

The actual determination of pH value by the colorimetric method is a very simple procedure. All that is necessary is to add a definite amount of indicator to a definite amount of the water sample (10 c.c.) and compare the color against color standards corresponding to the indicator used.

This control method has been so widely adopted that the pH values which should be maintained in connection with boiler water conditioning has been very definitely determined.

Technical Discussion of Hydrogen Ion Concentration and the Derivation of pH Values

According to the theory of electrolytic dissociation, all liquids, of which water is a constituent, contain free H and OH ions. When the number of H ions exactly equals the number of OH ions, the solution is said to be neutral. If the number of H ions exceeds that of the OH ions, the solution is said to be acid. Conversely, if the solution contains an excess of OH ions, it is said to be alkaline.

It is well known that acidity is due to the presence of H ions in a solution, the acidity increasing as the number of H ions increases. Strong acids are those which are highly dissociated in solution to give a large number of H ions. Weak acids are those which are but slightly dissociated in solution and, therefore, give relatively few H ions. For example, hydrochloric acid (HCl) is a strong acid and acetic acid is a weak one. In titration, 10 c.c. of N/10 HCl and 10 c.c. of N/10 acetic acid will, of course, each require 10 c.c. of N/10 NaOH for neutralizations. The number of H ions in N/10 HCl is, however, almost 70 times as great as the number of H ions in N/10 acetic acid. It is readily seen that the H ion concentration is not determined by simple titration. Since it is the H ion concentration and not total acidity which is the controlling factor in the majority of chemical reactions, the importance of making pH determinations is apparent.

Pure distilled water will conduct an electric current to a very slight degree. This shows that a very small proportion of the water is dissociated into H and OH ions. By the mass law.

$$\frac{\text{Concentration of H Ions} \times \text{Conc. of OH Ions}}{\text{Concentration of Undissociated } H_2O} = \text{a Constant}$$

Since the amount of undissociated water is relatively large, it can be taken as a constant, and the above equation becomes:

$$\text{Conc. of H Ions} \times \text{Conc. of OH Ions} = \text{a Constant}$$

By electrical conductivity measurements, this constant has been found to be 1/100,000,000,000,000 or 10^{-14} at 21 deg. cent. Since in pure distilled water the number of H ions is equal to the number of OH ions, each must have a concentration of 1/10,000,000 or 10^{-7}.

This method of expressing H ion concentration is very inconvenient and clumsy. Sorensen suggested the use of the term "pH," the pH value being the logarithm of the reciprocal of the hydrogen ion concentration. Thus,

$$pH = \log \frac{1}{(H+)}$$

Just as an acid solution is said to be normal when it contains 1 g. of ionizable hydrogen per liter, so a solution is said to be normal with respect to hydrogen ions when it contains 1 g. of ionized hydrogen per liter. Since

$$pH = \log \frac{1}{(H+)}$$

is the reciprocal of the normality of H ions in a solution, the pH value can also be defined as the logarithm of the denominator expressing the normality of H ions such as N/10, N/100, N/1000, etc.

This method of expressing H ion concentration has now been generally adopted. In the case of pure distilled water, in which the H ion concentration is 0.0000001 or N/10,000,000 the pH value would be the log of 1/0.0000001 or of 10,000,000, which is 7.0. This value 7.0 is the neutral point on the pH scale.

It will readily be seen that pH values below 7.0 such as 6.0, 5.0, etc., will denote acidity, the degree of acidity is increasing as the numbers decrease. For example, if a small amount of HCl is added to pure distilled water which has an H ion concentration of 10^{-7} or a pH value of 7.0, the acid will dissociate into positive H ions and negative Cl ions. The total number of H ions in the solution will be greater than 10^{-7}, and the solution will therefore be acid. Suppose the H ion concentration is found to be N/1,000,000. The pH value will be the log of 1,000,000, which is 6.0. Similarly, if the H ion concentration is N/100,000, the pH value will be 5.0, etc. It should be remembered that, since we are dealing with logarithmic values, a solution having a pH value of 6.0 contains 10 times as many H ions as one having a pH value of 7.0. Similarly, a solution of pH 5.0 contains 100 times as many H ions as one of pH 7.0.

Since by the law of mass action

$$\text{Conc. of H Ions} \times \text{Conc. of OH Ions} = \text{a Constant,}$$

it is apparent that as the H ion concentration increases the OH ion concentration must decrease, and vice versa. Even in a strongly alkaline solution there are, however, some H ions, and for the sake of simplicity it is advisable to express both acidity and alkalinity in terms of pH values.

From the fact that neutral water has an H ion concentration of N/10,000,000, it is apparent that an alkaline solution must contain a smaller number of H ions. Let us assume that, by adding a small amount of sodium hydroxide to pure water, we decrease the H ion concentration to N/100,000,000. The pH value of this solution will be 8.0. Similarly, if the H ion concentration is reduced to N/1,000,000,000, the pH value would be 9.0. This shows why all values higher than 7.0 indicate alkalinity, the degree of alkalinity increasing as the numbers increase. It should be remembered here also that a solution of pH 9.0 contains 10 times as many OH ions as one of pH 8.0.

It is therefore seen that the pH value is an absolutely accurate measure of the degree of acidity or alkalinity of a solution. By making these determinations, definite values are obtained which can be recorded and which can be duplicated exactly at any time by the same or different workers. We are, therefore, not dependent on such vague and meaningless terms as slightly acid or alkaline, moderately or strongly acid, or alkaline, etc.

The exact meaning of H ion concentration and pH values, and the derivation of the latter, can be made clear by a few concrete examples. A N/10 solution of hydrochloric acid is one which contains 3.65 g. of HCl or 0.1 g. of ionizable H per liter. Electrical conductivity measurements have shown that at 18 deg. cent. 91.4 per cent of the HCl is dissociated. This means that 91.4 molecules out of every 100 do not exist as molecules, but are split up into H and Cl ions. The remaining 8.6 per cent exist as molecules. If the HCl were completely ionized, the N/10 solution would contain 0.1 g. of H ions per liter. Since, however, only 91.4 per cent is ionized, it contains

$$0.1 \times \frac{91.4}{100} = 0.0914 \text{ g. of H ions per liter.}$$

The normality of this solution with respect to H ions is

$$\frac{1}{0..0914} = N/10.94$$

The pH value of N/10 hydrochloric acid is therefore the logarithm of 10.94 or 1.0.

A N/10 solution of acetic acid also contains 0.1 g. of ionizable H per liter. Electrical conductivity measurements show, however that at 18 deg. cent. it is dissociated only to the extent of 1.36 per cent. Hence the hydrogen ion concentration is

$$0.1 \times \frac{1.36}{100} = 0.00136 \text{ g. per liter.}$$

This is equivalent to a N/735 solution of H ions. The pH value of N/10 acetic acid is therefore the log of 735, which is 2.86.

Since the hydrogen ion concentration of N/10 HCl is 0.0914 g. per liter and of the acetic acid 0.00136 g. per liter, the hydrochloric acid contains almost 70 times as many hydrogen ions as the acetic acid.

The following table will give the worker some idea of the relationship between the total acidity and pH value of a few common acids and bases. The pH values have been given for N/10 solution and are rounded off to the nearest 0.1, as this is sufficiently accurate for general work. Thus, the above value for acetic acid, pH 2.86 is given as 2.9 in the table:

Acids	pH Value	Bases	pH Value
HCl	1.0	$C_6H_5NH_2$	7.8
H_3PO_4	1.5	$NaHCO_3$	8.4
CH_3COOH	2.9	$Na_2B_4O_7$	9.2
H_2CO_3	3.8	NH_4OH	11.3
H_3BO_3	5.2	Na_2CO_3	11.6
C_6H_5OH	6.0	$NaOH$	13.1

From the above discussion it will readily be seen that if the solutions encountered were only solutions of known pure acids and alkalis, the pH value could be calculated from the titration values and ionization constants. This is, however, seldom the case, as the solutions normally contain relatively indefinite quantities of other substances, and usually a number of unknown impurities. Many of these materials have what is known as "buffer action," which means that considerable quantities of acid or alkali can be added to them without changing their pH value.

STATEMENT BY THE LEEDS AND NORTHRUP COMPANY, PHILADELPHIA, PA.

pH Indicator

The Leeds & Northrup No. 7654 pH indicator is designed especially for pH measurements with the quinhydrone calomel electrodes, and because of reliability the set-up is better than any other now available. The instrument is compact and easily operated. The standard cell and galvanometer are included with the case, the working battery being connected externally. A photograph of the assembled indicator and cell is reproduced in Fig. 16.

A schematic diagram of the pH indicator is shown in Fig. 17.

Binding posts marked "Q" and "C" provide connections for the quinhydrone and calomel electrodes respectively. The indicator is calibrated in millivolts with a range from — 400 to + 100 millivolts, which corresponds to pH 1 to 9 (with the quinhydrone-calomel electrodes). The guaranteed accuracy of the instrument is 2.5 millivolts or approximately 0.04 pH. The galvanometer affords a sensitivity of 0.05 millivolt, or about 0.01 pH. The quinhydrone electrodes cannot be used where the pH is more than 8.5 or 9.0.

The calomel electrode, which serves as a reference potential, is prepared in the usual manner by placing in a suitable vessel mercury, calomel and potassium chloride solution (saturated KCl is generally used). The quinhydrone electrode is a gold, or unplatinized, platinum electrode, immersed in the test solution to which a few milligrams of quinhydrone have been added.

With the electrodes properly connected the procedure in making pH determinations may be outlined by the following steps:

1. Standardize potentiometer current by depressing "S C" key and rotating the knurled rheostat knob behind the gal-

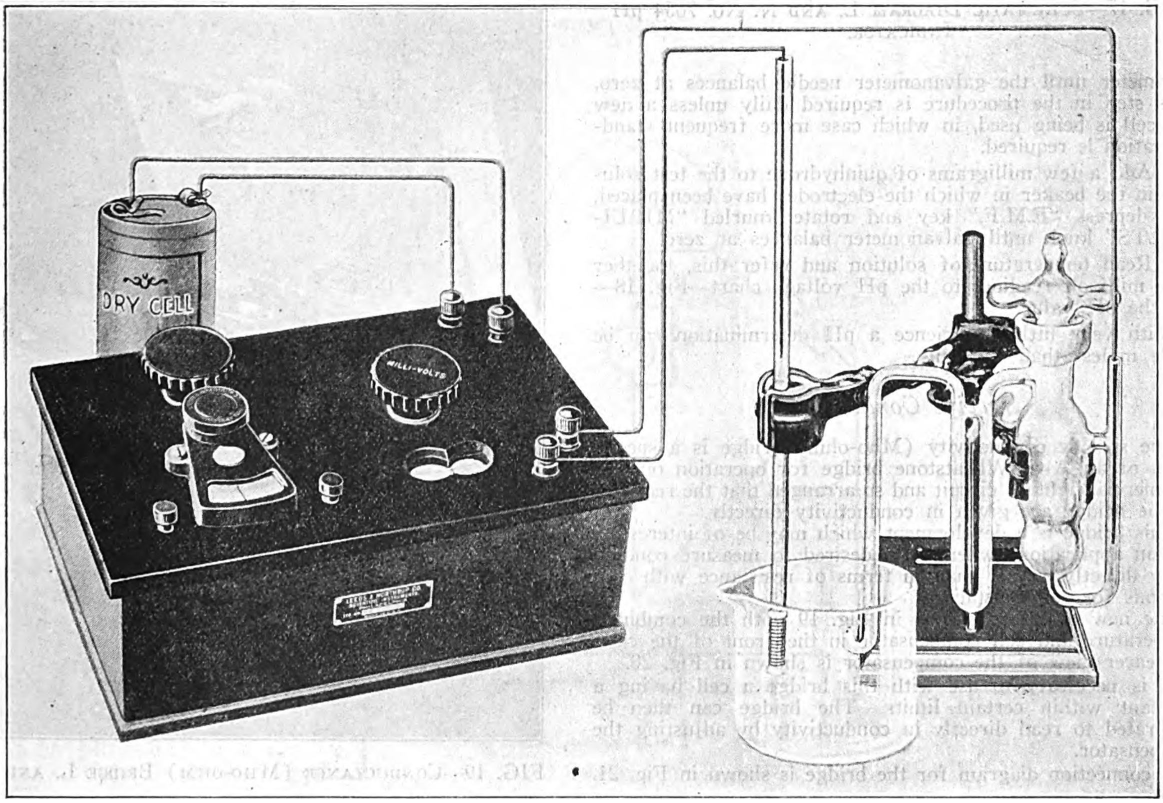

FIG. 16—L. AND N. No. 7654 pH INDICATOR.

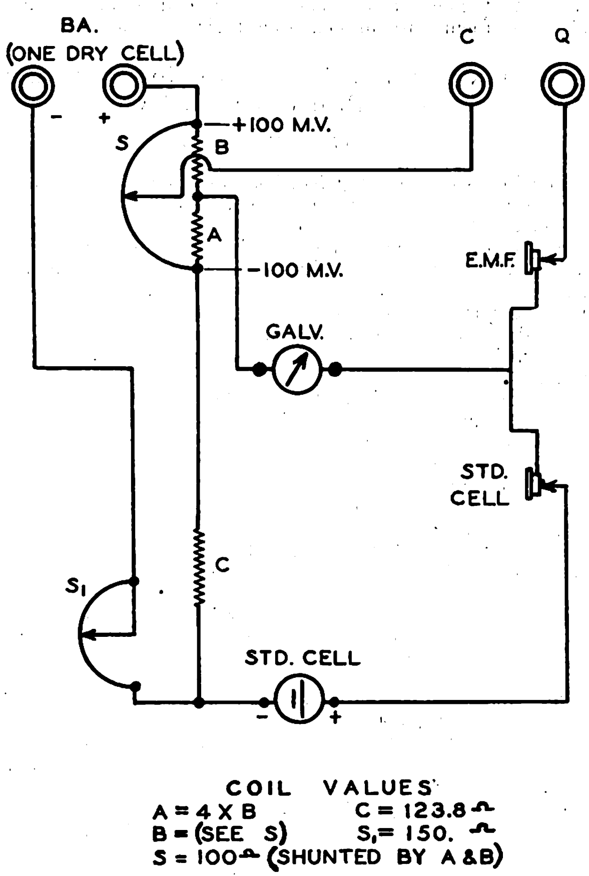

FIG. 17—SCHEMATIC DIAGRAM L. AND N. No. 7654 pH INDICATOR.

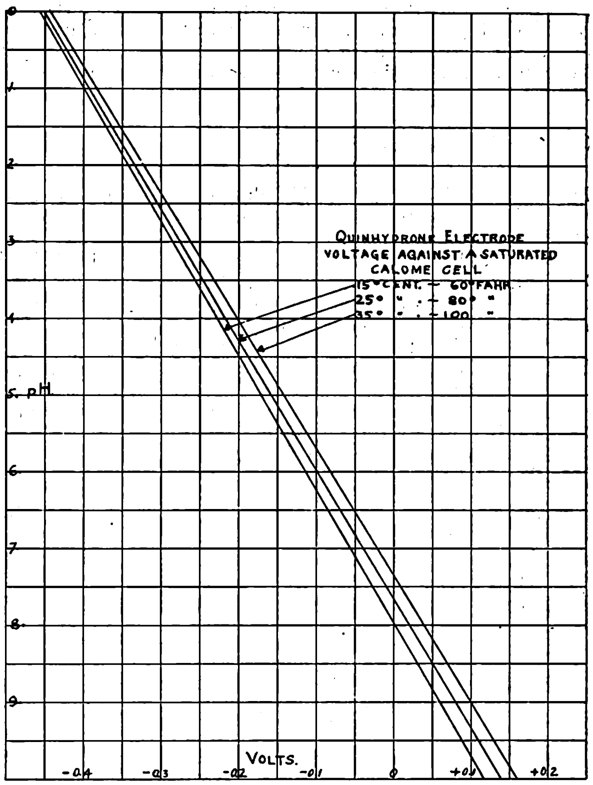

FIG. 18—pH VOLTAGE CHART—QUINHYDRONE ELECTRODE, L. AND N.

vanometer until the galvanometer needle balances at zero. This step in the procedure is required daily unless a new dry cell is being used, in which case more frequent standardization is required.

2. Add a few milligrams of quinhydrone to the test solution in the beaker in which the electrodes have been placed, stir, depress "E.M.F." key and rotate knurled "MILLIVOLTS" knob until galvanometer balances at zero.

3. Read temperature of solution and refer this, together with millivolt reading, to the pH voltage chart—Fig. 18—for the pH value.

With very little experience a pH determination can be made in less than a minute.

Specific Conductance

The specific conductivity (Mho-ohm) bridge is a special form of an A-C. Wheatstone bridge for operation on any commercial lighting circuit and so arranged that the readings of the bridge are given in conductivity directly.

This bridge is a development which may be of interest in certain applications where it is desired to measure conductivity directly, rather than in terms of resistance with corrections for cell constant.

The new bridge is shown in Fig. 19 with the combined temperature and cell compensator in the front of the case. A clearer view of the compensator is shown in Fig. 20.

It is necessary to use with this bridge a cell having a constant within certain limits. The bridge can then be calibrated to read directly in conductivity by adjusting the compensator.

A connection diagram for the bridge is shown in Fig. 21.

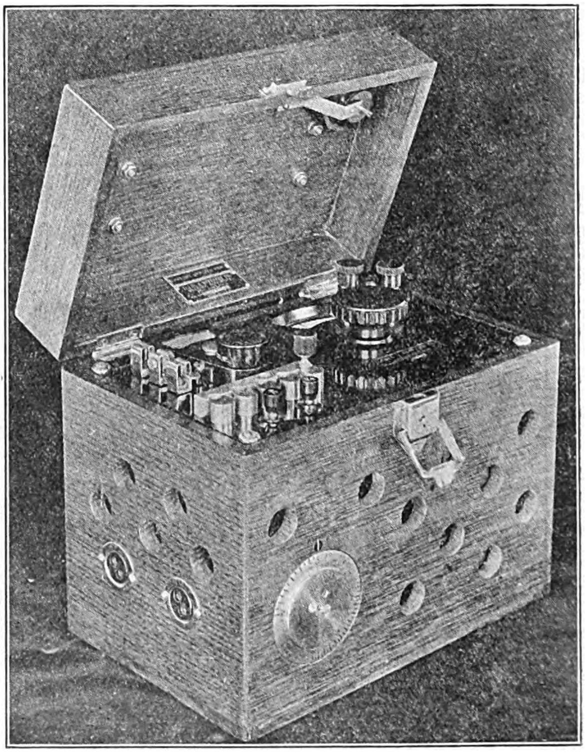

FIG. 19—CONDUCTANCE (MHO-OHM) BRIDGE L. AND N.

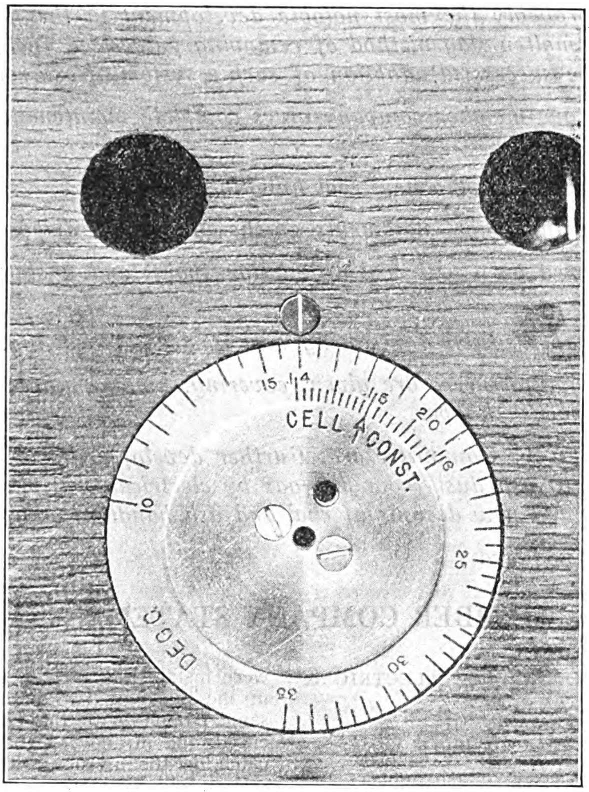
15
14
16
20
18
CELL CONST.
10
25
30
35
DEG C.

FIG. 20—CELL AND TEMPERATURE COMPENSATOR FOR CONDUCTANCE (MHO-OHM) BRIDGE, L. AND N.

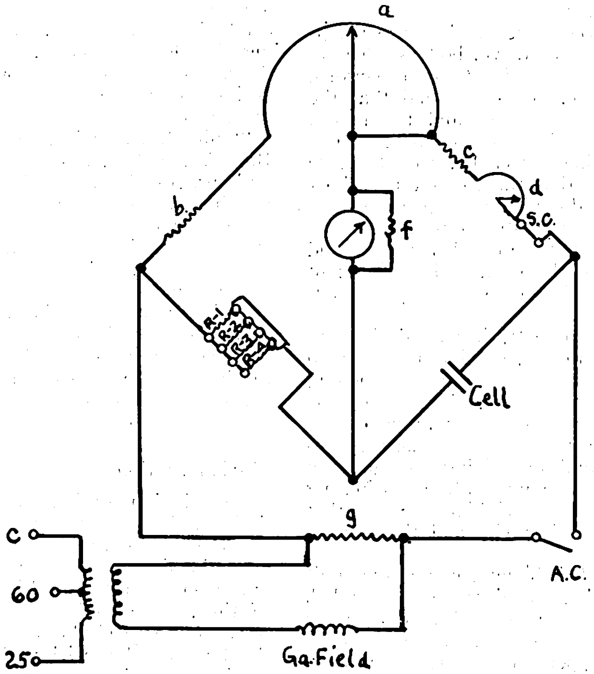
a
b
c
d
S.C.
f
R-1
R-2
R-3
R-4
Cell
g
A.C.
C
60
25
Ga.Field

FIG. 21—CONNECTION DIAGRAM OF CONDUCTANCE (MHO-OHM) BRIDGE, L. AND N.

COAL AND ASH HANDLING

During the past year probably the most notable development in the handling of coal and ash has been the introduction of the molten slag method of removing pulverized fuel ash from the furnace. Two member companies report the successful adoption of such a system of ash removal.

For stoker-fired boilers one member company gives complete maintenance costs for various types of ash hoppers and gates.

Two statements are offered showing new coal handling equipment.

Two member companies offer short statements on the commercial disposal of ash.

A complete test is reported on a new coal distributor spout, and a statement is made regarding its operation.

The use of the drag scraper system for storing coal is steadily growing.

Statements from five manufacturers are given, covering, among other items, a motor-operated ash gate and a new vestibule-type ash hopper.

Problems to be studied by the Committee are: Further developments in handling pulverized fuel ash as molten slag; the removal of ash dust from flue gas by electrical precipitators and other methods; the commercial disposal of ash; and new designs of coal and ash handling equipment.

A brief bibliography is included.

MEMBER COMPANY STATEMENTS

STATEMENT BY THE PUBLIC SERVICE ELECTRIC & GAS COMPANY

Ash Hoppers and Gates; Maintenance Costs

"The following data on various types of ash hoppers and gates are taken from the Essex, Marion, Burlington, Perth Amboy and Camden generating stations.

Essex Station

"At Essex Station the ash hoppers are of steel construction with brick lining and are of four different designs, the general features of which are as follows:

"Considerable difficulty was experienced with the ash hoppers under the eight 13,720 sq. ft. B. & W. boilers forming units 1 and 2. Each hopper is divided into two sections, each equipped with only one gate. It was found that the slope of the walls was not steep enough and the mouth opening was too small. As these boilers are not equipped with clinker grinders, large clinkers often hang on the side walls, choking the mouth, preventing the rapid removal of the ash and making the labor of dumping an expensive item. The mouth of the hopper was originally constructed with a heavy cast-iron throat piece, but repeated heatings and quenchings broke these castings, destroying the alignment of the gate slides and hindering the operation of the pneumatic gates.

"After ten years of service, in 1925, it was decided to change the design of the hopper mouth, eliminating as much metal as possible from contact with the ash and quenching water. This was done by riveting an angle iron to the hopper steel work to carry the load of brick lining above, by raising the channels supporting the gate-operating mechanism up to the hopper mouth and by sliding the gate on angles riveted to the channels. The intermittent sprinkling system was replaced by continuous sprinklers. Since that time the gates have operated satisfactorily and their maintenance has greatly decreased.

"The four 12,780 sq. ft. B. & W. boilers, comprising unit No. 3, were equipped with clinker grinders when installed. The ash hoppers were of the same general type as units 1 and 2, that is, there was a two-section hopper to each boiler. The walls of these hoppers, however, were made steeper and two gates, separated by a peaked division wall, were installed in each section, making four gates per boiler in the place of two per boiler, as previously used. The same trouble with the cast-iron throat pieces was experienced, and in addition there was a tendency for the ash to catch on the division wall between the two gates in each section and hinder its removal.

"After eight years of service, in 1926 the throat pieces were removed and a mouth design similar to redesigned units 1 and 2 was installed; continuous sprinklers replaced the intermittent type.

"The ash hoppers of unit No. 4, consisting of four 12,780 sq. ft. B. & W. boilers, were further improved by removing all internal division walls, making one large hopper per boiler, increasing the number of gates to five, and bringing the slope of the side walls nearer to the vertical. The throat pieces soon gave trouble and were replaced by the new design after five years' service, and continuous sprinklers were installed.

"Units No. 5 and 6, each consisting of four 12,980 sq. ft. B. & W. boilers, have been in service for over three years with practically no trouble. Since the original installation, which consists of one large hopper per boiler, no changes have been made. The hopper walls are very steep and the ends are vertical. Each hopper is equipped with six pneumatically operated gates.

"In general, it may be said that the ash hopper troubles at this station have been eliminated and the maintenance costs decreased by the removal of as much metal as possible from contact with the ash, and by using continuous sprinklers in place of the intermittent. Table I gives the maintenance costs of ash hoppers and gates for the boiler units at Essex Station.

Marion Station

"At Marion Station the ash hoppers are of three different designs, the general features of each being explained later.

"If the boilers are operated at ratings under 200 per cent, the linings in the hoppers last as long as the hoppers, but when operated at higher ratings for any great length of time, large clinkers are likely to drop into them, and in breaking these clinkers damage is done to the brick lining. As long as the brickwork is in good condition the outer castings of the hopper will not crack. An intermittent quenching system is used, operating only when the ashes are dumped from the grates. Because of this fact, during

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Publication No. 289-43, Serial Report, Prime Movers Committee.

TABLE I

MAINTENANCE COSTS ON ASH HOPPERS AND GATES ESSEX STATION

Year	Tons of Coal Burned	Cost of Ash Hopper and Gate Repairs	Cost of Repairs per Gross Ton of Coal Burned
Boiler Unit No. 1—Four—13,720 sq. ft. B. & W. Boilers			
1920	78,244	$1,710.66	2.181¢
1921	66,192	1,149.30	1.736
1922	69,704	1,733.78	2.481
1923	76,636	1,313.38	1.714
1924	76,900	1,223.88	1.592
1925	74,060	1,310.52	1.770
Total......	441,736	$8,441.52	1.911¢ avg.
Boiler Unit No. 2—Four—13,720 sq. ft. B. & W. Boilers			
1920	72,340	$1,980.73	2.738¢
1921	57,900	1,940.50	3.351
1922	59,980	1,784.14	2.974
1923	74,468	1,027.75	1.380
1924	77,336	2,133.46	2.758
1925	71,564	3,007.54	4.203
Total......	413,588	$11,874.12	2.871¢ avg.
Boiler Unit No. 3—Four—12,780 sq. ft. B. & W. Boilers			
1920	76,388	$544.83	0.713¢
1921	68,320	187.07	0.274
1922	54,440	217.56	0.399
1923	81,528	341.32	0.419
1924	74,984	279.61	0.373
1925	74,244	281.65	0.379
Total......	429,906	$1,852.04	0.431¢ avg.
Boiler Unit No. 4—Four—12,780 sq. ft. B. & W. Boilers			
1920	56,792	$483.84	0.852¢
1921	68,048	235.00	0.372
1922	67,000	619.15	0.924
1923	93,260	1,034.19	1.109
1924	76,988	3,304.78	4.292
1925	81,692	3,842.49	4.704
Total......	443,780	$9,537.45	2.149¢ avg.
Boiler Unit No. 5—Four—12,780 sq. ft. B. & W. Boilers			
1923	134,160	$341.32	0.254¢
1924	106,592	299.61	0.281
1925	120,824	367.85	0.357
Total......	361,576	$1,008.78	0.279¢ avg.

the past five years, common brick has been used when it became necessary to reline the hoppers. The results obtained were the same as when fire brick were used and at a lower cost. Another reduction in ash hopper maintenance consists in concreting all iron beams supporting the hoppers, thus preventing the rapid deterioration of the beams through the action of salt water and gases. Before the beams were concreted, hoppers often had to be taken down simply to replace a few supporting members.

Type 1

"In this group there are two hoppers and two gates for each boiler. Each hopper is made up principally of four sides and a bottom plate, all of which are of cast-iron, as are the gates themselves. The gates are pivoted at one point by means of a bolt and, in opening, travel along a supporting rail. The life of this type of hopper is from ten to fifteen years. During the life of the hopper the only parts necessary to replace are the bottom plates and the gates, which, not being protected by brick lining, are subject to rapid changes in temperature due to the hot ash and cold salt water and, therefore, crack. Both are replaced every five years without taking the boiler out of service. After the gates have been in service for a year or so they sag a little, due to the weight and heat of the hot ashes. This sag causes a considerable loss of draft and is remedied by taking up on the guide rail.

Type 2

"In this group there is one large hopper to each boiler, and each hopper has four doors which slide on guides. These doors are operated by hand, as are the gates of Type 1. The hopper is supported by steel girders at top and bottom. The sides of this type of hopper are of ⅜ in. sheet steel, whereas the bottom plates and gates are cast iron. The life of these hoppers is from ten to fifteen years. The parts that require replacing during the life of the hopper are the bottom plates, the gates and the beams upon which the lower part of the hopper rest. All of these are replaced every five years. The bottom plates and gates crack due to rapid temperature changes and from the effects of salt water and gases. The lower supporting beam becomes weakened from these causes and sags, thus throwing the guides out of line so that the gates will not close tightly, causing a loss of draft which necessitates the replacement of the beam and the lining up of the door guides. The boiler has to be taken off the line to replace the bottom plate, a gate or a beam. Replacement of one bottom plate or gate necessitates the removal of the side supports, the bottom supports and the other bottom plates and gates. To install a new support beam on the side requires the shoring up of the whole hopper.

Type 3

"This type of hopper, used on both underfeed and overfeed stokers, is of sturdy construction, with the hopper and gates of cast-iron. One large hopper and four sliding gates are furnished for each boiler. These gates are hand lever operated. The life of these hoppers is about fifteen years. The guides for the gates wear badly, necessitating a replacement to prevent too great a loss of draft on the underfeed stokers. The gates need to be replaced about every five years. The bottom castings or the gates can be replaced without taking the boiler out of service; yet, on account of the heavy construction the charges on this work run a little higher than on Type 1, but less than on Type 2.

"Since the separate costs on each of the types mentioned are not available, the costs of maintaining ash hoppers and gates on fifty 6000 sq. ft. B. & W. boilers are given in Table II.

TABLE II

MAINTENANCE COSTS ON ASH HOPPERS AND GATES

Year	Tons of Coal Burned	Cost of Ash Hopper and Gate Repairs	Cost of Repairs per Gross Ton of Coal Burned
Marion Station—Fifty—6,000 sq. ft. Boilers			
1923	325,768	$3,560.04	1.093¢
1924	259,392	5,527.83	2.131
1925	220,040	1,934.17	0.879
1926	168,385	3,246.61	1.928
Total......	973,585	$14,268.65	1.465¢ avg.
Burlington Station—Four — 6,000 sq. ft. B. & W. Boilers Four—6,130 sq. ft. Edge Moor Boilers			
1922	83,936	$640.78	0.763¢
1923	56,640	740.51	1.307
1924	68,560	112.27	0.164
1925	68,288	666.85	0.976
Total......	277,424	$2,160.41	0.779¢ avg.

Burlington Station

"At this plant there are four 6000 sq. ft. B. & W. boilers, four 6130 sq. ft. Edge Moor boilers and two 14,180 sq. ft. B. & W. boilers. The eight smaller boilers have one hopper of steel plate construction, brick lined, to each unit. The cast-iron gates are of the clam-shell type, one to each boiler. They are hand operated, the lever lifting one side and this side lifting the other three segments. On the two 14,180 sq. ft. boilers, the hoppers, one to each boiler, are also of the steel-plate construction, brick lined, but the gates, of which there are six per boiler, are cast iron of the sliding type, operated by compressed air. The hoppers and gates under the two larger boilers were installed in 1923, and, to date, excluding the air cylinders, there have been no repairs or maintenance. The ashes are quenched by water sprays during and immediately after dumping, and the pits are emptied as soon as possible. As there is a much larger opening on the hoppers of the larger boilers, they are, of course, much more desirable. The manual operation of the gates on the smaller boilers and the prying loose of clinkers through the narrow gate opening sometimes require strenuous effort. The maintenance costs for the eight small boilers are shown in Table II.

Perth Amboy and Camden Stations

"At Perth Amboy the eight 6000 sq. ft. B. & W. boilers are each equipped with one divided, sheet-steel hopper lined with fire brick. The bottom ends and gates are of cast-iron. The gates are pivoted at one end by a bolt, and in opening travel along a supporting guide rail; they are manually operated by a lever and move in a horizontal plane. After the gates have been in service a year or so, they sag a little due to wear and the weight and effect of hot ashes, but this is remedied by taking up on the guide rail. All the iron beams that support the hoppers are faced with fire brick as protection from the hot gases. The intermittent system is used to quench ashes.

"The original hoppers were in service from 1911 to 1917 and 1918, when they were rebuilt. In 1922 four of these hoppers were again renewed and the others repaired. They were all renewed in 1924. The average life of the frame and gate is five years, while the brick lining is repaired when necessary and the iron work painted once a year. Over a period of seven years the average cost of maintaining the ash hoppers and gates at this plant has been 3.455 cents per gross ton of coal burned, the coal consumption over this period being 344,711 tons.

"At Camden Station there are six 5000 sq. ft. Altman Taylor and two 6000 sq. ft. Edge Moor boilers. The hoppers are of the single type, one to each boiler, and are of cast-iron. The gates, one to each hopper, being of the same type as those just described, are subject to the same troubles. The hoppers are lined with fire brick and their average life is about fifteen years, while the bottom castings and gates give about five years' service. All iron beams supporting the hoppers are protected by a layer of fire brick laid up in Portland cement and have not been renewed in twenty-two years. The intermittent sprinkler system of quenching is also used at this plant. The maintenance cost of ash hoppers and gates at Camden Station, over a period of eight years, averages only 0.524 cents per gross ton of coal burned; however, during this period only 245,505 tons of coal were consumed."

STATEMENT BY THE CONSOLIDATED GAS, ELECTRIC LIGHT & POWER CO.

Commercial Disposal of Pulverized Fuel Ash

"The furnace ash is collected in the ash pits located below the water-screen tubes. These ash pits are equipped with Allen-Sherman-Hoff gates and water jet system, sluicing the ash into a pit outside the plant, where, at the present, it is removed by a crawler crane equipped with a clamshell bucket. Such soot as collects in the soot hoppers of the boilers is run through pipes to the sluiceway and is mixed with the furnace ash. The contents of the clamshell bucket are dropped into a dump truck, hauled to a nearby site, and used for fill purposes.

"So far we have found no use for this ash from which a satisfactory income can be derived. We will soon be unable to use the nearby site, and our ash-disposal costs will be increased. The ash is not very suitable fill material, if the made ground is called upon to sustain any appreciable weight, and, for this reason, there is no demand for this use.

"From investigations we have made, its use in making Portland cement is about the only one of promise, though in our case, because of the small amount produced, this cannot be considered. We have experimented with building blocks similar to those known as 'cinder blocks,' but the characteristics as to strength, etc., were far inferior to the ordinary cinder blocks.

"On the basis of tons of dry refuse, computed from coal and ash analyses, we realize an average return of approximately 34 cents per ton for ash from stoker-fired plants, this figure being obtained by dividing total money received from sale by tons produced. It should be noted that not all ash produced is sold, some being hauled to a nearby dump. However, in our case the amount of money received for ash is favorable to the stoker-fired plant, and is of such an amount that it may affect the choice of equipment, depending, of course, upon how close the costs are to a balance"

STATEMENT BY THE DETROIT EDISON CO.

Commercial Disposal of Ash

"The stoker ash, or cinders, from each of The Detroit Edison Co.'s stoker-fired plants is sold in the local market. The credit resulting from the sale of this ash amounts to approximately 90 per cent of the total cost of ash disposal. Average costs and credits of ash disposal for the combined stoker-fired plants for the year 1927 are given in Table III.

TABLE III

ASH DISPOSAL COSTS—STOKER-FIRED PLANTS

Item	Cost in Cents per Ton of Coal Burned
Operating costs	4.6
Maintenance costs	1.4
Total costs	6.0
Credit from sale of cinders	5.4
Net cost of ash disposal	0.6

"The most common commercial uses of stoker ash are as an aggregate for concrete roof and floor slabs, and as the body of cinder blocks used in building construction. It has been used experimentally as a constituent in a furnace refractory patching material and also in a road-surfacing material, but these cannot as yet be considered commercial uses.

"Although the question of ash disposal may often be of minor importance in the selection of the fuel-burning equipment, it may, on the other hand, have a very decided influence.

TABLE IV

ASH DISPOSAL COSTS—PULVERIZED FUEL PLANTS

Item	Cost in Cents per Ton of Coal Burned
Operating costs	1.2
Maintenance costs	1.0
Total costs	2.2
Credits	0
Net cost of ash disposal	2.2

"In Table IV are given the costs of ash disposal for pulverized fuel plant for the year 1927.

"Comparison with Table III shows that, while the operating and maintenance costs of ash disposal are considerably lower for the pulverized fuel equipment, this advantage is more than offset by the credit resulting to the stoker-fired equipment from the sale of cinders. It should also be noted that there is no market up to the present time for the fine ash produced by pulverized fuel furnaces. The question of ash disposal assumes its greatest importance, then, in the choice of fuel-burning equipment, when the proposed plant location prohibits 'dumping' the pulverized fuel ash near at hand, and where there is, at the same time, an assured market for stoker ash."

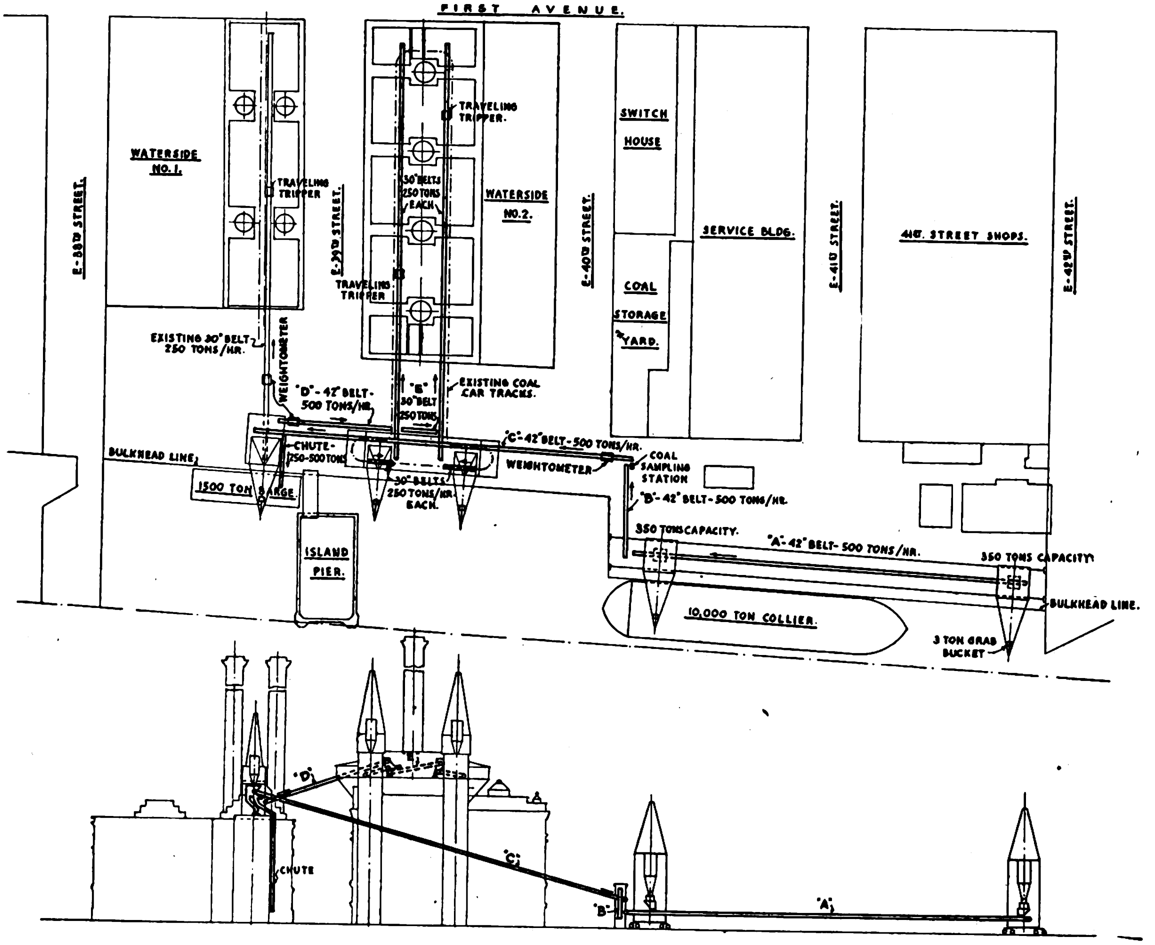
FIRST AVENUE.
E-38TH STREET.
WATERSIDE NO. 1.
TRAVELING TRIPPER
E-39TH STREET.
TRAVELING TRIPPER.
30" BELTS 250 TONS EACH
TRAVELING TRIPPER
WATERSIDE NO. 2.
E-40TH STREET.
SWITCH HOUSE
COAL STORAGE YARD.
SERVICE BLDG.
E-41ST STREET.
41ST. STREET SHOPS.
E-42ND STREET.
EXISTING 30" BELT 250 TONS/HR.
WEIGHTOMETER
"D"-42" BELT-500 TONS/HR.
"E" 30" BELT 250 TONS
EXISTING COAL CAR TRACKS.
BULKHEAD LINE.
CHUTE-250-500 TONS
1500 TON BARGE.
30" BELTS 250 TONS/HR. EACH.
"C"-42" BELT-500 TONS/HR.
WEIGHTOMETER
COAL SAMPLING STATION
"B"-42" BELT-500 TONS/HR.
ISLAND PIER.
350 TONS CAPACITY.
"A"-42" BELT-500 TONS/HR.
350 TONS CAPACITY
BULKHEAD LINE.
10,000 TON COLLIER.
3 TON GRAB BUCKET
"D"
"E"
CHUTE
"C"
"B"
"A"

FIG. 1—COAL HANDLING SYSTEM, WATERSIDE STATIONS, NEW YORK EDISON CO.

STATEMENT BY THE NEW YORK EDISON COMPANY

New Coal Handling System

"The new coaling system at the Waterside Stations, Fig. 1, was installed to unload and handle coal direct from ocean-going colliers of large capacity, in addition to the existing barge unloading facilities.

"The coal is unloaded by two traveling towers of 350 tons per hr. capacity each, is crushed and delivered to the belt conveyor 'A,' from which it is taken by other belt conveyors for distribution to Stations No. 1 and 2. These outside conveyors are completely housed. The sampling and weighing is done en route.

"The existing unloading facilities for Station No. 2 have been arranged with short belt conveyors which connect to the new system.

"From conveyor 'C' coal can be transferred, by a chute, to barges for transportation to the other stations of the New York Edison and Allied Companies system."

STATEMENT BY THE IOWA RAILWAY & LIGHT CORPORATION

Coal Handling in a Small Plant

"At the Boone, Iowa, plant of the above company are installed four 4100 sq. ft. and one 5200 sq. ft. Edge Moor boilers, all fired by chain grate stokers, and 6000 kw. of generating capacity. The coal-handling equipment consists of an 18 in. apron feeder of 25 tons capacity at 15 ft. per min. taking coal from the hopper under the railroad tracks and delivering it to a 10 in. by 8 in. continuous bucket elevator with a lift of 48 ft. and a capacity of 25 tons at 100 ft. per min. This elevator discharges the coal directly into a 4 ton, driving weigh larry, which in turn feeds the stoker hoppers, with an extension capacity of two tons each. The entire outfit is electrically driven. This scheme has the advantage of rather low cost for a small plant, and with the driving weigh larry coal weights can be obtained to give a check on evaporation and plant performance. The entire layout is shown in Fig. 2."

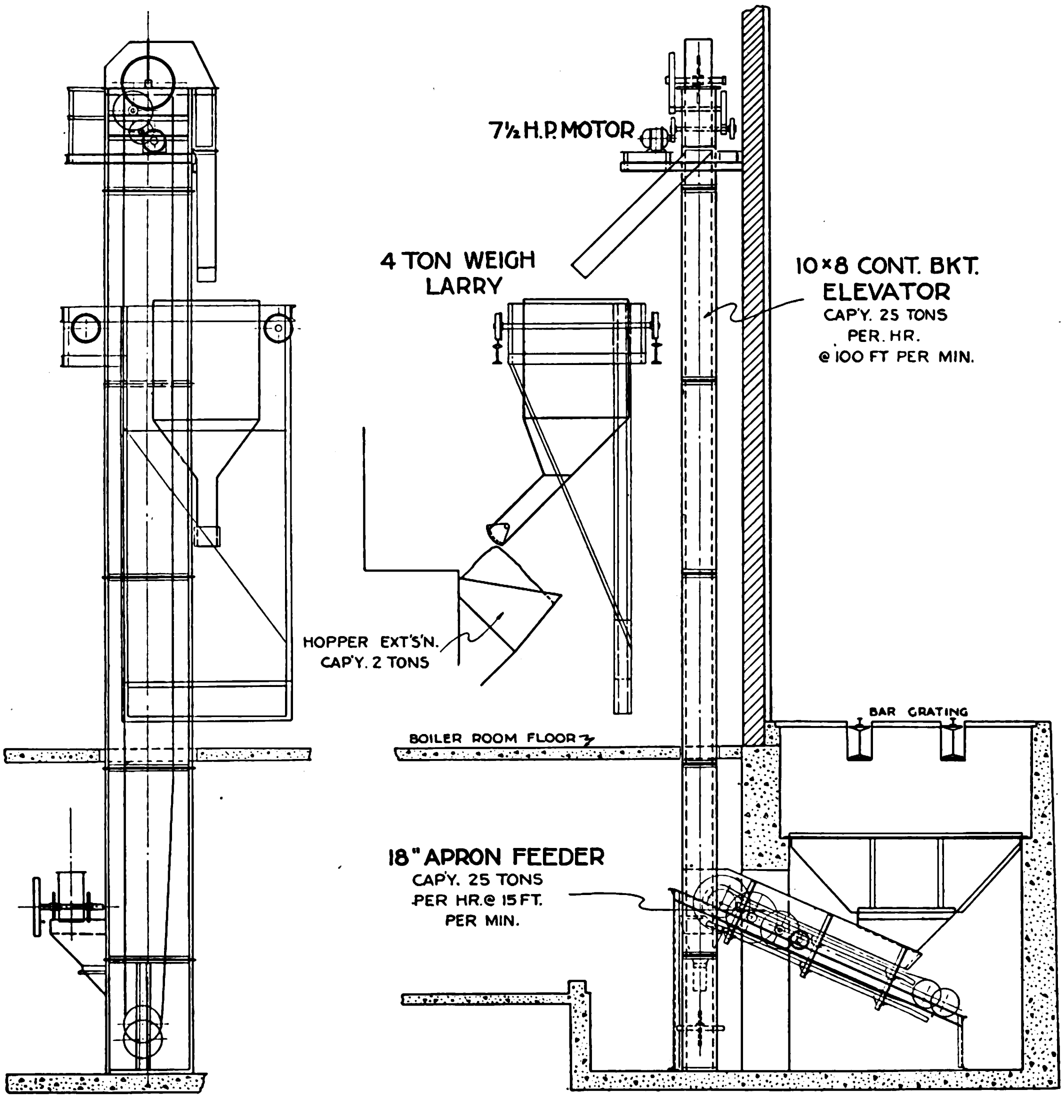
7½ H.P. MOTOR
4 TON WEIGH LARRY
10×8 CONT. BKT. ELEVATOR
CAP'Y. 25 TONS PER. HR. @ 100 FT PER MIN.
HOPPER EXT'S'N. CAP'Y. 2 TONS
BOILER ROOM FLOOR
BAR GRATING
18" APRON FEEDER
CAP'Y. 25 TONS PER HR. @ 15 FT. PER MIN.

FIG. 2—COAL HANDLING SYSTEM, IOWA RAILWAY & LIGHT CORP.

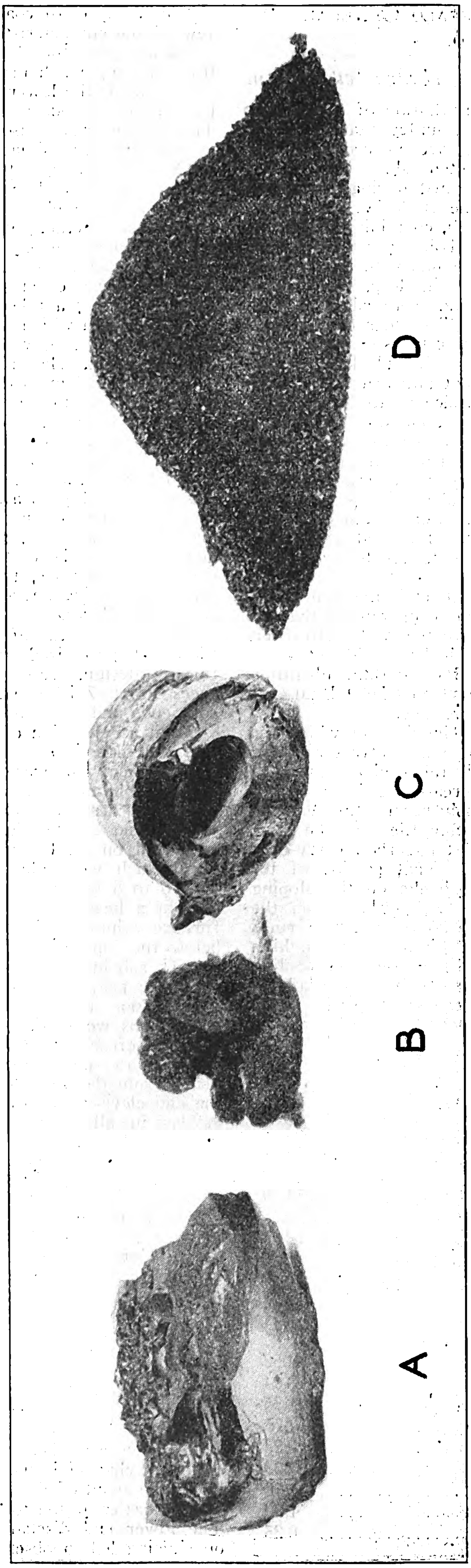

FIG. 3—SLAG FORMATIONS, BUFFALO GENERAL ELECTRIC CO.

STATEMENT BY THE BUFFALO GENERAL ELECTRIC CO.

Removing Molten Ash by the Hydro-Jet System

"Among the innovations in the installation of the pulverized fuel boilers at the Charles R. Huntley Station, where comparatively low-fusion-ash coals are burned, was the hydro-jet system of removal of molten ash.

"All four of the new boilers erected during the recent extension of the station were of the B. & W. cross-drum type, 44 tubes wide and 11 tubes high, containing 12,500 sq. ft. of boiler heating surface. Each boiler is provided with a separate economizer. The furnace under the first boiler included a well 8 ft. square and 11 ft. deep, sunk into a furnace floor that was 17 by 25 ft. and averaged 12 ft. 9 in. to the bottom row of boiler tubes. The sides of this well were formed by 3¼ in. tubes on 6 in. centers covered on the fire side with solid calorized-steel Bailey blocks. At the top of the well these tubes were bent outward at an angle and ran uncovered through the furnace to the headers on the outside of each wall. The well floor was constructed of carborundum tile covered by blocks of the same material. The bottoms of these tile formed the roof of a plenum through which the secondary air entered the furnace, flowing in back of the well tubes. No water tubes were installed in this floor. Burners were set in each wall halfway between the furnace center line and right-hand adjacent wall, in such a manner as to create a rotating effect when in operation.

"It was expected that the cyclonic effect in the well would keep it free from ash, which would drop out as the gas expanded into the main furnace above the well. However, it soon became apparent that bare blocks would not withstand the high combustion rate of 1,100,000 B.t.u. liberation per cu. ft. of well volume, equivalent to 62,000 B.t.u. per cu. ft. of combined furnace and well volume.

"Subsequent changes in the well blocking, in which the calorized-steel blocks were replaced with refractory-faced Bailey blocks and the sloping well tubes above the well covered with clay tile, served to increase the furnace temperature to the point where the ash became molten and dropped directly or ran from the clay tile into the well. This increased temperature reduced the carbon carry-over and improved combustion generally. That portion of the slag which ran down the clay tile banks on the sloping tubes continued downward into the well, flowing on the face of the wall. Upon reaching the floor, the slag formed a pool, remaining in the molten state because of the high temperature of the furnace above and the absence of cooling tubes below. This fluid could be tapped through a hole in the bottom of the well, but the problem was to find a satisfactory means of disposal after tapping.

TABLE V

COAL (DRY BASIS)

	Per Cent
Fixed carbon	53.29
Volatile matter	34.66
Ash	12.05
Sulphur	2.85

Fusing point of ash, about 1950 deg. fahr.

SLAG ANALYSIS

Silica (SiO_2)	44.52
Aluminum oxide (Al_2O_3)	18.64
Iron oxide (Fe_2O_3)	31.35
Titanium oxide (TiO_2)	0.76
Phosphorus pentoxide (P_2O_5)	0.25
Calcium oxide (CaO)	1.33
Magnesium oxide (MgO)	1.10
Sulphur trioxide (SO_3)	1.80
Undetermined	0.25

"The analyses of coal and slag are given, together with a few of the characteristics of the slag, in Table V.

"When solid, the slag had a very low coefficient of heat transmission, which made it a good heat insulation for the well floor, as the lower part of the slag solidified due to the passing of secondary air beneath the bottom of the well. This characteristic also added to the problem of handling, as will be discussed later.

"At a high temperature and below its melting point, the slag was tough and viscous, like molten glass. When cool it was a dense black solid, often with a coppery opalescence at a fracture; it was hard enough to cut glass and weighed approximately 200 lb. per cu. ft. When running from the slag spouts into the open air, the outer part of the stream congealed and the flow continued through the center, forming a tube or pipe, one of which is shown at C in Fig. 3, in which are shown: A, a solid block of slag; B, mineral or slag wool; C, the slag tube formation, and D, the granular slag from the sluice discharge.

"The original method of slag disposal, pending a solution of the ash-handling problem, was to allow it to run onto the floor each night before shutting the boiler down, and remove it the next day with a pick and shovel gang. This method was mussy and, of course, impractical, involving a high labor cost, and the concrete floor on which the hot slag was dropped chipped away due to the heat. The slag would spread around the floor, working outward from a point underneath the spout, resembling a bed of molten volcanic lava. A water hose turned upon it served only to chill a skin at the surface, the interior remaining in the molten state and flowing onward, bursting through the chilled skin at various places.

"While the status of the problem was as set forth, three additional pulverized fuel-burning boilers, of a different furnace design, were placed in service. These had furnaces 15 ft. 7 in. square with walls going straight up at both ends and expanding on the sides to a width of 25 ft. 8 in., at an elevation of 7 ft. 6 in. above the furnace floor. The well floor line was 30 ft. from the lower boiler tubes. The furnace walls were of the refractory-faced Bailey block construction and had the same tube spacing as the boiler previously described, there being, however, greater cooling surface and greater furnace volume. The well floor was supported on steel girders and consisted of a steel plate, over which were placed two layers of firebrick, covered with 6 to 8 in. of burned dolomite. These furnaces operated at a heat release of 37,000 B.t.u. per cu. ft. of total furnace volume, which is equal to 236,000 B.t.u. per cu. ft. below the top of the burners.

"The ash in these boilers assumed the same molten form as in the previous boiler, but the slag spouts, being closer to the floor, made the solution more difficult. Numerous suggestions were offered as to the best method of disposal, such as refractory-lined larry cars, handling the ash in the molten state, pouring the slag into water-filled dump cars direct from the furnace, and various combinations of sluicing and elevating into the cars. But the spouts on the boilers last installed were too low to permit an ordinary car to be placed beneath them, and, although handling molten ash in such cars is everyday practice around blast furnaces, it was considered too hazardous for installation in the boiler plant.

"While the new furnaces were in construction, experiments were made of dropping the slag directly from the furnace into a concrete buggy filled with water. Strangely, no explosion occurred and there was little sputtering. The slag stream formed its own insulating tube to the bottom of the buggy and built up as if there were no water on top of it. The sheet metal casing on the bottom of the buggy became red hot long before the surface of the water showed any signs of boiling. When the bucket was half full of slag, it was rolled to one side, and some fifteen minutes later it was emptied and the interior of the slag was still red hot.

"Sluicing was then tried out by placing an 8 ft. length of 12 in. channel iron, sloped at an angle of about 30 deg., under the spout of the original boiler and placing two ¾ in. water nozzles at the top, so as to sweep the channel clean. The lower end discharged into an ash car. These tests on sluicing led to observations that were of great value in

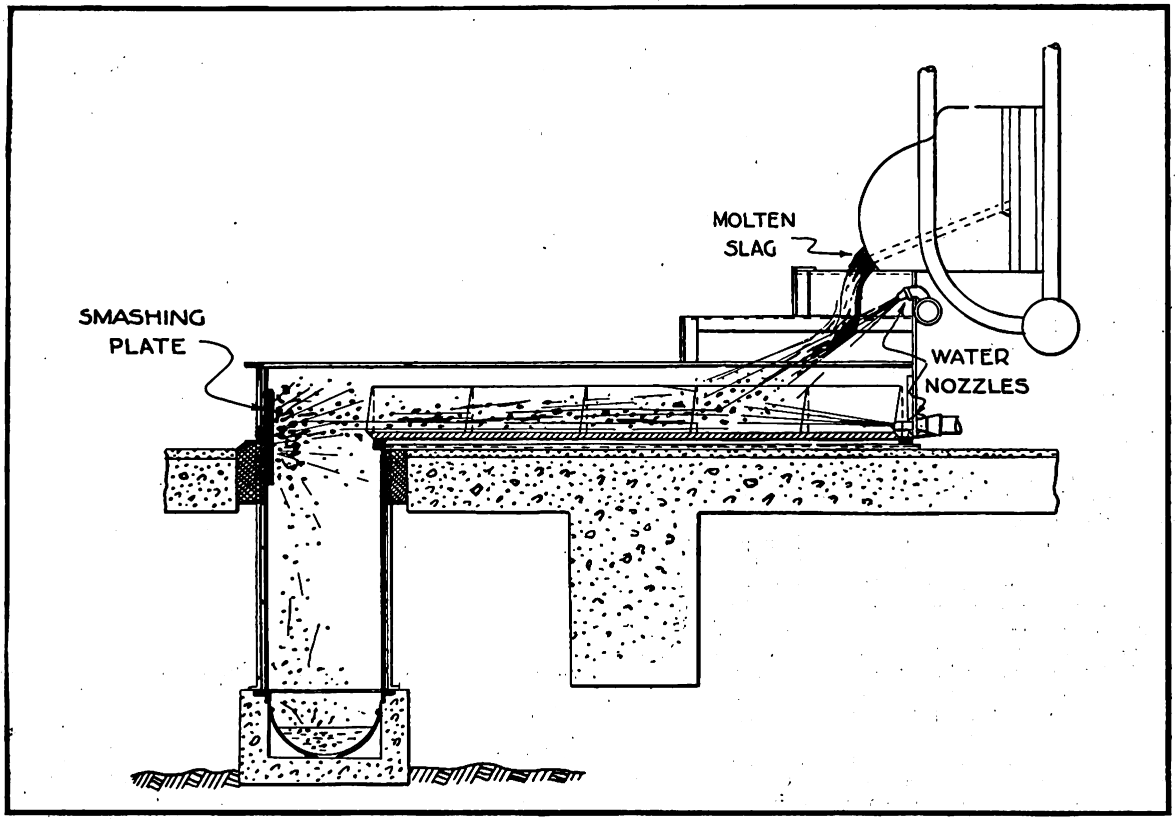
MOLTEN SLAG
SMASHING PLATE
WATER NOZZLES

FIG. 4—LAYOUT OF HYDRO-JET ASH REMOVAL SYSTEM, BUFFALO GENERAL ELECTRIC CO.

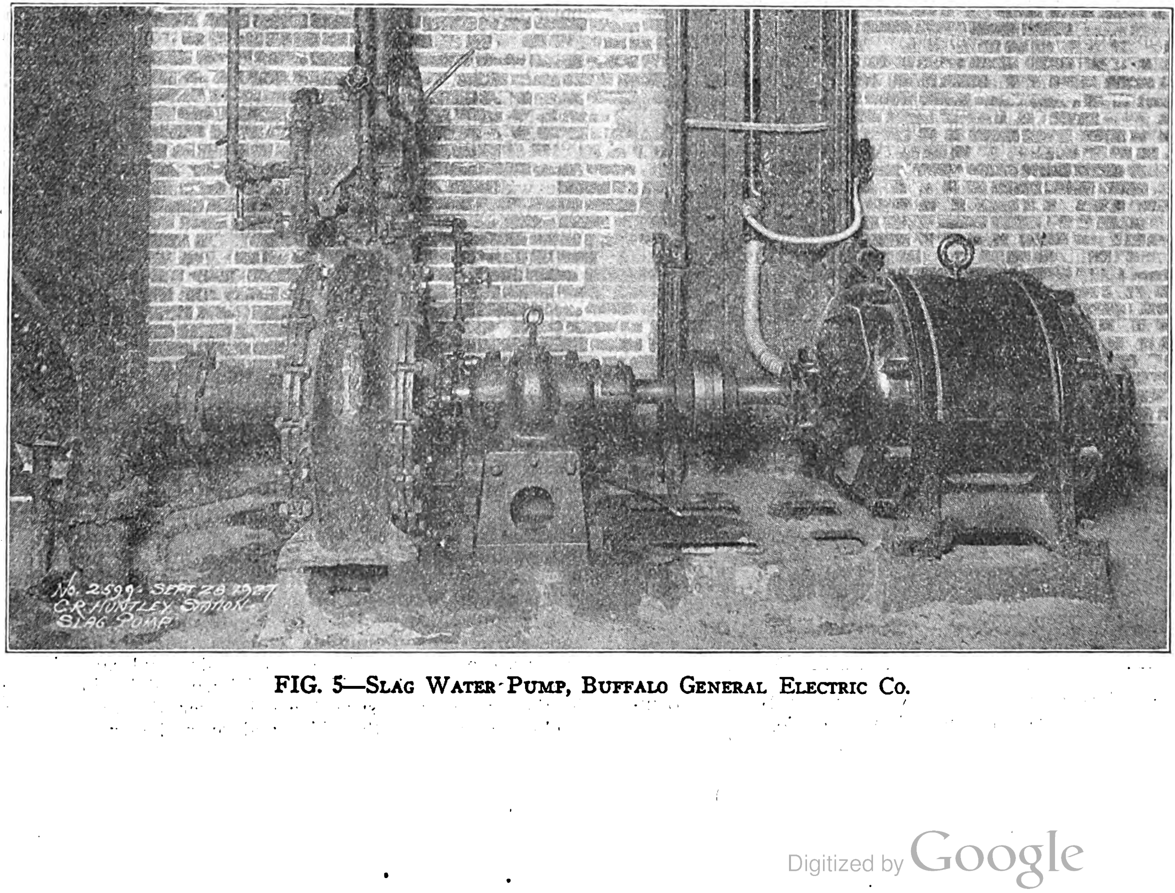
No. 2599. SEPT 28 1927
C.R. HUNTLEY STATION
SLAG PUMP

FIG. 5—SLAG WATER PUMP, BUFFALO GENERAL ELECTRIC CO.

arriving at the final solution. The slag stream was broken into small pieces by the mechanical force of the jets, and these pieces in turn tended to shatter into smaller pieces, owing to the rapid chilling effect of the water made possible by the exposing of greater surface areas per unit volume of slag. These facts indicated the necessity of using comparatively large volumes of water and were responsible for hydro-jet handling.

"A test equipment was then installed under one boiler by the Allen-Sherman-Hoff Co. This consisted of three primary jets which threw parallel streams, forming, owing to the close spacing, a water table within a cast-iron disintegrating chamber. On this the molten slag fell directly, being broken into small pieces and partly chilled at this point. Falling from here into a U-shaped cast-iron trough, the slag was carried crosswise of the building with the aid of two carrier jets for a distance of approximately 10 ft., and still further chilled in the process, owing to the additional cold water. This flow hit a cast-iron smashing plate, where it was turned at right angles into another U-shaped cast-iron trough running lengthwise of the building and discharging at a distance of approximately 50 ft. in the adjoining yard. Two additional carrier nozzles, working in tandem, were placed at the head end of this run. The results from this test equipment exceeded expectations. The slag was deposited in a fine granular state at the discharge of the chute.

"Steps were, therefore, taken to provide a permanent installation, but, owing to the fact that the best point for permanent disposal was about 1000 ft. from the boilers, it was found necessary to pump the mixture of slag and water after discharge from the hydro-jet system. The layout decided upon is shown in Fig. 4. To meet this requirement a pit was designed into which the sluices discharged. Two special manganese steel pumps, each of approximately 760 g.p.m. capacity, were provided for this service, and a cast-iron suction pipe run into the discharge pit. Fig. 5 shows one of these pumps. All elbows in the suction and discharge piping are of manganese steel. One pump is intended for a spare, as both are connected in parallel to the same discharge main, which is of 6 in. steel pipe running along the side of the building and out across the adjacent land to the point of disposal. The pipe is pitched to make it self-draining and is not insulated. Fig. 6 shows this discharge in service. Note that the material discharged spreads over a wide area instead of forming a pile beneath the pipe, as had been expected.

"In operation this system has worked out as satisfactorily as on test, although it has been found desirable to increase the pressure at the nozzles from 100 to 140 lb. in order to handle a higher rate of slag flow. These rates of flow are uncertain, being dependent upon the length of time the boiler is in service, the furnace temperature and the prior day's firing condition.

"The tapping of slag from these four boilers requires the services of two men for a period of one to three hours daily. The quantity of water pumped depends more upon the time required than upon the actual weight of slag removed, as it is necessary to provide enough water during the early stages of tapping to care for the maximum flow that may be encountered, and this is a somewhat indefinite quantity on account of the standby peak load operation of the station. The slag may vary from a mere trickle to a 6 in. diameter stream, coming fastest just after the flow is established and decreasing in amount as time progresses. Fig. 7 shows the slag spout in action. When the flow decreases, the pressure at the jets may be throttled down as experience dictates.

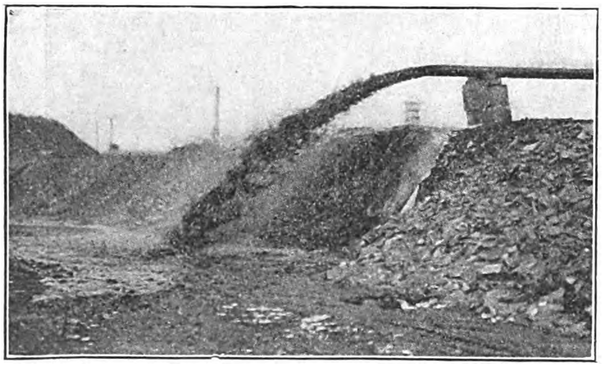

FIG. 6—DISCHARGE FROM SLAG DISPOSAL SYSTEM, BUFFALO GENERAL ELECTRIC CO.

"As the slag is highly abrasive, renewable wearing plates were placed in the sluiceways at all right-angle turns and were also placed in the concrete receiving pit to take the direct impingement of the slag-bearing water.

"It is remarkable that this installation, which is the first to be designed for handling molten slag from boiler furnaces by the hydro-jet system, should have proved so successful from the start. Had not the low furnace floor levels of the boilers last installed made the handling of this slag in the molten stage by means of slag cars extremely difficult, this happy solution of the problem might not have been found."

STATEMENT BY THE PENNSYLVANIA-OHIO POWER & LIGHT CO.

Handling Pulverized Fuel Ash as Molten Slag at Toronto Power Station

Slag Bottom No. 5 Boiler

"Slag bottom No. 5 boiler is a Springfield cross-drum boiler, having 21,620-sq. ft. heating surface, a water-cooled furnace surface of 2578 sq. ft., lined with refractory-faced block, and with Bailey walls on all four sides and on the ashpit slopes.

"The cooling surface as originally designed is divided as follows: side walls, 1247 sq. ft.; front wall, 726 sq. ft.; rear wall, 605 sq. ft., and hopper floors, 706 sq. ft., making a total effective cooling surface of 3284 sq. ft. The front and rear walls are covered with refractory-faced blocks. The side walls have all refractory-faced blocks, except the last four rows at the bottom which are bare cast-iron blocks. The two ashpit slopes are covered with bare cast-iron blocks. The furnace has a volume of approximately 18,000 cu. ft. and is fired with five Calumet intertube burners, designed to burn 8000 lb. of coal per hr. each at maximum. These burners are equally spaced across the front wall, the coal entering the furnace at an angle of 45 deg. to the horizontal. The air for combustion is preheated to about 370 deg. fahr. by a plate-type preheater.

"The ash removal system originally installed on No. 5 boiler required a great deal of labor and close attention for successful operation. The ash accumulated on the side walls and slopes at low ratings, and when the rating was raised on the boiler, this ash melted and avalanched down into the ashpit where, unless it was watched and dumped as fast as it came down, it blocked the ashpit gates or bridged over between the two ashpit slopes. When this happened it was necessary to break the slag out with bars and long pipes in order to get the gates and the opening between the front and rear slope clear again. To overcome these difficulties, a new bottom permitting the liquid removal of the slag was designed.

"The installation of this system required that the original bottom be changed somewhat. Four 21 in. I-beams are placed through the bottom parallel to the front and rear walls. On top of these and at right angles to them are placed eleven 9 in. I-beams equally spaced across the furnace from side wall to side wall. These 9 in. beams carry the ½ in. steel floor plate that completely covers the bottom. On top of this plate are two layers (5 in.) of standard fire brick and on top of the brick 9 in. of burned dolomite. A tap hole in the middle of the side wall is fitted with a cast-iron spout, which is closed by a gate operated with a wheel and worm gear. Suitable troughs, nozzles and breaker plates are provided to break up the slag and carry it to the ash sluiceway. About 35 tons of burned dolomite were put in the bottom and spread evenly over the fire brick and banked up against the sides and over the front and rear

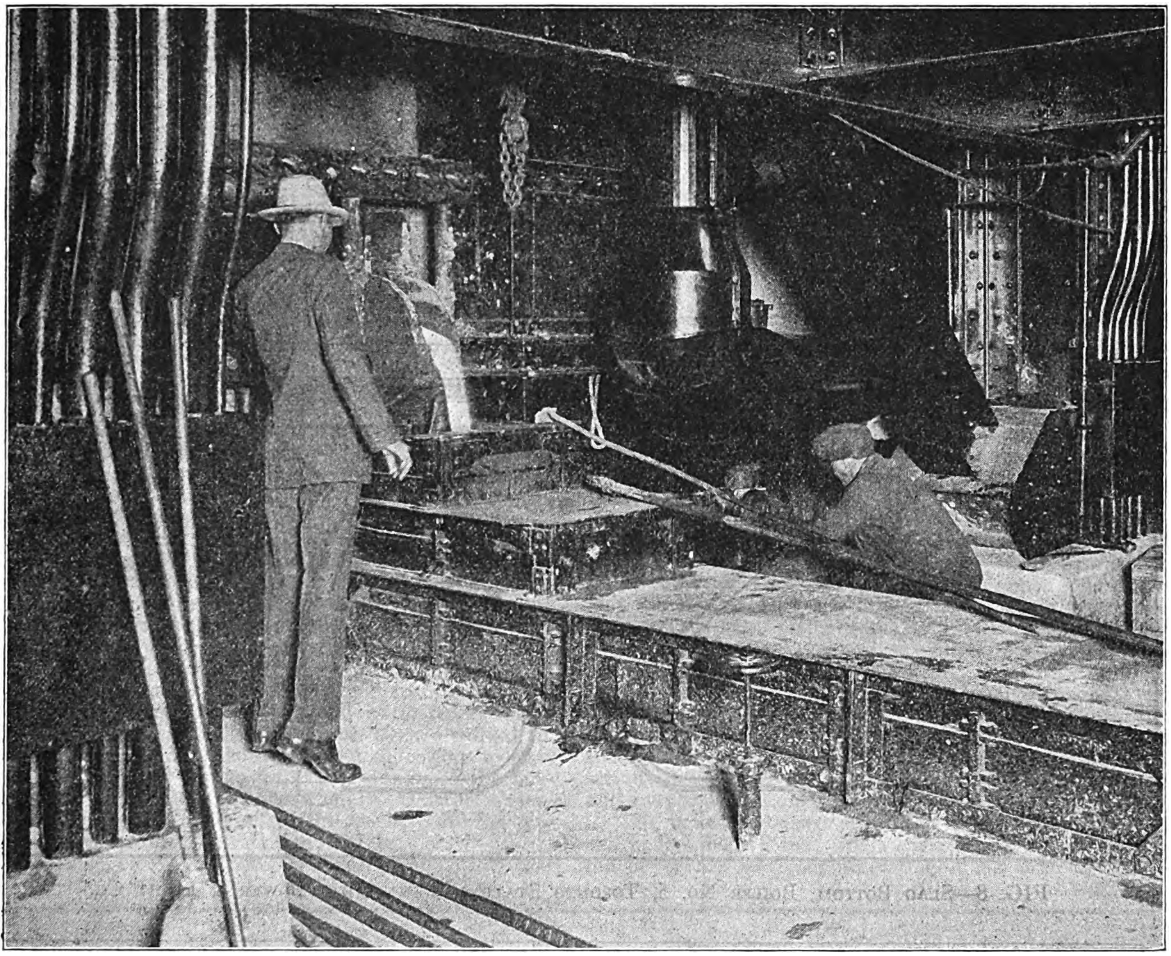

FIG. 7—SLAG SPOUT DISCHARGING MOLTEN ASH, BUFFALO GENERAL ELECTRIC CO.

wall intermediate header. Fig. 8 and 9 show the construction of the bottom and the manner in which the dolomite was banked up.

"This work was started March 14, 1928, and finished March 28, 1928. The furnace was not tapped the first day, and the boiler was operated straight through without banking. Slag was tapped the first time after 27 hr. operation and again 4 hr. later. It was then found that the dolomite which had been banked up against the front and rear intermediate headers had been washed off of these headers onto the bottom. The boiler was banked the night of March 30 to solidify the dolomite on the bottom.

"The tap hole is kept plugged with clay. In tapping, a bar is driven through this clay to the liquid slag. (An air-operated 'rivet buster' is now successfully used for this operation). The slag runs out through this hole down the cast-iron spout and falls into a spray of water, which breaks it up and carries it about 4 ft., where it strikes a breaker plate and falls into another stream of water moving at right angles to the first. This stream carries it about 4 ft., where it strikes another breaker plate and drops into the ash sluiceway. From here it is washed to the ash pump and pumped out to a fill. When the slag has been drained down to the proper level, the tap hole is plugged with clay and the flow stopped.

"Under normal operating conditions the slag is tapped once every 24 hr. The average run takes about 1½ hr. This varies, however, depending upon the boiler rating and the ash in the coal. No trouble has been encountered at any time in keeping the slag hot enough to run. The temperature of the slag leaving the spout varies from 2300 to 2700 deg. fahr. The temperature naturally affects the speed at which the slag runs, but at no time has it been low enough to retard the removal of the slag.

"The coal burned is bituminous and comes from several mines in Pennsylvania and from a strip mine near the plant. The percentage of ash varies from 10 to 15 per cent and the fusion point from 1900 to 2200 deg. fahr. As an experiment coal from eastern Pennsylvania containing 8 per cent ash and having a fusion point of 2900 deg. fahr. was burned in this furnace. This coal burned remarkably well, the slag liquefying and running as readily as that having a lower ash-fusion temperature, but it was thought probable that this was because this coal was somewhat mixed with other coal having a low ash fusion temperature, and another test was run on No. 4 boiler, which showed that Georges Greek Big Vein coal, having an ash-fusion temperature of about 2900 deg. fahr., could not be melted and tapped, and in order to remove the ash, it was necessary to fire coal having a low ash-fusion temperature so that the mixture of this ash with the ash already in the furnace formed a fluid which could be removed in molten form.

"Only two leaks have developed in the bottom since its installation: One between the south side wall and the bottom about halfway back, dripped for a few minutes and then froze; the other, between the north side wall and the bottom at the slag spout, was a larger leak, requiring the use of a water hose to stop it. Neither leak did any damage nor affected the operation of the boiler.

"The boiler has been in operation a little over six months with this type of bottom, and no unforeseen problems of operation or maintenance have arisen. The ash pit now needs attention only while being tapped, and when plugged can be forgotten until the next day. The slag comes to the

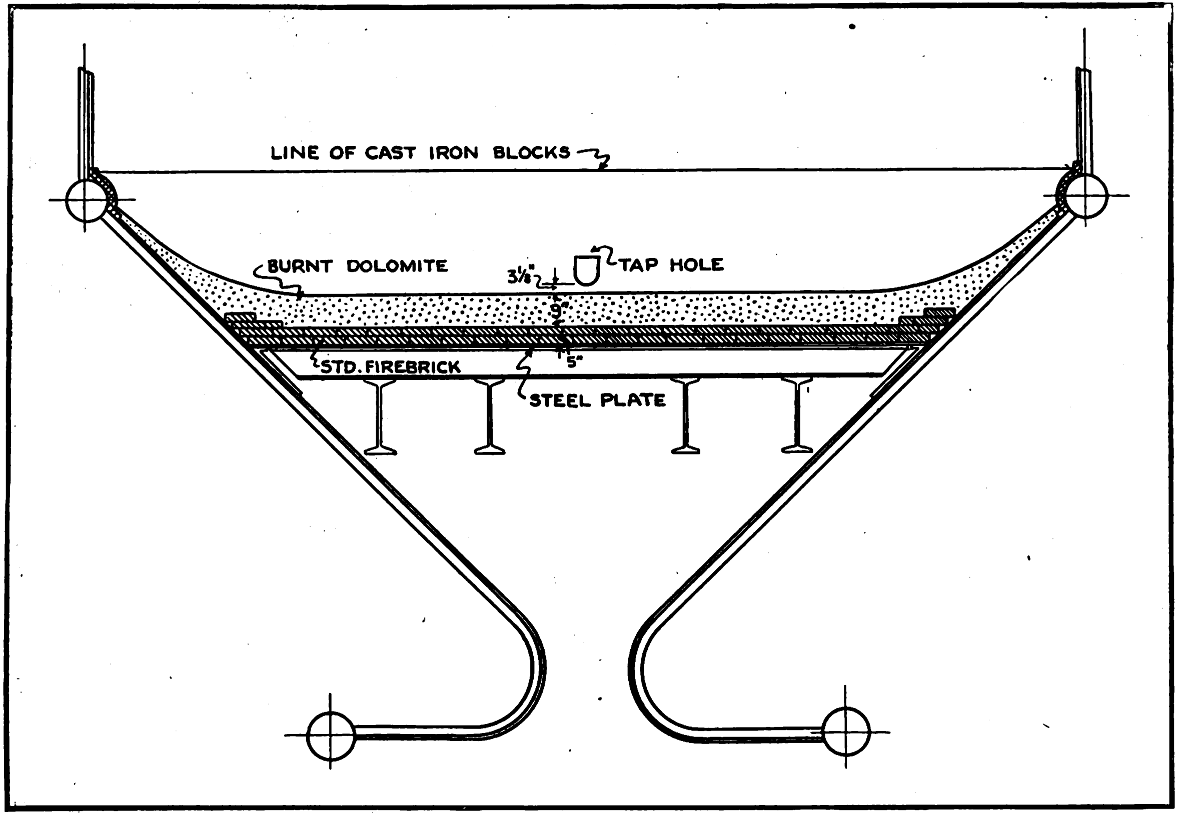
LINE OF CAST IRON BLOCKS
BURNT DOLOMITE
3⅛"
TAP HOLE
9"
STD. FIREBRICK
5"
STEEL PLATE

FIG. 8—SLAG BOTTOM, BOILER NO. 5, TORONTO STATION, PENN-OHIO POWER & LIGHT CO.

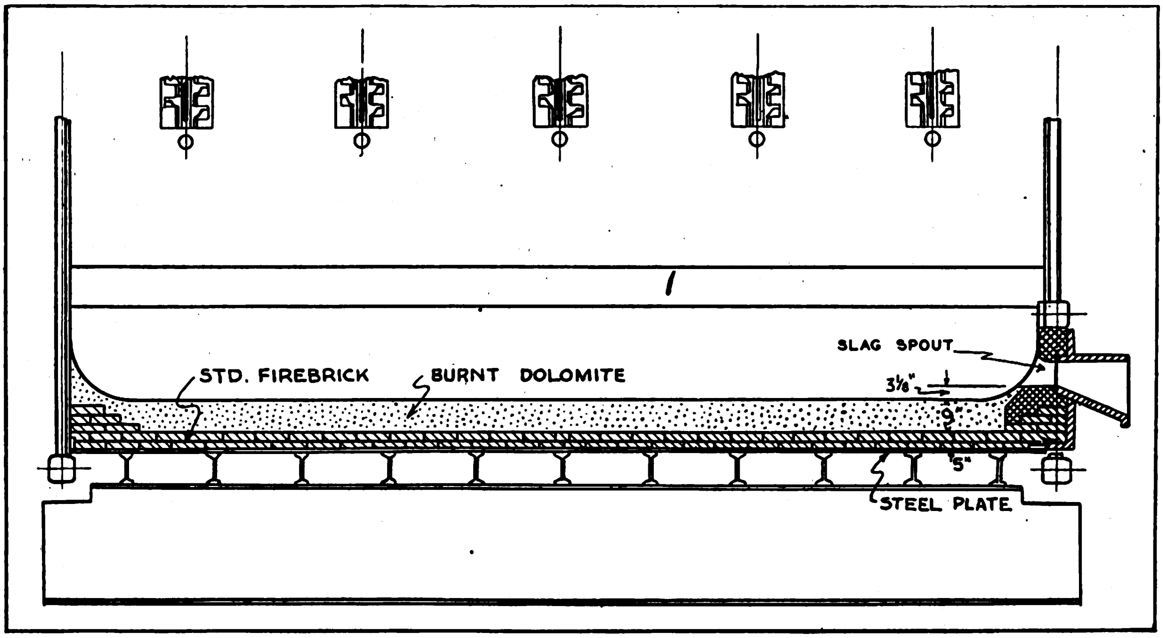
SLAG SPOUT
STD. FIREBRICK
BURNT DOLOMITE
3⅛"
9"
5"
STEEL PLATE

FIG. 9—SLAG BOTTOM, BOILER NO. 5, TORONTO STATION, PENN-OHIO POWER & LIGHT CO.

pump in a fine granular state resembling ground black glass, the largest grains being about the size of buckwheat. The slag washes and pumps easily, and a large amount of slag can be handled in a fraction of the time required under the old system."

Slag Bottom No. 4 Boiler

"Slag bottom No. 4 boiler is a B. & W. cross-drum boiler, with 20,470 sq. ft. heating surface and a water screen surface of 2100 sq. ft.

"The furnace as originally designed and constructed is of brick throughout. The side rear walls and bottom are protected by bare tube water screens. The center of these tubes is 6 in. from the walls and the tubes are spaced 10½ in. center to center. The side walls are of hollow wall-type construction, the secondary air passing through the walls from the rear to the wind box around the burners in the front. The furnace is 25 ft. high, 25 ft. long and 20 ft. 10 in. wide, and has a total volume of 13,000 cu. ft. The boiler is fired with six Toronto-type Peabody burners in two rows of three each, one above the other, which fire horizontally through the front wall. The same coal is burned as in No. 5 boiler. The air for combustion is preheated to about 300 deg. fahr. in a plate-type preheater.

"In operating the boiler as originally constructed, the ashes accumulated in a hopper at the bottom of the furnace, and from there were dropped into an ash sluice and washed to a pump from which they were pumped out to a fill near the plant. Difficulty was encountered with ashes and slag accumulating on the sides of the hopper and on the water-screen tubes. This was hard to get off and required a great deal of labor to keep the ash pits and water-screen tubes clean. Due to these difficulties and the labor involved, it was decided to experiment with a design of bottom to permit the liquid removal of the ash. The design of the bottom that was installed is shown in Fig. 10. This is a temporary installation and is sloped to follow the bottom water screen. The permanent installation will be flat.

"In changing No. 4 furnace, the rear wall below the water-screen tubes was cut out to permit the placing of I-beams to support the bottom. The bottom was built so that the tops of the 8 in. I-beams were above the tops of the water-screen tubes. On top of these beams was placed ½ in. steel plate, a layer of 2½ in. standard silocel brick, a layer of 2½ in. standard fire brick and 9 in. of burned dolomite banked up around the edges. The tap hole was placed at the end in the corner, about 5 ft. from the center of the bottom right-hand corner. A refractory lined spout was placed so as to discharge the slag into a steel trough. In this trough are the water jets into which the molten slag falls and is broken up and carried along the trough for about 9 ft. Here it strikes a breaker plate, drops into another trough and jets and is carried to the ash sluice. The sluice carries the granulated slag to the ash pump from which the slag is pumped to the fill.

"The boiler was fired up May 3 and was put on the line 8 hr. later. The boiler was tapped 8 hr. after this, and the slag ran for 55 min. It was tapped again after another 8 hr. and ran for 35 min. The temperature taken with an optical pyrometer during these runs was 2760 deg. fahr.

"After a day's run the slag broke through the bottom about 6 ft. out from the front wall, directly in front of the lower right-hand burner. The boiler was operated until it was convenient to take it off the line, when it was found that the silocel brick had broken down under the heat and exposed the steel plate to the slag. All the silocel brick were removed and standard fire brick put in their place, making two layers of fire brick and 9 in. of dolomite on the furnace bottom. These repairs required about a day's time. A number of times, due to the temporary construction of the bottom, the slag leaked through the openings around the water screen tubes. None of the leaks were serious or caused any outage. The permanent installation will overcome this difficulty.

"The boiler is tapped once each 24 hr., the average slag run being about 2 hr.; this varies, depending on how long the boiler has been on, the rating it has been operated at,

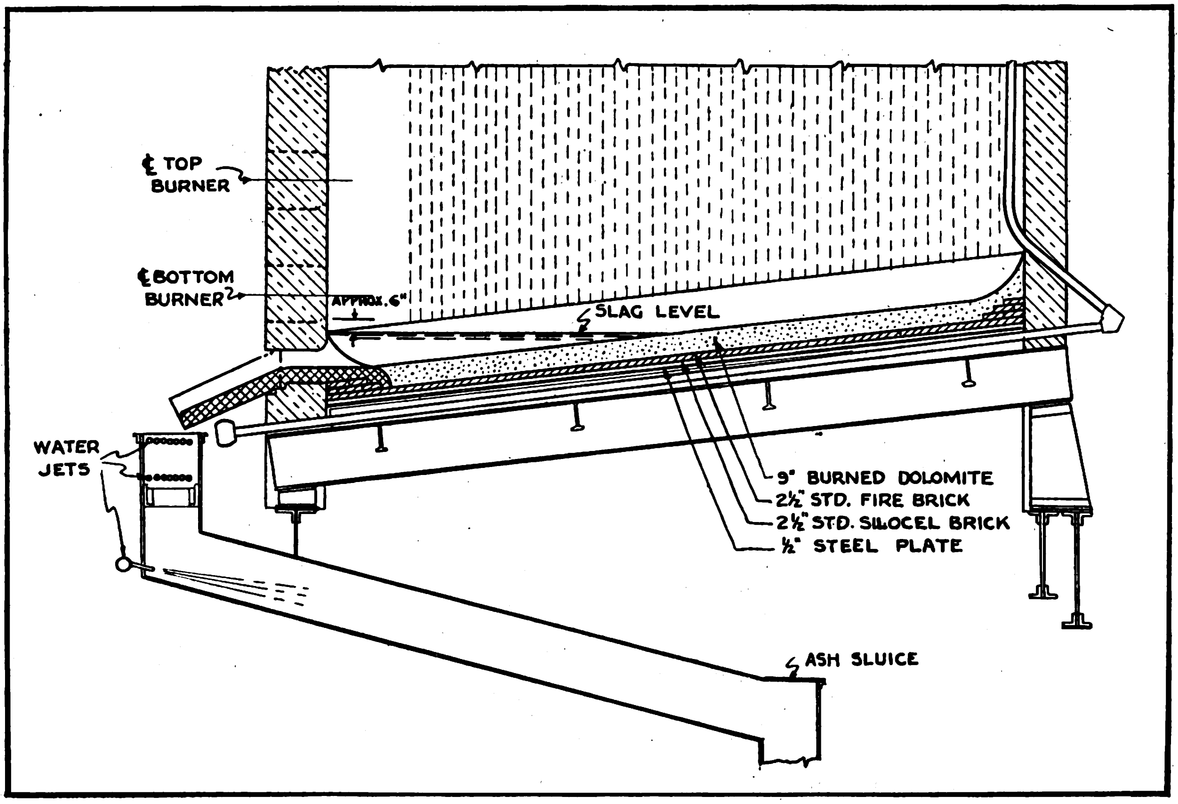

FIG. 10—Slag Bottom, Boiler No. 4, Toronto Station, Penn-Ohio Power & Light Co.

and the ash in the coal. Up to this time there has been no erosion of the brick work around the slag line.

"Approximately 30 tons of dolomite were used in the bottom when it was put in, and about 20 tons have been used since that time for repairs.

"There has been no change in the method of starting up the boiler. The same method is used with the slag bottom as was used before its installation."

STATEMENT BY THE OHIO PUBLIC SERVICE CO.

Development of the Non-Segregating Coal Distributors

"To obtain homogeneity and equal distribution, so necessary for good combustion efficiency, the natural tendency of coal to segregate into its various sizes while feeding into the stoker hopper must be checked. The problem of coal segregation has received a great deal of thought from plant operators throughout the country, and a number of devices for eliminating this trouble have been tried, with varying success. All of these devices have motors or other moving parts which require attention and are subject to wear and breakage. They require power to operate, and quite a number of them fail, at times, under certain conditions, to accomplish their objective. In addition to these disadvantages, they are quite expensive, so that the carrying charges on them make a material cut into the savings effected by them.

"The reason these spreaders fail to perform the purpose for which they were intended is easily seen. They miss the fundamental of the problem viz., the cause of segregation. All of the spreaders allow segregation to take place at will and then undertake to re-mix the coal and get it mixed in uniform proportions across the width of the stoker hopper. While considering this problem at the Lorain Plant, an idea was hit upon to prevent the start of segregation.

"Coal sliding down an inclined plane behaves in the same way as when poured into a pile. The small sizes work their way straight down the dip of the planes and crowd the larger pieces aside. When the coal reaches the hopper, after sliding down a fantail chute, most of the dust and slack is in the middle, while the nut size is nearly all collected in two clearly defined, narrow strips at the ends of the hopper. A chute was designed in which there is no steepest path. Instead of a plane surface, a conical surface was used as the sliding plane of the chute, on which all paths of descent have the same slope.

"To test the principle just explained, two model chutes were built, one being a replica of those in use at the time, having a plane as the sliding surface; the other patterned after the new design, using the outside of the cone as the sliding surface. These models were built to one-quarter size and provided with hoppers, at the top, for filling. The hoppers were filled with a representative mixture of coal, and the chutes were dragged backward over the floor, allowing the coal to discharge at the bottom of the chute in a manner similar to the way the stoker rams would push out the coal from the large chutes in actual practice. The swath of coal thus discharged was divided into eight parallel strips, which represented the discharge from eight sections of the width of the chute. These divided quantities were then passed through screens and the relative proportions by weight of the various sizes computed.

"The results of a series of parallel tests of the two chutes were plotted on coordinates and are shown in Fig. 11. Three screens were used, 2-mesh, 4-mesh and 8-mesh per in. The percentage, by weight, of the four sizes obtained were plotted as ordinates, and the width of the chute was used as the abscissa. The average proportion of each size in the total mixture is shown by the dotted line, and the figures are given below the curves for each test. The results are plotted in cumulative fashion to throw the curves apart. If perfect distribution obtained, the points which represent the characteristics of the chute would coincide with the dotted lines, indicating that the mixture contained its average proportion of all sizes at all points. Departures from these lines measure the degree of segregation. It will be noted that in all the tests the performance of the conical chute approached very nearly to the perfect line, the maximum deviation being only about 5 per cent, while the test of the straight chute showed several variations as high as 25 per cent in adjacent sections.

"The first shovelful of coal put into the straight chute went directly down the middle, whereas the first coal put into the conical chute was distributed equally across the entire width. When the hopper was emptied during a test, and the chute dragged back until all coal was discharged, it was noticed that the coal left off along a sort of parabolic curve from the straight chute, but left off evenly along a straight line from the conical chute. When burning out a hopper full of coal before shutting down a boiler, it has always been necessary to run the stoker a long time to get rid of the coal over the middle rams, or else get a long-handled shovel and distribute it over the other rams. With the conical chute we are assured that all rams will be coaled equally by the first coal that comes down, and that, if it be necessary to burn out the hopper to stop smoking, or for any other reason, that the hopper will be emptied at all parts at about the same time.

"At all times during the test extreme care was exercised in making the test conditions the same for both chutes. In dividing the coal for sizing and weighing, the ends of the piles are discarded in order to base the figures on only that coal which would be discharged during continuous operation. A further advantage would accrue to the conical spout if the starting and stopping coal had been included.

"The design of the conical chute is as follows:

"The surface on which the coal slides (the bottom of the chute) is a cone whose apex is at the spout under the weigh scales and whose base circle lies in the horizontal plane through the top edge of the stoker hopper, and passes through the front end corners of the hopper. The chute was designed to fit the present hoppers and weigh scale spouts, and, therefore, it will be readily seen the altitude and base radius of the cone, and consequently the slope of its surface, were arbitrarily fixed by our boiler-room layout. Since the dimensions of the hopper were not such as to permit the use of a complete circular base arc, the cone was cut off at the lower end, as can be seen in Fig. 12, by a vertical plane passing through the front edge of the stoker hopper. A number of partitions were placed in this lower section to stiffen the structure and prevent segregation after the coal had passed over this knee on its travel vertically downward into the hopper.

"The results of the test being highly satisfactory, two full-sized chutes were built and put into actual use.

Conical Spouts in Service

"The conical chute was installed on one boiler, fired by an underfeed stoker, sixteen retorts wide. At the very outset it was apparent that the chutes were successful. The fuel bed was even all the way across the furnace, and for the first time there were no holes under the side observation doors. The depth over the ash pit was uniform, and when the clinker grinders were operated the level was depressed evenly clear across the width. This latter characteristic was new and hitherto unknown to the operators.

"Since these chutes were put into operation, the plant coal rate has been materially reduced, and while all of this gain cannot be attributed to these chutes it is believed that very appreciable gain in economies has been effected by them. Comparison of ashpit analyses shows a decided improvement in combustible losses in favor of the boiler equipped with the conical chute. The firemen report that it is much easier to keep the Bailey meter hands together on this boiler than on the others, since they have better control of the excess air. It was also found unnecessary to manipulate the sectional dampers across the width of the stoker, as the even fuel bed permitted the use of a steady air pressure across the stoker. This made possible a greater steaming capacity on this boiler, since no part of the stoker need be held in check.

"Flue gas analyses, taken from time to time, show that there is much less stratification of gases in this unit, and the carbon dioxide recorder also shows that the average

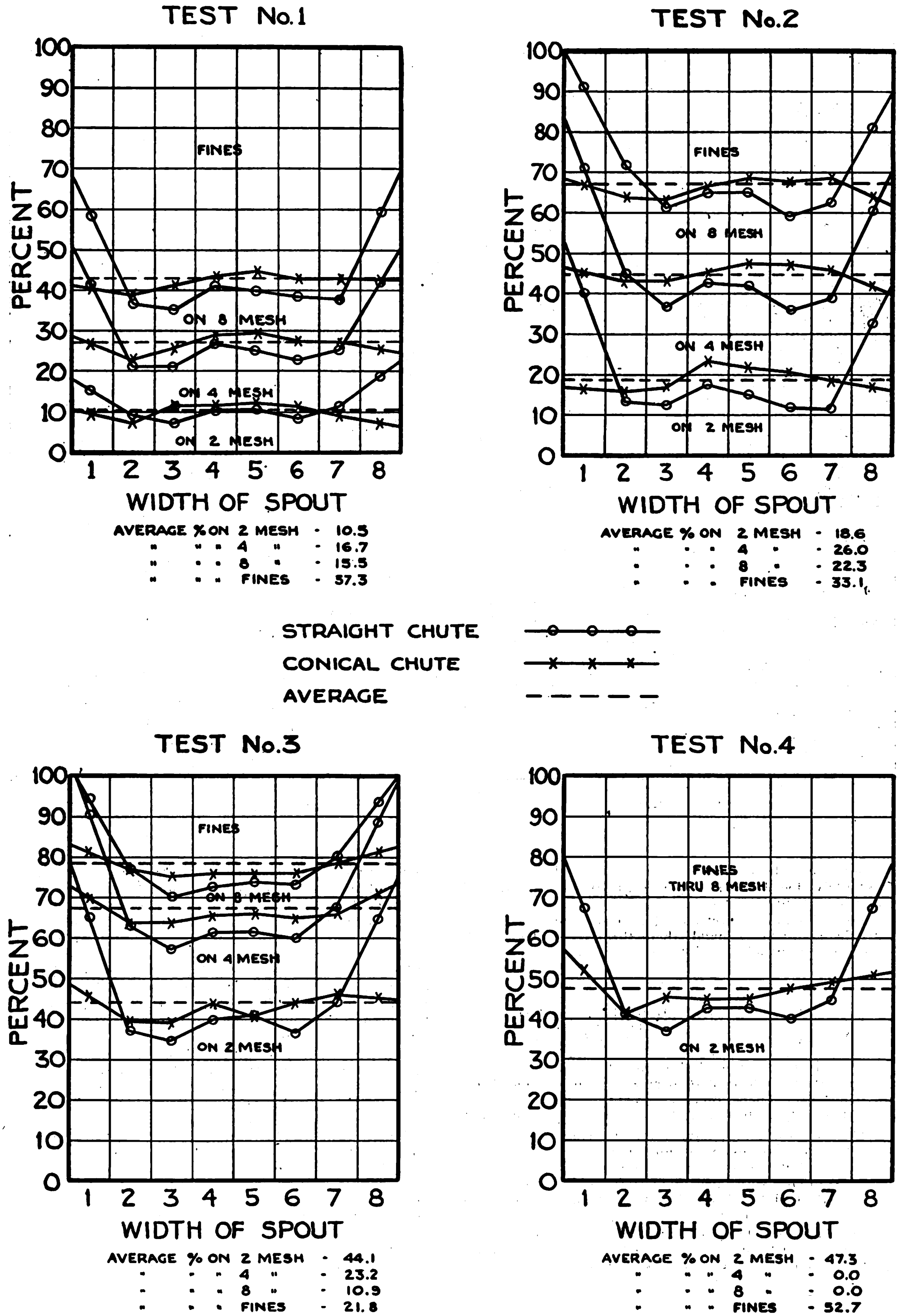

FIG. 11—RESULTS OF TESTS ON SPOUTS, SHOWING DEGREE OF COAL SEGREGATION, OHIO PUBLIC SERVICE CO.

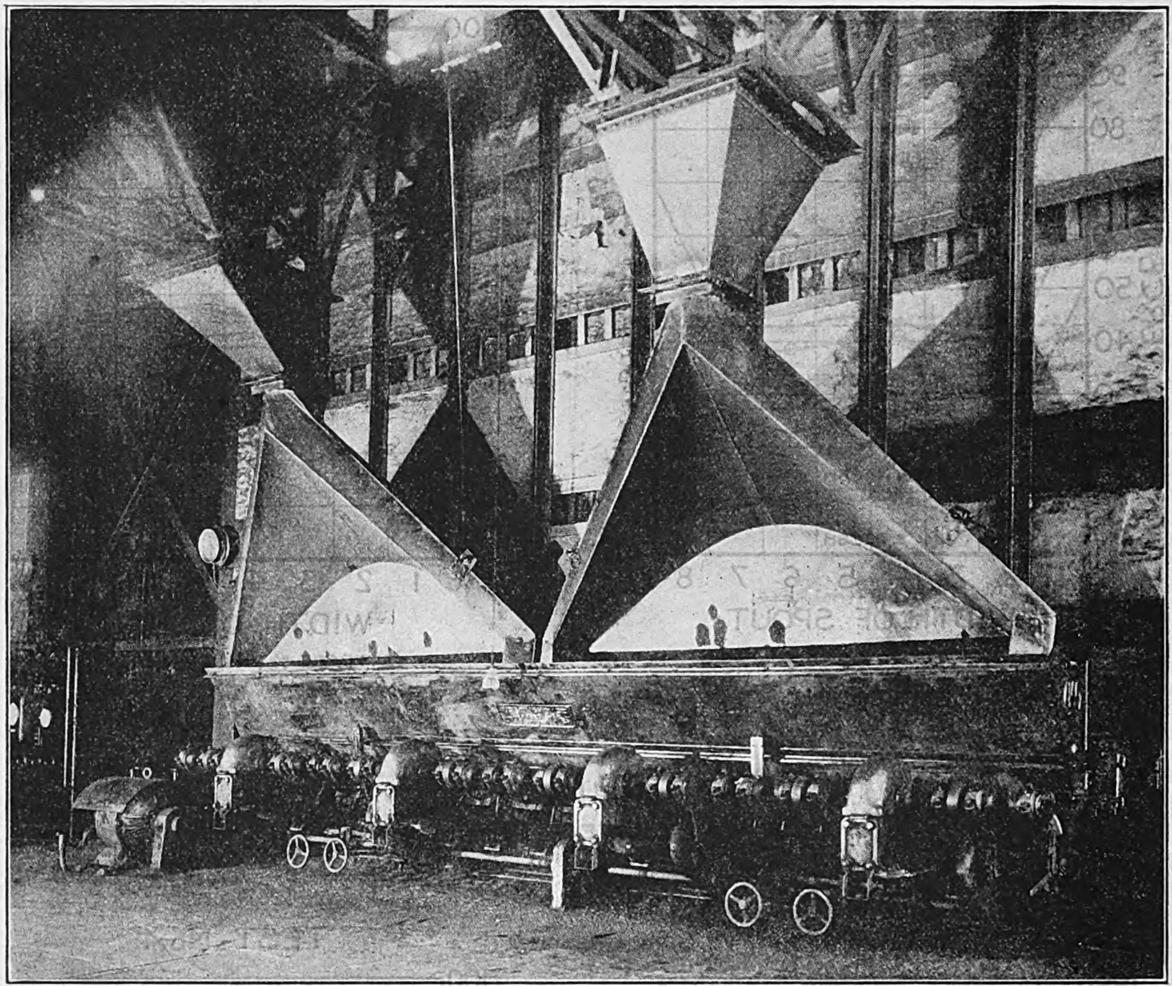

FIG. 12—COAL DISTRIBUTOR IN SERVICE, OHIO PUBLIC SERVICE CO.

CO_2 content has been decidedly improved, the variation being scarcely more than 2 per cent over a period of nine hours.

"The conical chute is considered entirely successful, and plans are being made to install them throughout the plant."

STATEMENT BY THE OHIO EDISON CO.

Non-Segregating Coal Distributors

"There are in use at the Mad River Plant at Springfield, Ohio, four of the Rolland Gardner Co. non-segregating coal distributors. These served two 14 retort, 29 tuyere Taylor stokers. The coal used is an eastern Kentucky and West Virginia bituminous, having an ash content of about 9.3 per cent with 3.6 per cent moisture.

"The distributors have been in use about ten months. Ordinarily 2 in. nut and slack coal is used, but some mine run is burned, which, of course, goes through a crusher before going to the bunkers. The coal burned will run, on the average, approximately 50 per cent coarse, 30 per cent medium and 20 per cent fine. The coarse coal is of such size that it would all pass through a 2 in. screen. Considerable coal has also been reclaimed from storage, and this coal contained about 10 per cent moisture. Even this quality of coal flows freely down the spouts and through the non-segregating distributors, without any tendency to clog. At no time has there been any clogging of coal in the spouts or distributors.

"One of the benefits derived from the use of these chutes is that the fuel bed is kept in an even condition, the coarse and fine coal being fed into the stoker hopper thoroughly mixed, there being no tendency toward segregation. There is no doubt that increased furnace efficiency results from an even and well distributed fuel bed, but no tests have been made at our plant to determine the increase. On the B. & W. boilers of the type used in our station the only brickwork used is in the front wall, and thus far there has been no maintenance on this wall.

"The distributors are made of ¼ in. steel plate, with riveted and welded joints, and no extreme wear has been found on them. With coals of higher ash content or with a more abrasive action, the distributor linings would probably show more wear.

"We believe this type of distributor serves as an excellent means of getting fuel to the stokers, and that it is a decided improvement over the ordinary spout in that it is a non-segregating affair and has no moving parts."

MANUFACTURERS' STATEMENTS

The Prime Movers Committee does not assume responsibility for any manufacturers' statements.

STATEMENT BY SAUERMAN BROTHERS, INC.

Description of Power Drag Scraper System

"The drag scraper system described here was designed to solve the problem of placing two kinds of coal in separate piles in one storage area; either coal to be delivered on either side of the area and all coal reclaimed at one point. The storage area, approximately 1000 ft. long by 400 ft. wide, was laid out with a slip on one side and rail tracks on the other, so that either cargo boats from the lake or cars could be unloaded. The problem, therefore, was unusual in that two grades of coal would be received either by water or by rail. The stocking out machinery had to be suitable for stocking these in separate piles in the same storage area. All of the coal had to be reclaimed at one common point, a receiving hopper which fed a belt conveyor. The coal received by water came in two kinds of boats, one the self-unloader type, the other of the type which requires a dock crane for unloading. Either of these types created a long, high pile of coal when the boat was unloaded. The coal received by rail came in the usual manner through an overhead chute which deposited the coal on an initial pile. The unusual features of this problem, therefore, can be set down as follows: 1—Coal entering the storage area on two opposite sides; 2—two grades of coal which had to be kept separate in the storage area; 3—the unusual height and length of the 'initial pile' created at the point where the boats were unloaded; 4—large capacity required at long hauls on account of size of storage area. The problem was solved by the installation of a 7 cu. yd. Sauerman Power Drag Scraper Storage System.

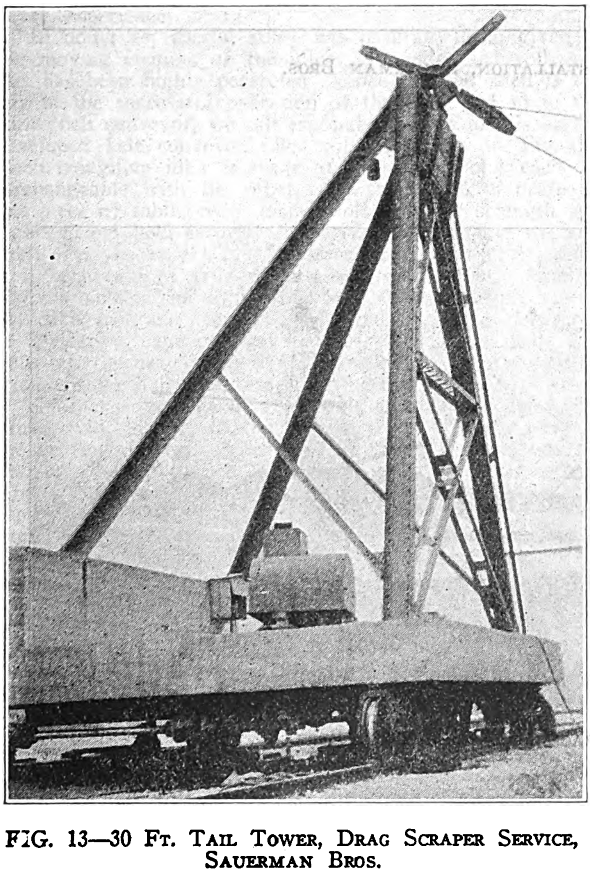

FIG. 13—30 FT. TAIL TOWER, DRAG SCRAPER SERVICE, SAUERMAN BROS.

"It was decided to put a track around three sides of the storage area on which two tail towers, Fig. 13, of the scraper system could operate. This track was so arranged that on the water side of the area it could also serve as the track for the dock crane that unloads the boats which are not self-unloaders. These towers are an unusual feature of the installation because of their exceptional height, 30 ft. from top of rail to bearing of sheave block, made necessary because of the high initial pile. Both of these high tail towers are self-propelling.

"The reclaiming hopper with the head post was located on the rail side of the storage area, about halfway from each end. The scraper was installed with an operating cable of the endless type, that is, the cable was threaded through the sheaves on the tail towers, then through the fairlead blocks on the head post, and then to the hoist drums, where one end of the cable was attached to the rear drum of the hoist and the other end of the cable to the front drum. Attachments were provided so that the cable could be connected to the scraper bucket at any point. Both drums of the hoist have the same rope speed and line pull so that the loaded scraper can be operated from either drum. The result of this is an operating cable in the form of a triangle, one point being the head post, the other two points being the movable tail towers. The scraper can be operated in either direction on any side of the triangle. The movable tail towers, which operate at a speed of 100 ft. per min., can quickly be located at any desired point on the track and the scraper then placed in operation in whatever manner the exigencies of the situation require. This is made possible, of course, only because two points of the triangle (the tail towers) are movable.

"A total storage capacity of 100,000 tons is provided for in this installation. While the reclaiming belt conveyor is designed for a handling capacity of 150 tons per hour, the scraper equipment is actually capable of handling about 200 tons per hour across the width of the area. The length of scraper haul varies considerably, the electric hoist operating under load for a longer period of time on the long hauls than on the short hauls, and for this reason the power consumption per ton of material handled will vary from ½ to ¾ kw., depending upon the length of the haul.

"The general layout of the storage area is shown in Fig. 14, while Fig. 15 shows the cargo boat slip, the unloading crane, one of the movable tail towers and the position of the high initial pile of coal unloaded from boats.

"In addition to the height of the tail towers, the use of two movable towers in one scraper installation is quite unusual. The equipment was put in operation late in the spring of 1928 and is operating in a very satisfactory manner, the large capacity requirements being met in the manner anticipated."

STATEMENT BY THE LINK-BELT COMPANY

Improved Conveyor Belt Idler

"Handling large quantities of material at low cost is work to which the belt conveyor is admirably suited. Its large capacity, due to its continuous delivery of material at a relatively high speed, its low upkeep and its small power consumption make for a minimum handling cost per ton.

"To take the utmost advantage of the possibilities that the belt conveyor offers, four things are required: 1—Low coefficient of friction of its moving parts with its attendant decreased power consumption; 2—long belt life; 3—low rate of depreciation, and 4—small maintenance cost. Depreciation and maintenance can be kept down by the use of high-grade equipment. The other essentials to economical service, belt protection and low power consumption are largely controlled by the character of the idlers.

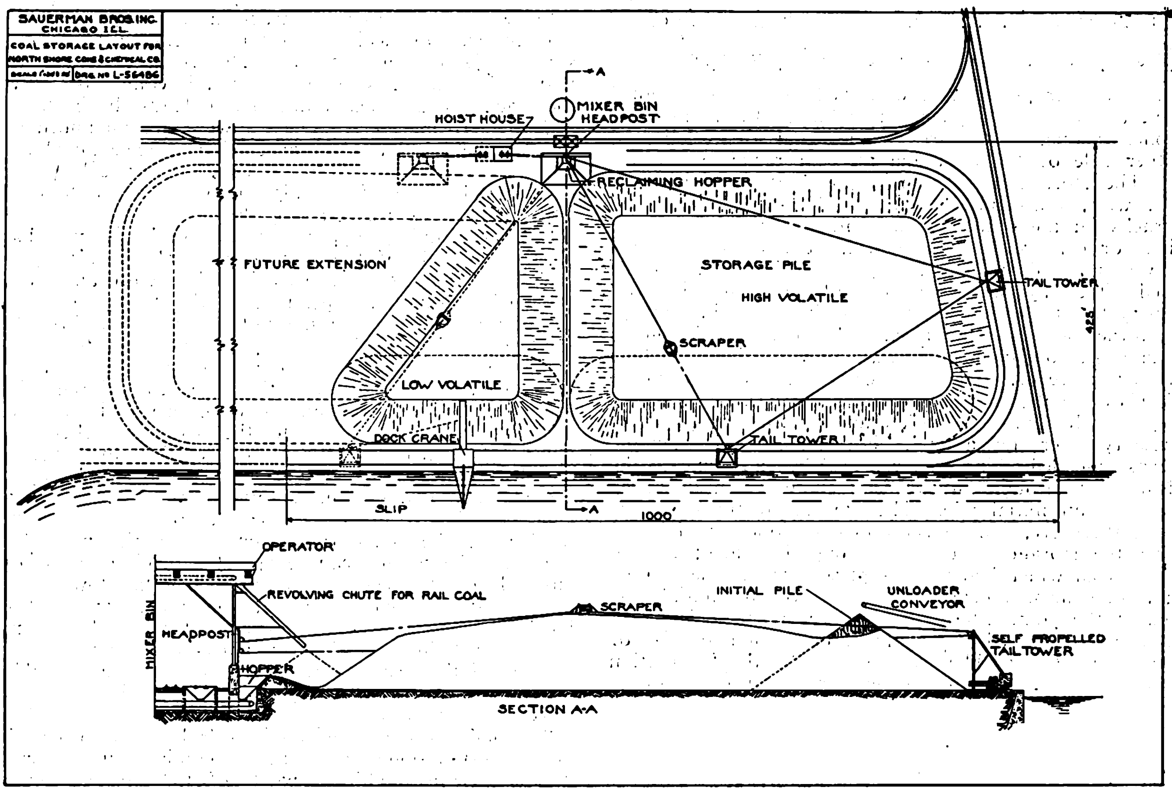
SAUERMAN BROS. INC.
CHICAGO ILL.
COAL STORAGE LAYOUT FOR
NORTH SHORE COKE & CHEMICAL CO.
DRG. NO. L-56486
A
MIXER BIN
HEADPOST
HOIST HOUSE
RECLAIMING HOPPER
FUTURE EXTENSION
STORAGE PILE
HIGH VOLATILE
TAIL TOWER
425'
SCRAPER
LOW VOLATILE
DOCK CRANE
TAIL TOWER
SLIP
A
1000'
OPERATOR
REVOLVING CHUTE FOR RAIL COAL
MIXER BIN
HEADPOST
HOPPER
SCRAPER
INITIAL PILE
UNLOADER CONVEYOR
SELF PROPELLED TAIL TOWER
SECTION A-A

FIG. 14—POWER DRAG SCRAPER INSTALLATION, SAUERMAN BROS.

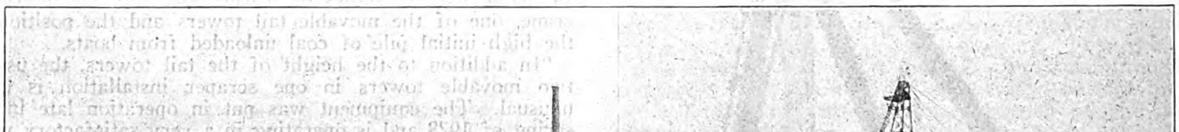

FIG. 15—GENERAL VIEW OF STORAGE YARD, SAUERMAN BROS.

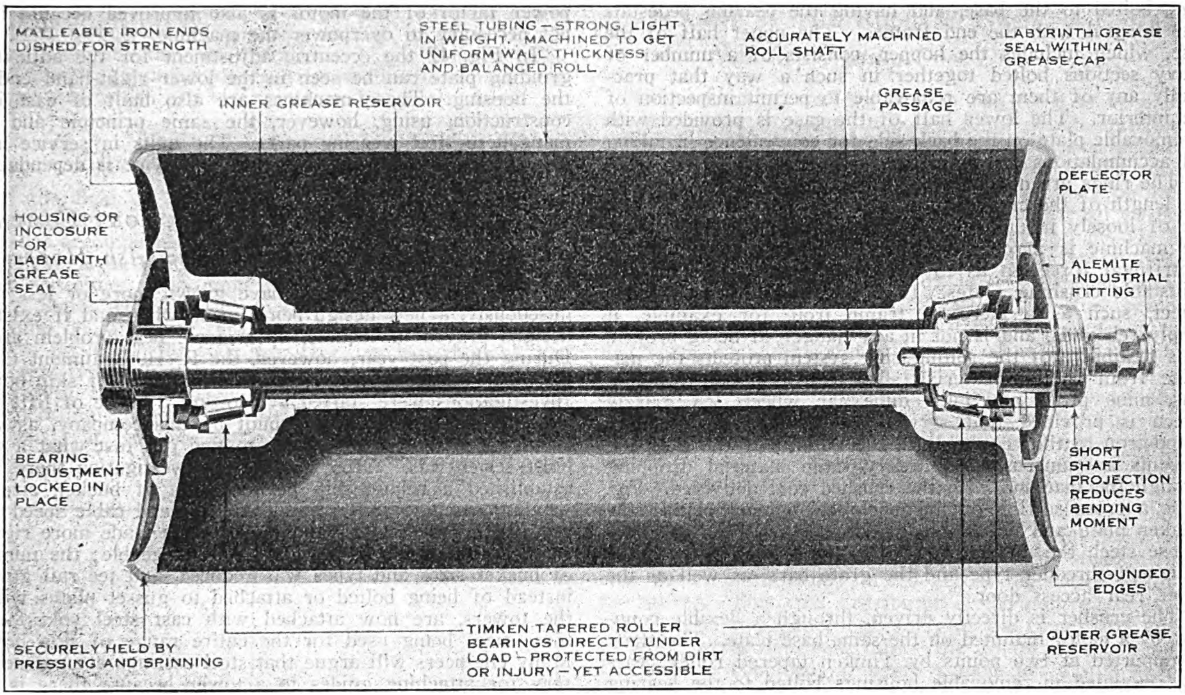
MALLEABLE IRON ENDS DISHED FOR STRENGTH
STEEL TUBING—STRONG, LIGHT IN WEIGHT. MACHINED TO GET UNIFORM WALL THICKNESS AND BALANCED ROLL
ACCURATELY MACHINED ROLL SHAFT
LABYRINTH GREASE SEAL WITHIN A GREASE CAP
INNER GREASE RESERVOIR
GREASE PASSAGE
DEFLECTOR PLATE
HOUSING OR INCLOSURE FOR LABYRINTH GREASE SEAL
ALEMITE INDUSTRIAL FITTING
BEARING ADJUSTMENT LOCKED IN PLACE
SHORT SHAFT PROJECTION REDUCES BENDING MOMENT
ROUNDED EDGES
TIMKEN TAPERED ROLLER BEARINGS DIRECTLY UNDER LOAD—PROTECTED FROM DIRT OR INJURY—YET ACCESSIBLE
OUTER GREASE RESERVOIR
SECURELY HELD BY PRESSING AND SPINNING

FIG. 16—IMPROVED IDLER ROLLER, LINK-BELT CO.

which constitute the road bed on which the belt travels. The service given by the conveyor depends, therefore, upon the construction of the idlers, and it is upon this that the Link-Belt Company has focused particular attention, building into Link-Belt idlers the results of years of belt conveyor experience.

"In doing so, special study has naturally been given to the moving element of the idlers, the individual roll, and this has been highly perfected. Since the roll shell is the key to the successful operation of the idler and so to the entire belt conveyor, we call especial attention to this highly developed belt conveyor idler roll as shown in Fig. 16. Each troughing idler is made of three unit rolls, each interchangeable with the other. The roll shell is made of one piece of tubing with dished roll ends for strength and rigidity, and held securely in position by spinning the roll shell over the ends. This construction gives a shell which is light in weight, true running and with smooth, rounded edges which cannot injure the belt. The roll ends are of malleable iron and are part of the end castings which serve as a bearing cage and grease reservoir. Both shells and hubs are accurately bored and turned to secure concentricity of the hub with respect to the roll shell.

"Another advantageous feature is an adequate supply of grease which is contained in the reservoir on both sides of the bearing, so that gravitation will supply grease to the bearing whether the roll be in an inclined or level position. The grease seal of the roller bearings is of the labyrinth type, contained in a cap or housing, making it a unit in itself, and protected by a deflector plate, both of which very effectively prevent any foreign matter getting into the bearing.

"The design is such as to permit the removal of the rolls without the use of tools. The brackets supporting the rolls are securely riveted to the tee iron frame which acts as a self-cleaning base and prevents the collection of material which would cause the roll to become a brake wheel rather than an idler roll.

"The Link-Belt Company through years of experiment and tests recommend and furnish idler rolls fitted with shells, made of material having the greatest wear value and such that will best resist the bearing action imposed upon them, whether it be abrasion or corrosion or a combination of both."

STATEMENT BY THE AMERICAN PULVERIZER COMPANY

Ring Coal Crusher

"The American Ring Coal Crusher, used for preparing coal, coke or lignite for automatic stokers or as a breaker ahead of pulverizers, is different from other crushers in that it employs manganese steel rings as a crushing medium. Because of its unique design, this crusher offers the following characteristics and advantages: Simplicity in construction and operation; exceptional ability for passing tramp iron without damage, due to the flexibility of the rolling ring system; low power consumption per ton of crushed material; unusually low maintenance cost, because of manganese grinding parts, and capability of producing various size products, due to the adjustable grinding plates.

"Fig. 17 shows one of the types of American Ring Crushers, with the upper housing removed. The crusher proper is mounted on a heavy cast iron base, extended at one end to provide a mounting for the driving motor. The lower half of the crusher case consists of heavy steel cast-

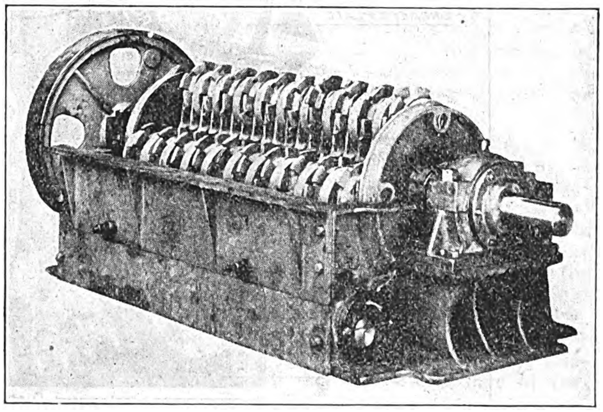

FIG. 17—AMERICAN RING CRUSHER, AMERICAN PULVERIZER CO.

ings, bolted to the base, and having the bearing pedestals cast integral with the end frames. The upper half of the case, which includes the hopper, consists of a number of heavy sections bolted together in such a way that practically any of them are removable to permit inspection of the interior. The lower half of the case is provided with a removable plate on the back side for convenience in taking out accumulations of tramp iron.

"The rings are mounted on a carbon steel shaft extending the length of the crusher, and, in reality, consist of a number of loosely mounted smooth and shredder rings. When the machine is in operation the rings are thrown out by centrifugal force, so as to crush the material against the adjustable crushing plates. If a ring strikes a refractory object, such as a piece of tramp iron, for example, it simply rebounds, and is not in any danger of being broken. This flexibility of the rolling ring system protects the machine from foreign material, such as fish plates, coupling pins, mine props and even mine car wheels. A grizzly screen is provided that serves two purposes: it deflects tramp iron to the receptacle in the bottom of the case and prevents any uncrushed or heavy lump material dropping through the machine with the crushed coal delivered. Fig. 18 is a cross section of the machine, showing plainly the breaker plate and adjustable grinding plate, both of manganese steel, the manganese steel rolling rings of both the plain and shredder type and the grate bars, as well as the lower rear access door.

"The crusher is directly driven, through a flexible coupling, by a motor mounted on the same base plate. The shaft is supported at two points by Timken tapered roller bearings, mounted in removable housings bolted to the bearing pedestals. Each mounting includes two bearings mounted indirectly on the shaft, the method of mounting being such that the assembly on the motor end is fixed, while that on the other end is permitted to float. The whole arrangement is such that perfect shaft alignment is permanently maintained, provision being made for shaft expansion. A heavy flywheel is mounted on the shaft opposite the driven end, which smooths out the operating load peaks, and thus serves to remove some of the strains on the driving motor. Because of the roller bearings, the machine, in starting, comes up to speed very quickly and without undue effort on the part of the motor, or disturbances on the line. The power factor of the motor is also improved because it is not necessary to overpower the machine.

"In Fig. 17 the eccentric adjustment for the adjustable grinding plate can be seen in the lower right-hand end of the housing. These machines are also built of cast iron construction, using, however, the same principle and the manganese steel wearing parts. The units in service have proved entirely satisfactory and the service is dependable."

STATEMENT BY THE R. H. BEAUMONT COMPANY

Skip Hoist Standardization and Ash Hoppers

"Skip hoists in the past have grown more or less promiscuously, a new design being made when and if existing designs proved inadequate, or if some new problem arose. During the past year, however, the R. H. Beaumont Company has brought out a complete new series of skip hoists. Investigations were started by plotting a curve of lifts and capacities of all skips ever built by this company, as well as all those that were bid on, to find out just what a skip hoist series was. After months of investigation there was established a relationship between size of bucket, size of winding machine and motor, cable lift and cable speed and tons per hour. Towers and guides were made more rigidly standard and in many respects interchangeable; the number of bucket sizes and types was reduced, and tee rail guides, instead of being bolted or attached to gusset plates within the towers, are now attached with cast steel yokes, only three sizes being used for the entire range of skip hoists. Many engineers will argue that steel castings are not necessary for attaching guides to a tower because there is not sufficient shock to cause a break normally in cast iron, but this company felt that the annoyance of replacing such a chair or yoke in a tower was sufficiently great to justify the additional expense of steel castings, and by simplification and standardization, the steel castings can be produced cheaply enough to warrant their use under almost all conditions.

"Winding machines are now all roller bearing, there being only four sizes of winders to cover the entire range of capacities. Only two sizes of roller bearings occur in each winder. Sheaves are all roller bearing with standard supporting beams, permitting the use of the same beams in

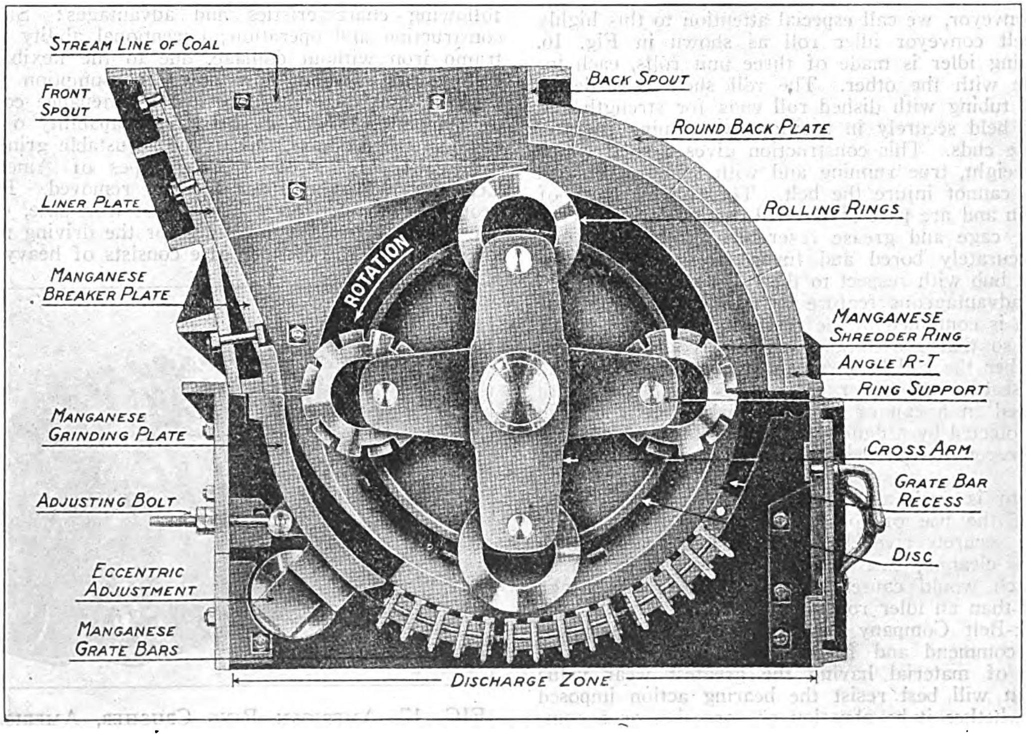

FIG. 18—CROSS SECTION OF RING CRUSHER, AMERICAN PULVERIZER CO.

any type of cable layout. The patented simplex loader has been completely redesigned, making it more rigidly aligned and smoother in operation. Many more detailed improvements, simplifications and standardizations have been accomplished which are too numerous to mention here.

Electrically Operated Ash Gates

"In the field of ash-handling equipment the Beaumont Mfg. Company, a subsidiary of the R. H. Beaumont Company, has accomplished several very interesting things, notably among these being the development of electrically operated ash gates. This application is now fully covered by United States letters patent on both the spur gear operated units and on the screw type of operation. All installations made so far are of the spur gear type, but it is thought that the screw type will be the one most commonly used in the near future, as it can readily be adapted to replacing existing operating cylinders in other types of gate operation. The spur gear type of electric drive for ash gates is shown in Fig. 19.

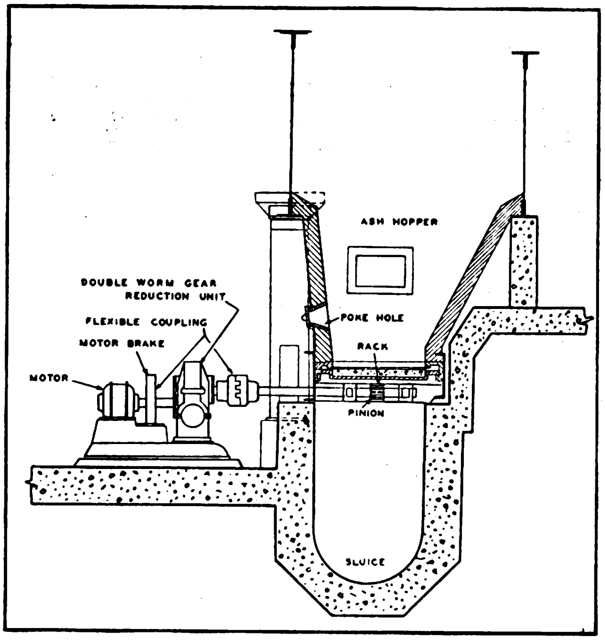

FIG. 19—MOTOR OPERATED ASH GATE, R. H. BEAUMONT Co.

Vestibule Ash Hopper

"Another development of this company is the so-called vestibule ash hopper for pulverized fuel installations, which is a system for quenching pulverized fuel and ash prior to disposal and without interfering with the boiler operation. The object is, of course, to handle the ashes by a car and skip hoist system, thereby eliminating not only the expensive sluicing system, but the many nasty problems attendant on the use of a sluice.

This vestibule system, shown in Fig. 20, consists of a copper-steel furnace bottom very similar to the ash furnace bottom used in pulverized fuel systems. The bottom opening of this furnace floor is fitted with horizontal, air-tight, slide gates, either hand or power operated, usually power. Below these gates is attached our standard gravity, copper-steel, discharge ash hoppers which are lined with vitrified shale brick and equipped with spray quenchers, poke holes, drained pivoted gates, etc. With such a system, ashes can be discharged from the furnace into the quenching hopper, and after the upper gates are closed any action which goes on within the quenching hopper is not transmitted to the furnace."

STATEMENT BY THE ROLLAND GARDNER COMPANY

Non-Segregating Coal Distributor

"Elimination of coal segregation has come to be one of the paramount problems in boiler room design and operation. High CO$_2$ and efficient combustion depend primarily upon the intimate mixture of air and coal in the correct ratio. This ratio of total air to total coal may be accurately controlled, but this does not mean that all parts of the fuel bed receive their proper quantities of air. If part of the fuel bed consists of coarse coal and part of fine, the air will follow the path of least resistance, that is, through the coarse coal. This part of the fuel bed will burn out faster, lowering its resistance, and hence further increasing the excess air. On the other hand, the fines will receive less than the proper amount of air and will burn slowly and incompletely, resulting in liberation of CO, stratification of gases and excessive combustible in the ash. Proper air distribution, uniform combustion, uniformly high CO$_2$ and low combustible can be maintained only if the fuel bed has coarse and fine evenly distributed.

"The purpose of the non-segregating coal distributor, manufactured under the trade name of 'Non-Seg,' is to prevent this segregation and to deliver to the stoker hopper coal which is uniformly mixed across the entire width of the stoker. This coal distributor is the outgrowth of extensive tests and a thorough study of the causes and effects of coal segregation and offers the following advantages: 1—Uniform fuel bed; 2—Even combustion across stoker; 3—Less stratification of gases; 4—Higher average CO$_2$; 5—Increased boiler rating; 6—Higher combined boiler and furnace efficiency; 7—Lower stoker and furnace maintenance, and 8—Less attention to fire.

"The 'Non-Seg' coal distributor is based upon a very simple theory that is most effective in practice. The bottom plate of the distributor is a section of a cone having a vertical axis, hence the slope is the same down all elements of the cone. If coal is delivered at the apex, it slides down all elements in equal quantity without any tendency to roll sidewise or segregate. Each particle of coal, regardless of size or condition, follows its straight line element, and the coal is uniformly distributed across the stoker hopper. There are no moving parts and consequently no upkeep. The spout is effective, and its design is such that it can easily be installed in all plants distributing coal from overhead bunkers or by larries running at suitable height. One or more distributors may be used for a given boiler width, depending upon height available or the number of openings desired from overhead storage. In construction the plates of the spout are electrically welded throughout, thus eliminating siftings and drips.

"Down spouts to non-segregating coal distributors may be vertical or they may slope toward the boiler, but they should not incline laterally at an appreciable angle unless suitable means are provided to correct segregation in the down spout itself, for the fines naturally sift to the lower side of the spout. This condition may be corrected by inserting a spiral feeder, manufactured by this company, at the entrance of the distributor to change the position of the coarse and fines and permit of proper entry into the distributor.

"Inasmuch as a distributor has to be built up so as to have passage through which the coal may travel without congestion, there is a slight difference between the theoretical distributor consisting of a single conical surface and the actual chute consisting of that volume inclosed between two conical surfaces. A slight amount of sifting can take place with this latter design, but it is not parallel to the stoker front but rather perpendicular to it. This slight segregation causes no ill effect in operation of stoker and, to a great extent, the coal is remixed before it reaches the stoker itself. Further analysis of the design of the non-segregating spout reveals the fact that the volume of coal between an increment of width at the center of the distributor outlet and the apex is the same as the volume of coal between an equal increment of width at the end of the distributor outlet and the apex. This means that when the

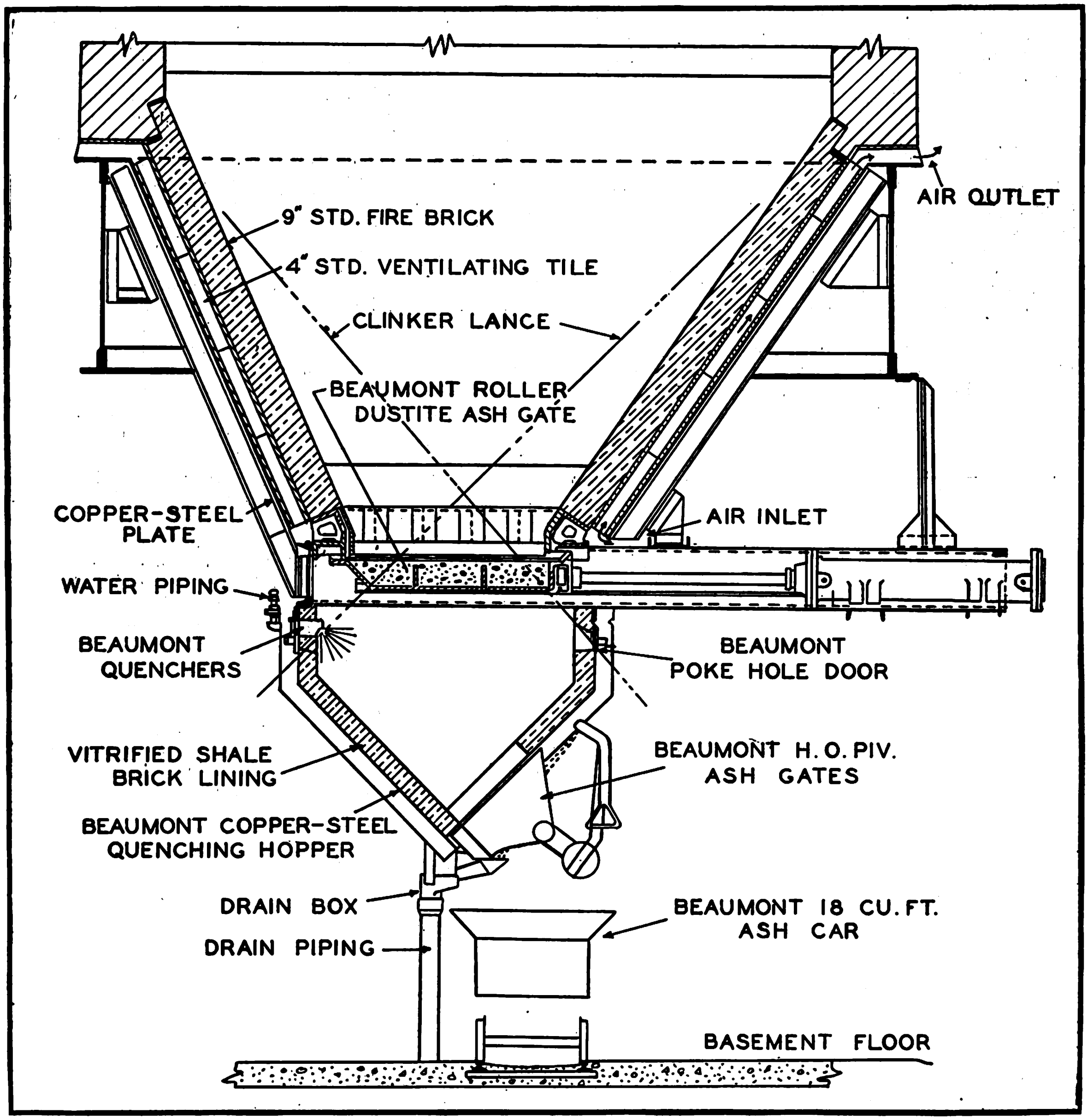
9" STD. FIRE BRICK
4" STD. VENTILATING TILE
CLINKER LANCE
BEAUMONT ROLLER DUSTITE ASH GATE
AIR OUTLET
COPPER-STEEL PLATE
AIR INLET
WATER PIPING
BEAUMONT QUENCHERS
BEAUMONT POKE HOLE DOOR
VITRIFIED SHALE BRICK LINING
BEAUMONT H. O. PIV. ASH GATES
BEAUMONT COPPER-STEEL QUENCHING HOPPER
DRAIN BOX
DRAIN PIPING
BEAUMONT 18 CU. FT. ASH CAR
BASEMENT FLOOR

FIG. 20—VESTIBULE TYPE ASH HOPPER, R. H. BEAUMONT CO.

distributor is emptied it will empty straight across rather than running out at the ends first and in the center last. This feature is a decided advantage whenever it is desired to empty the stoker hopper.

"Losses and difficulties due to coal segregation are prevalent and the non-segregating coal distributor eliminates them simply and completely."

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SPECIFICATIONS

The purpose of the Specifications Subcommittee's work is to formulate general specifications for the major items of power plant equipment. The aim is to assist the specification writer in producing specifications which will clearly describe the equipment wanted and the performance expected of it under given conditions.

It is recognized that inflexible standards cannot be set up to apply in all cases. Therefore, no attempt has been made to place any limits on the characteristics of the equipment. It is assumed that the specification writer is sufficiently familiar with the equipment wanted to determine the necessary details, and to place the limits to meet his own particular conditions. It is hoped that with these forms before him, he will be able to produce a specification which will cover in the present report material on several related sub- with a minimum of effort.

The previous reports covered a general outline and standard forms for specifications for boilers, boiler feed pumps, surface condensers, underfeed stokers, forced draft fans, superheaters, economizers, chain grate stokers, induced draft fans, turbo-generators, evaporators, piping, pulverized fuel equipment and coal handling equipment. The present report covers a general outline and standard forms for specifications for air preheaters, closed heaters and deaerating equipment. These forms are intended to be used primarily as a checking list and as an outline of a form to be used. It is not expected that all items are necessarily included or that all of the items covered in the form will be required in each case, and spaces have been left where specific items should be filled in by the specification writer. All paragraphs not needed should be omitted. To make the forms clear, certain figures and statements have been inclosed in parentheses to indicate that these items are to be changed to suit conditions.

In addition to the usual general outline and standard forms for specifications for power plant equipment, this Subcommittee has, upon request, included in the present report material on several related subjects of particular interest to the specification writer or purchaser. This additional matter includes a form for analysis of proposals, an index of generally accepted standards and lists of reports of investigations.

PURPOSE OF SPECIFICATIONS

The purpose of specifications is to set forth in as brief and concise a manner as possible the requirements of the purchaser and to state the information which the purchaser desires the bidder to submit in order that the proposals may be properly considered and compared.

To obtain the best results, the specifications must describe clearly what is wanted, but should restrict the manufacturer only in so far as is necessary to obtain the desired quality and capacity. Being too explicit regarding the manner in which the purchaser's requirements shall be met often requires specially designed equipment at a higher price than would be asked for a standard type which would satisfactorily meet the real requirements.

The information requested of bidders should be of such a nature, and in such detail, as to make possible a complete and impartial analysis and comparison of the quality and performance of the material or equipment quoted on. Only information necessary to such selection should be requested; any other information desired can best be obtained later from the successful bidder.

A complete contract for a major item of power plant equipment will usually consist of:

A. Formal Agreement.
B. General Conditions of the Contract.
C. Specification.
D. Instructions to Bidders.
E. Manufacturer's Specifications.
F. Drawings.

A. The Agreement is the formal and legal part of the contract and usually sets forth the legal name and address of the contracting parties, the price and terms of payment, that previous communications conflicting with the contract shall be null and void, etc.

B. The General Conditions of the contract should cover such items as:

1. Definitions of Terms Used.
2. Engineer's Status.
3. Inspection and Supervision.
4. Damages.
5. Changes in Work.
6. Insurance, Fire, Public Liability, Workmen's Compensation, etc.
7. Ownership or Acceptance.
8. Permits.
9. Liens.
10. No Waiver Clause.
11. Patent Rights.
12. Sub-Contracts.
13. Other Work Coincident with Work in Question.
14. Removal of Debris.
15. Prosecution of Work in Harmony with Other Contractors.

Publication No. 289-49, Serial Report, Prime Movers Committee.

16. Interpretation of Drawings and Specifications.
17. Control of Labor Forces.
18. Arbitration.
19. Statement of Completion.
20. Termination of Contract.
21. Any Other Items Desired by Purchaser.

C. The Specification proper should include only requirements which can be definitely stated, but no items which properly belong in the Agreement, the General Conditions of the contract, or in the Instruction to Bidders. The Specification should include:

HEADING, PLACE AND DATE

1. Scope.
2. Service.
3. Operating Conditions.
4. Description of Apparatus.
5. Description of Appurtenances.
6. Materials.
7. Drawings.
8. Guarantee.
9. Test.
10. Insurance.

D. Instructions to Bidders should supplement the Specification proper, including any additional items of information necessary for intelligently submitting a bid.

Items to be included are:

1. General:
   - (a) State when and where proposals are due, whether in duplicate or otherwise, and whether they should be signed by an authorized member of the firm submitting the bid.
   - (b) State where plans and specifications may be seen.
   - (c) Right to reject bids.
   - (d) Contract.
2. Form of Proposal:
   - (a) State whether bidders shall quote lump sum price, or otherwise.
   - (b) Preliminary drawings.
3. Facilities:
   - (a) Railroad.
   - (b) Siding.
   - (c) Water.
   - (d) Electric Power.
   - (e) Compressed Air.
   - (f) Crane.
   - (g) Storeroom for Materials.
   - (h) Office.
   - (i) Shanties, Scaffolding and False Work.
4. Shipping Instructions.
5. Unloading:
   - (a) State who will unload.
   - (b) State who shall be responsible for material unloaded.
6. Labor Conditions.
7. Terms of Payment.
8. Information accompanying proposal.

E. Manufacturer's Specifications should include in detail type of equipment, size or capacity, guaranteed performance, dimensions and weights, construction, materials, erection, and facilities for repairs, renewals, or cleaning.

F. The Drawings, if necessary, should accompany the Specification and form a part thereof.

AIR PREHEATER(S)

Instructions to Bidders

For Air Preheater(s) for Power House at
(Philadelphia, Pa.)
(A.B.C. Power Company)
Specification No. (.......)

(Philadelphia, Pa.)
(Date)

General

1. (Duplicate) proposals will be received at the office of (the Purchasing Agent of the A. B. C. Power Co. at Philadelphia, Pa.) up to (5 p.m., Nov. ....) for the work outlined in the inclosed specification.

2. Bid price shall be submitted on a sheet separate from all other data.

3. Bidders shall visit the site and familiarize themselves with every phase of the work before submitting proposals.

4. All drawings and specifications furnished with requests for bids shall remain the property of the (Purchaser), and shall be returned with the proposals.

5. The right is reserved to reject any or all bids.

6. The successful bidder shall enter into a written contract with the Purchaser for the performance of the work included in the specifications.

7. This contract will be drawn up by the (Purchaser) and will include (Purchaser's) and (Contractor's) Specifications, Instructions to Bidders and the "General Conditions" of the contract, copy of which is attached hereto. In case of conflict between (Purchaser's) and (Contractor's) specifications, the (Purchaser's) specification shall rule.

8. BOND: The successful bidder shall (....) be required to furnish a written bond, for the full amount of the contract price, to the Purchaser. The cost of this bond will be paid by the Purchaser.

9. FORM OF PROPOSAL: Bidders are requested to state a (lump sum price) for furnishing, (and delivering and erecting) the equipment specified.

10. Each proposal shall be accompanied by drawings giving general dimensions, and drawings or cuts showing in detail the construction of the equipment offered.

11. DELIVERY: Delivery (and completion of erection) desired (....).

12. FACILITIES:
- (a) The plant is located on the (B. & O.) Railroad (with a siding entering the plant).
- (b) Water will (....) be furnished (free) by the Purchaser.
- (c) Power will (....) be furnished (free) by the Purchaser.
- (d) Power available is (220) volts (a-c.) (60 cycles) (3 phase).
- (e) Compressed air (at 100 lb.) will (....) be furnished (free) by the Purchaser.
- (f) Crane of (....) ton capacity is available. Crane operator will (....) be furnished (free) by the Purchaser.
- (g) Storage space will be available (inside the plant), or remote storage alongside the tracks of the (B. & O. Railroad) with-(out) store houses approximately (....) miles from the plant.
- (h) Office space (with telephone, light and heat) will (....) be furnished (free) by the Purchaser.
- (i) (Contractor) shall supply tool and work shanties, scaffolding and falsework.

13. SHIPPING: Purchaser will furnish shipping instructions.

14. UNLOADING: The (Purchaser) will unload materials delivered by the Contractor and (advance) (freight) (and carting charges). The (Contractor) shall assume all responsibility for care and protection of the same after unloading.

15. LABOR CONDITIONS: (Union) (Non-union) labor.

16. TERMS OF PAYMENT:
- (....) per cent on receipt of (bill of lading) for (complete) shipment.
- (....) per cent on completion of (....) per cent of erection.
- (....) per cent on completion of erection.
- (....) per cent (....) days after acceptance by the (Engineers).

Information

17. The following information shall be given with each proposal and will be made a part of the contract entered into with the successful bidder:
- (a) Sq. ft. of active heating surface in contact with (flue gas) (air) in (each) preheater.
- (b) Dimensions, gage, shape, material, number and arrangement of heating elements in (each) preheater.
- (c) Dimensions of space occupied by (each) preheater.
- (d) Number and arrangement of passes for gas and air in (each) preheater.
- (e) Method of and space required for removing and replacing heating elements.
- (f) Complete description of equipment provided for removal of soot from gas passages.
- (g) Description of preheater supports.
- (h) Details of casing(s), details and location of inlet and outlet connections and method of attaching heat insulation.
- (i) Facilities provided for inspecting and cleaning preheater(s).
- (j) Details of design and construction of rotor(s), supports, bearings and guides, if required.
- (k) Number, type and details of design, construction and operation of fans, if included.
- (l) Details of design, construction and operation of driving mechanism(s), if required.
- (m) Rating and speed of motor(s) (included) (required), and speed of rotor(s), if used.
- (n) Description of tools and accessories included.
- (o) Complete manufacturer's specifications of the equipment.
- (p) Guaranteed performance of (each) (number) preheater(s), under conditions of boiler operation as stated in accompanying specification, with boiler(s) served by preheater(s) operating at (100, 200, 300 and 400) per cent of rating.
    - 1—Draft loss through flue gas side of preheater(s), in. of water.
    - 2—Draft loss through air side of preheater(s), in. of water.
    - 3—Temperature of flue gas leaving preheater(s), deg. fahr.
    - 4—Temperature rise of air, deg. fahr.
    - 5—Temperature of air leaving preheater(s), deg. fahr.
    - 6—Rate of leakage between air and gas elements, lb. per hr.
    - 7—Heat recovered by preheater(s), B.t.u. per hr.
- (q) Power required to operate (each) preheater, if any.
- (r) Power required to operate fans, if included.
- (s) Weight of (each) preheater, including casing, and motor and fans, if included.
- (t) Weight and size of largest piece.
- (u) Shipping point.
- (v) Date of shipment (and time necessary to complete erection).
- (w) Per diem charge for services of Contractor's erector or representative not covered by the contract.
- (x) Any other details wanted by Purchaser.

Specification

For Air Preheater(s) for Power House at (Philadelphia, Pa.)

(A.B.C. Power Company)

Specification No. (......)

(Philadelphia, Pa.)
(Date)

Scope

1. This specification covers the furnishing, (and delivery and erection) of (number) air preheater(s)

for the (new) (present) power plant of the (A. B. C. Power Co.) located at (Philadelphia, Pa.). The preheater(s) shall be furnished (and installed) with all appurtenances directly a part thereof and necessary to place (them) in successful operation, with the exception of such appurtenances as may be herein otherwise provided for.

[NOTE: This specification applies only to the usual types of air preheaters which utilize waste heat in the boiler flue gas. Under certain conditions it may be more feasible to use a preheater which employs steam or hot water as the heating medium.]

Service

2. The preheater(s) will be installed in connection with (number) (type) boiler(s) (and number) (type) (economizers) as shown on drawing(s) (numbers and titles) attached hereto.

3. ALTERNATE: The preheater(s) will be installed in connection with (number) boiler(s) (and number) (economizers) as follows:

(a) Type of boiler, (horizontal) (water tube).
(b) Arrangement of boiler tubes, (number high and number wide).
(c) Width of (each) boiler setting, inside, (....) ft.
(d) Boiler(s) set (in battery).
(e) (Number) pass, (reversed) setting(s).
(f) Size and location of boiler flue opening(s), (....).
(g) Type of economizer(s).
(h) (Arrangement of economizer tubes).
(i) (Width of each economizer setting, inside, ... ft.).
(j) (Size and location of economizer gas outlets).
(k) (Each economizer will serve .... boilers).

4. HEATING SURFACE: The following heating surface will be provided ahead of (each) (number) preheater(s):

(a) (....) sq. ft. of boiler heating surface.
(b) (....) sq. ft. projected area of water-cooled wall surface.
(c) (....) sq. ft. of (type) superheater surface.
(d) (....) sq. ft. of economizer surface.

5. OPERATING PRESSURE: Boiler(s) will be operated at (....) lb. per sq. in. gage steam pressure. (Economizers will be operated at .... lb. per sq. in. gage pressure).

6. FUEL BURNING EQUIPMENT: (Each) boiler will be provided with (type and size) (stoker).

7. DRAFT EQUIPMENT: (Number) (type and size) forced draft and (number) (type and size) induced draft fans will be provided. (State also number of each per boiler).

8. ALTERNATE-DRAFT EQUIPMENT FURNISHED BY CONTRACTOR: Forced and induced draft fans, integral with the preheater(s), shall be furnished (and installed) by the Contractor. Fans shall be of ample capacity, of suitable design and shall maintain the following static pressures when boiler(s) served by the fans (is) evaporating (....) lb. of water per hour under specified conditions of operation:

(a) Forced draft fan(s), (....) in. of water.
(b) Induced draft fan(s), (....) in. of water.

9. OPERATING CONDITIONS: The preheater design shall be governed by the following operating conditions:

(a) The boiler(s) will be operated at a normal load of (....) per cent and a maximum load of (....) per cent of manufacturer's rated capacity, with performance data for (each) (number) boiler(s) as follows:

Boiler load % of rating	(100)	(200)	(300)	(400)
Water evaporated, lb. per hr......	(35,000)	(70,000)	(105,000)	(140,000)
Flue gas to preheater(s), lb. per hr.	(.....)	(.....)	(......)	(......)
Total combustion air, lb. per hr..	(.....)	(.....)	(......)	(......)
Air to preheater(s), % of total	(.....)	(.....)	(......)	(......)
Air to preheater(s), lb. per hr.	(.....)	(.....)	(......)	(......)
Temp. of flue gas to preheater(s), °F.	(.....)	(.....)	(......)	(......)
Temp. of air to preheater(s), °F.	(.....)	(.....)	(......)	(......)

(b) The fuel to be burned is (bituminous coal) (from .... field) having (....) per cent sulphur and (....) per cent moisture, as fired.

Description

10. DESIGN AND CONSTRUCTION: (Each) preheater shall be designed and constructed

(a) to withstand safely and without distortion a continuous maximum flue gas temperature of (800) deg. fahr., forced draft pressure of (+10) in. of water and induced draft pressure of (−10) in. of water.
(b) gas and air tight so that there will be not more than (0.5) per cent CO_2 loss in gas passages from inlet to outlet under any conditions of operation.
(c) with proper provision for expansion and contraction.

11. TYPE: The preheater(s) shall be of the (stationary) (rotating) (plate) (tubular) (unit) (sectional) type.

12. ARRANGEMENT: There shall be (number) preheater(s) for (each) (number) boiler(s). The preheater(s) will be located (....), to receive gas from (economizers), deliver gas to (induced draft fans), receive air from (forced draft fans) and deliver air to (boiler furnaces). The maximum space to be occupied by (each) preheater shall not exceed (....).

13. GAS FLOW: The flue gas flow shall be (upward) and (counter) (parallel) to the air flow.

14. CAPACITY: Sufficient heating surface shall be provided in (each) (number) preheater(s) to give an increase in air temperature of not less than (....) deg. fahr. when boiler(s) served by the preheater(s) (is) evaporating (....) lb. of water per hr. under specified conditions of operation.

15. SOOT REMOVAL EQUIPMENT: Suitable and adequate means for the removal (and collection) of soot from the gas passages of the preheater(s), (while in operation), shall be furnished (and installed) by the (Contractor). (Steam at a pressure of .... lb. per sq. in. gage and a total temperature of .... deg. fahr will be available. All flanged outlets to which Purchaser's piping connects shall be steel faced, drilled and constructed in accordance with the A.S.A. American Standard for this pressure and temperature, with bolt holes spot faced on back).

16. SUPPORTS: All preheater (and motor) supports, including structural steel other than beams and columns forming part of the building structure, shall be furnished (and installed) by the (Contractor).

17. STEEL CASING(S): Preheater casing(s) constructed of steel plate not less than (3/16) in. thick and suitably reinforced shall be furnished (and installed) by the Contractor. Where possible all joints in casing(s) subject to gas or air leakage shall be (welded). Where necessary for erecting or dismantling, joints shall be bolted and provided with suitable gaskets. Adequate provision shall be made for the attachment of heat insulating covering, which will be furnished (and installed) by the (Purchaser).

18. INLET AND OUTLET CONNECTIONS: The flue gas and air inlets and outlets of (each) preheater shall be arranged for suitable and convenient connection to ducts or other equipment. Connection(s) between preheater(s) and (boilers) (economizers) (forced draft fans) (induced draft fans) shall be made by the (Contractor). (Purchaser to give details of connections to be made by Contractor).

19. ACCESSIBILITY: All parts of the preheater(s) shall be provided with a sufficient number of air or gas tight (cast iron) doors, manholes and hand holes to make the interior readily accessible for inspection, repair or for the removal of internal parts or foreign matter.

20. DRIVE(S): A complete driving mechanism for (each) preheater, if of the rotating type, shall be furnished (and installed) by the Contractor. A (Manufacturer) (variable) speed (slip ring) (a-c.) motor of suitable capacity, for (....) volts, (.... phase), (.... cycles) shall be provided for (each) preheater. Motor(s) shall be capable of continuous operation at full speed and load with a temperature rise not exceeding (40) deg. cent. above an ambient temperature of (40) deg. cent. and shall be provided with proper starting and control equipment (with overload and under voltage protection). If preheater(s) (is) provided with integral fans, motor(s) shall have sufficient capacity to properly drive both preheater(s) and fans connected with (it). All rotating parts of preheater(s) shall be designed and constructed to withstand a starting torque equal to (300) per cent of normal full load torque.

21. ALTERNATE—MOTOR(S) FURNISHED BY PURCHASER: Motor(s) and control equipment specified herein will be furnished (and installed) by the Purchaser. (The Contractor shall send the half couplings for the motor shafts to the motor manufacturer, express prepaid, to be mounted on the drive shafts. The other half couplings shall be mounted on the driven shafts).

22. TOOLS: The Contractor shall furnish one complete set of special tools and wrenches necessary for the operation and maintenance of the equipment.

23. MATERIAL: All parts of the equipment coming in contact with steam at a temperature above (450) deg. fahr. shall be of (steel, monel or ....). All steel plate work coming in contact with flue gas shall be (....). All tubes shall be (....).

24. MATERIAL BY PURCHASER: The Purchaser will furnish and install the following:

(a) Preheater (and motor) foundation(s) (and supports), foundation bolts, washers and grouting.
(b) Ducts and connections, including dampers, between preheater(s) and other equipment (except as otherwise specified).
(c) (Insulating covering).
(d) (Soot removal equipment).
(e) Piping, if required.
(f) (Forced and induced draft fans).
(g) (Motors).
(h) Electric wiring (and install only, switches and controllers), if required.
(i) Field paint.

25. PAINTING: Preheater casing(s) shall be given one shop coat of (....) heat resisting paint and all structural iron and steel work one shop coat of (red lead) paint before shipment. (All finished parts shall be slushed over before shipment and cleaned by the Contractor after erection is completed).

26. ERECTION: The (Contractor) shall be responsible for the erection and preliminary operation of the equipment covered by this specification under the general direction of the (Engineers).

Drawings

27. (Two) copies of certified drawings shall be submitted to the (Purchaser or his) Engineers for approval within (....) calendar days after contract is placed. The (Purchaser or his) Engineers will examine these certified drawings only for gen-

eral design, general dimensions and apparent suitability, and will approve them or return them for changes desired. Such approval will not relieve the Contractor of responsibility to furnish equipment which will perform successfully under the specified conditions. After drawings are approved (four) copies shall be furnished (as soon as possible). After installation is completed (two) more copies of corrected drawings shall be furnished.

28. (Two) copies of sectional views and lists of parts with piece numbers shown thereon shall be furnished the Purchaser to facilitate the ordering of repair parts.

29. (Two) copies of any special operating instructions shall be furnished to the (Engineers) when preheater(s) (are) shipped.

Guarantee

30. The Contractor guarantees that the apparatus to be furnished will be free from all defects in design, workmanship and material, and will give successful service under the conditions required and specified. The Contractor agrees to replace f.o.b. (....), without expense to the purchaser, any part of the apparatus which may prove defective within (....) year(s) after apparatus is placed in operation.

[NOTE: Purchaser may wish to insert here, or in the formal contract, a requirement for a broader guarantee, calling for the Contractor to be responsible for furnishing equipment which will perform successfully under the specified conditions and to make good, without cost to the Purchaser, any defects of whatever kind, even including removal of the entire equipment and replacement thereof by similar or differently designed apparatus, which will perform in successful manner.]

Tests

31. Purchaser's Inspector shall have free access to the equipment during the process of its manufacture and construction.

32. If the Purchaser so desires, an acceptance test shall be run on (one of) the air preheater(s) at the expense of the Purchaser and under the rules of the latest A.S.M.E. Test Code (....). This test shall be made within (180) days after the preheater(s) (is) placed in service. The Contractor will be given an opportunity to have a representative present to see that the preheater(s) (is) operated properly, and he will be given every opportunity to take observations or to apply any instruments desired, unless a different arrangement is made by mutual agreement. Should this test indicate that the equipment does not meet all guarantees included in the contract, the Contractor shall, at his own expense, make such other tests as may be necessary to show that the contract has been fulfilled.

[NOTE: It may be desirable under certain special conditions to add at this point a bonus and penalty clause or liquidated damages clause.]

CLOSED HEATER(S)

Instructions to Bidders

For Closed Heater(s) for Power House at
(Philadelphia, Pa.)
(A.B.C. Power Company)
Specification No. (......)

(Philadelphia, Pa.)
(Date)

General

1. (Duplicate proposals will be received at the office of (the Purchasing Agent of the A. B. C. Power Co. at Philadelphia, Pa.) up to (5 p.m., Nov. ....) for the work outlined in the inclosed specification.

2. Bid price shall be submitted on a sheet separate from all other data.

3. Bidders shall visit the site and familiarize themselves with every phase of the work before submitting proposals.

4. All drawings and specifications furnished with requests for bids shall remain the property of the (Purchaser), and shall be returned with the proposals.

5. The right is reserved to reject any or all bids.

6. The successful bidder shall enter into a written contract with the Purchaser for the performance of the work included in the specifications.

7. This contract will be drawn up by the (Purchaser) and will include (Purchaser's) and (Contractor's) Specifications, Instructions to Bidders and the "General Conditions" of the contract, copy of which is attached hereto. In case of conflict between (Purchaser's) and (Contractor's) specifications, the (Purchaser's) specification shall rule.

8. BOND: The successful bidder shall (....) be required to furnish a written bond, for the full amount of the contract price, to the Purchaser. The cost of this bond will be paid by the Purchaser.

9. FORM OF PROPOSAL: Bidders are requested to state a (lump sum price) for furnishing, (and delivering and erecting) the equipment specified.

10. Each proposal shall be accompanied by drawings giving general dimensions, and drawings or cuts showing in detail the construction of the equipment offered.

11. DELIVERY: Delivery (and completion of erection) desired (....).

12. FACILITIES:
   (a) The plant is located on the (B. & O.) Railroad (with a siding entering the plant).
   (b) Water will (....) be furnished (free) by the Purchaser.
   (c) Power will (....) be furnished (free) by the Purchaser.
   (d) Power available is (220) volts (a-c.) (60 cycles) (3 phase).
   (e) Compressed air (at 100 lb.) will (....) be furnished (free) by the Purchaser.

(f) Crane of (....) ton capacity is available. Crane operator will (....) be furnished (free) by the Purchaser.
(g) Storage space will be available (inside the plant), or remote storage alongside the tracks of the (B. & O. Railroad) with-(out) store houses approximately (....) miles from the plant.
(h) Office space (with telephone, light and heat) will (....) be furnished (free) by the Purchaser.
(i) (Contractor) shall supply tool and work shanties, scaffolding and falsework.

13. SHIPPING: Purchaser will furnish shipping instructions.

14. UNLOADING: The (Purchaser) will unload materials delivered by the Contractor and (advance) (freight) (and carting charges). The (Contractor) shall assume all responsibility for care and protection of the same after unloading.

15. LABOR CONDITIONS: (Union) (Non-union) labor.

16. TERMS OF PAYMENT:

(....) per cent on receipt of (bill of lading) for (complete) shipment.
(....) per cent on completion of (....) per cent of erection.
(....) Per cent on completion of erection.
(....) per cent (....) days after acceptance by the (Engineers).

Information

17. The following information shall be given with each proposal and will be made a part of the contract entered into with the successful bidder:

(a) Sq. ft. of active heating surface in (each) heater.
(b) Number, length and arrangement of tubes in (each) heater. (Name of manufacturer and process of manufacture).
(c) Number of passes for water in (each) heater.
(d) Method of and space required for removing and replacing tubes.
(e) Complete details of attachment of tubes to tube sheet(s).
(f) Diameter, length and thickness of shell(s).
(g) Thickness of tube sheet(s).
(h) Complete details of all gasket joints in (each) heater.
(i) Number and size of staybolts in (each) heater.
(j) Description of tools and accessories included.
(k) Complete manufacturer's specifications of the equipment.
(l) Water pressure drop through (each) heater under maximum operating conditions.
(m) Temperature of drips from (each) heater.
(n) Weight of (each) heater under operating conditions.
(o) Weight of (each) heater with steam and water spaces filled with water.
(p) Weight and size of largest piece.
(q) Shipping point.
(r) Date of shipment (and time necessary to complete erection).
(s) Per diem charge for services of Contractor's erector or representative not covered by the contract.
(t) Any other details wanted by Purchaser.

Specification

For Closed Heater(s) for Power House at (Philadelphia, Pa.)

(A.B.C. Power Company)
Specification No. (......)

(Philadelphia, Pa.)
(Date)

Scope

1. This specification covers the furnishing, (and delivery and erection) of (number) closed heater system(s) for the (new) (present) power plant of the (A. B. C. Power Co.) located at (Philadelphia, Pa.) The heater(s) shall be furnished (and installed) with all appurtenances directly a part thereof and necessary to place (them) in successful operation, with the exception of such appurtenances as may be herein otherwise provided for.

Service

2. The heater(s) will be used for heating boiler feed water by means of steam extracted from the main turbine(s) (and exhaust steam from auxiliary turbines) as shown on diagram(s) (numbers and titles) attached hereto.

3. ARRANGEMENT: (Each) system shall consist of (four) heater(s). (The condensate and air from each of the higher pressure heaters will be discharged into the next lower pressure heater). The air from the (low pressure) heater will be discharged (into the condenser) (by a steam jet air pump); the condensate will be (pumped to the boiler feed suction header) (drained to the condenser hot well).

4. OPERATING CONDITIONS: The design of (each) heater system shall be governed by the following (maximum) operating conditions:

	Heater A	Heater B	Heater C	Heater D
Water flow, lb. per hr.	(.....)	(.....)	(.....)	(.....)
Water inlet temperature, °F.	(.....)	(.....)	(.....)	(.....)
Water outlet temperature, °F.	(.....)	(.....)	(.....)	(.....)
Steam pressure, lb. per sq. in. abs	(.....)	(.....)	(.....)	(.....)
Total heat content of steam, B.t.u. per lb.	(.....)	(.....)	(.....)	(.....)
Drips to heater, lb. per hr.	(.....)	(.....)	(.....)	(.....)
Temperature of drips, °F.	(.....)	(.....)	(.....)	(.....)
Maximum quantity of steam vented from heater (lb. per hr.) (% of steam flow)	(.....)	(.....)	(.....)	(.....)

Description

5. Design and Construction—General: The heater(s) shall be designed and constructed in accordance with the A. S. M. E. Code for Unfired Pressure Vessels insofar as this code does not conflict with the laws and regulations prevailing at the place of installation. In addition, the heater(s) shall be capable of withstanding the collapsing pressure due to perfect vacuum.

6. Design and Construction—Details: The heater design and construction shall conform to the following requirements:

	Heater A	Heater B	Heater C	Heater D
Type	(vertical) (floating head)	(horizonal) (bowed tubes)	(............) (hairpin tubes)	(............) (............)
Tube sheet(s) material	(Muntz metal)	(Admiralty metal)	(............)	(............)
Tubes secured by	(rolling in)	(ferrules)	(metallic packing)	(............)
Tube packing	(............)	(fiber)	(metallic)	(corset lace)
Tube material	(Muntz metal)	(Admiralty metal)	(electrolytic copper)	(............)
Specification	(A. S. T. M.) (............)	(............)	(............)	(............)
Diameter, in.	(............)	(............)	(............)	(............)
Gage (B.W.G.) No.	(............)	(............)	(............)	(............)
Water box(es) material	(cast steel)	(cast iron)	(steel plate)	(............)
Water box cover(s) material	(cast steel)	(cast iron)	(steel plate)	(............)
Separate or integral with water box	(............)	(............)	(............)	(............)
Shell material	(cast iron)	(steel plate)	(............)	(............)
Joints	(............)	(welded)	(riveted)	(............)
Test pressure steam space, lb. per sq. in.	(............)	(............)	(............)	(............)
Water space, lb. per sq. in.	(............)	(............)	(............)	(............)
Steam connections, size, in.	(............)	(............)	(............)	(............)
Number	(............)	(............)	(............)	(............)
Water connection, size, in.	(............)	(............)	(............)	(............)

7. Hot Well(s): (Each) heater shall be provided with a hot well of not less than (....) gal. capacity, equipped with a (¾) in. gage glass and fitting.

8. Staybolts: Staybolts shall be (forged bronze) conforming to A. S. A. Specification (H7-1925) and so installed as to prevent leakage.

9. Pipe Connections: Outlets to which Purchaser's piping connects, (2) in. diameter and larger, shall be flanged. Welded necks on steel shell(s) shall be of extra heavy pipe with (steel) flanges (screwed and welded) on, face of flange to be not less than (7) in. from crown of sheet. Welded connections less than (2) in. diameter shall be extra heavy couplings retapped after welding. Flanged connection shall be faced, drilled and constructed in accordance with the A. S. A. American Standard for the pressure handled.

10. Bolts: Bolts for joints subjected to high pressure (300 lb. or more) shall be high temperature alloy studs with nuts at both ends. Where the flanged connections to the heater(s) require studs for attachment of Purchaser's piping, they shall be furnished with the heater(s) by the Contractor.

11. Tube Supports: (Cast Iron) tube support plate(s) shall be provided to give sufficient rigidity to the tubes. Holes in the tube support plate(s) shall be drilled and chamfered on both sides.

12. Heater Supports: (Saddles) (lugs) to support the heater(s) in (horizontal) (vertical) position, shall be provided by the Contractor.

13. Interchangeability: (Tube bundles of heaters A, B, C, D, shall be removable and interchangeable.)

14. Tools: The Contractor shall furnish one complete set of special tools and special wrenches necessary for the operation and maintenance of the equipment.

15. Material by Purchaser: The Purchaser will furnish and install the following:

(a) Foundations, foundation bolts, washers and grouting.
(b) All piping, valves and fittings.
(c) Insulating covering.
(d) Pumps and drainers.
(e) Heater tubes, in required straight lengths, f.o.b. ......

16. Painting: One shop coat of (flat black) paint shall be applied to (each) heater before shipment.

17. Erection: The (Contractor) shall be responsible for the erection of the heater(s) under the general direction of the Engineers.

Drawings

18. (Two) copies of certified drawings shall be submitted to the (Purchaser or his) Engineers for approval within (....) calendar days after contract is placed. The (Purchaser or his) Engineers will examine these certified drawings only for general design, general dimensions and apparent suitability, and will approve them or return them for changes desired. Such approval will not relieve the Con-

tractor of responsibility to furnish equipment which will perform successfully under the specified conditions. After drawings are approved (four) copies shall be furnished (as soon as possible). After installation is completed (two) more copies of corrected drawings shall be furnished.

19. (Two) copies of any special operating instructions shall be furnished to the (Engineers) when heater(s) (are) shipped.

Guarantee

20. The Contractor guarantees that the apparatus to be furnished will be free from all defects in design, workmanship and material, and will give successful service under the conditions required and specified. The Contractor agrees to replace f.o.b. (....), without expense to the Purchaser, any part of the apparatus which may prove defective within (....) year(s) after apparatus is placed in operation.

[NOTE: Purchaser may wish to insert here, or in the formal contract, a requirement for a broader guarantee, calling for the Contractor to be responsible for furnishing equipment which will perform successfully under the specified conditions and to make good, without cost to the Purchaser, any defects of whatever kind, even including removal of the entire equipment and replacement thereof by similar or differently designed apparatus, which will perform in successful manner.]

Tests

21. Purchaser's inspector shall have free access to the equipment during the process of its manufacture and construction.

22. After the heater(s) (have) been erected, all pressure parts shall be given a hydrostatic test at the test pressure specified in Paragraph 6, and any and all other tests as may be required by law or ordinance. All apparatus for these tests shall be furnished by the (Contractor).

23. If the Purchaser so desires, an acceptance test shall be run on (one of) the closed heater system(s) at the expense of the Purchaser and under the rules of the latest A. S. M. E. Test Code. This test shall be made within (180) days after the closed heater(s) (is) placed in service. The Contractor will be given an opportunity to have a representative present to see that the heater(s) (is) operated properly, and he will be given every opportunity to take observations or to apply any instruments desired, unless a different arrangement is made by mutual agreement. Should this test indicate that the equipment does not meet all guarantees included in the contract, the Contractor shall, at his own expense, make such other tests as may be necessary to show that the contract has been fulfilled.

[NOTE: It may be desirable under certain special conditions to add at this point a bonus and penalty clause or liquidated damages clause.]

DEAERATING (HEATER) EQUIPMENT

Instructions to Bidders

For Deaerating (Heater) Equipment for Power House at
(Philadelphia, Pa.)
(A.B.C. Power Company)
Specification No. (......)

(Philadelphia, Pa.)
(Date)

General

1. (Duplicate proposals will be received at the office of (the Purchasing agent of the A. B. C. Power Co. at Philadelphia, Pa.) up to 5 p.m., Nov. ....) for the work outlined in the inclosed specification.

2. Bid price shall be submitted on a sheet separate from all other data.

3. Bidders shall visit the site and familiarize themselves with every phase of the work before submitting proposals.

4. All drawings and specifications furnished with requests for bids shall remain the property of the (Purchaser), and shall be returned with the proposals.

5. The right is reserved to reject any or all bids.

6. The successful bidder shall enter into a written contract with the Purchaser for the performance of the work included in the specifications.

7. This contract will be drawn up by the (Purchaser) and will include (Purchaser's) and (Contractor's) Specifications, Instructions to Bidders and the "General Conditions" of the contract, copy of which is attached hereto. In case of conflict between (Purchaser's) and (Contractor's) specifications, the (Purchaser's) specification shall rule.

8. BOND: The successful bidder shall (....) be required to furnish a written bond, for the full amount of the contract price, to the Purchaser. The cost of this bond will be paid by the Purchaser.

9. FORM OF PROPOSAL: Bidders are requested to state a (lump sum price) for furnishing, (and delivering and erecting) the equipment specified.

10. Each proposal shall be accompanied by drawings giving general dimensions, and drawings or cuts showing in detail the construction of the equipment offered.

11. DELIVERY: Delivery (and completion of erection) desired (....).

12. FACILITIES:
   (a) The plant is located on the (B. & O.) Railroad (with a siding entering the plant).
   (b) Water will (....) be furnished (free) by the Purchaser.
   (c) Power will (....) be furnished (free) by the Purchaser.
   (d) Power available is (220) volts (a-c.) (60 cycles) (3 phase).

(e) Compressed air (at 100 lb.) will (....) be furnished (free) by the Purchaser.
(f) Crane of (....) ton capacity is available. Crane operator will (....) be furnished (free) by the Purchaser.
(g) Storage space will be available (inside the plant), or remote storage alongside the tracks of the (B. & O. Railroad) with-(out) store houses approximately (....) miles from the plant.
(h) Office space (with telephone, light and heat) will (....) be furnished (free) by the Purchaser.
(i) (Contractor) shall supply tool and work shanties, scaffolding and falsework.

13. SHIPPING: Purchaser will furnish shipping instructions.

14. UNLOADING: The (Purchaser) will unload materials delivered by the Contractor and (advance) (freight) (and carting charges). The (Contractor) shall assume all responsibility for care and protection of the same after unloading.

15. LABOR CONDITIONS: (Union) (Non-union) labor.

16. TERMS OF PAYMENT:

(....) per cent on receipt of (bill of lading) for (complete) shipment.
(....) per cent on completion of (....) per cent of erection.
(....) Per cent on completion of erection.
(....) per cent (....) days after acceptance by the (Engineers).

Information

17. The following information shall be given with each proposal and will be made a part of the contract entered into with the successful bidder:

(a) Sq. ft. of active heating or cooling surface; diameter, length, thickness and material of tubes; number of water passes and friction loss at maximum flow in (each) closed heater or condenser.
(b) Sq. ft. of tray surface in (each) shell.
(c) Steam loss, lb. per hr., from (each) vent condenser.
(d) Water pressure required at inlet to deaerating equipment.
(e) Method of and space required for removing trays or tubes from each portion of the equipment.
(f) Facilities provided for inspection and cleaning each portion of the equipment.
(g) Thickness of shell(s) and tube sheets.
(h) Size, number and description of safety valves, blow-off valves and float valves included.
(i) Description of tools and accessories included.
(j) Complete manufacturer's specifications of the equipment.
(k) Guaranteed performance of (each) (deaerator).
(l) Weight empty, weight operating and weight with all spaces full of water of each piece of equipment.
(m) Weight and size of largest piece.
(n) Shipping point.
(o) Date of shipment (and time necessary to complete erection).
(p) Per diem charge for services of Contractor's erector or representative not covered by the contract.
(q) Any other details wanted by Purchaser.

Specification

For Deaerating (Heater) Equipment for Power House at

(Philadelphia, Pa.)

(A.B.C. Power Company)

Specification No. (......)

(Philadelphia, Pa.)
(Date)

Scope

1. This specification covers the furnishing, (and delivery and erection) of (number) (deaerators) (deaerating heaters) for the (new) (present) power plant of the A. B. C. Power Co.) located at (Philadelphia, Pa.). (Deaerators) shall be furnished (and installed) with all appurtenances directly a part thereof and necessary to place (them) in successful operation, with the exception of such appurtenances as may be herein otherwise provided for.

Service

2. The (deaerators) shall remove the air from the boiler feed water and will be a part of the feed water system as shown on Heat Balance Diagram No. (....) attached hereto.

[NOTE: Where possible the diagram should show quantities and temperature of water or vapor passing through each part of the system under normal operating conditions.]

3. OPERATING CONDITIONS: The design of (each) (deaerator) shall be governed by the following operating conditions:

(a) Flow of water to (deaerator), lb. per hr.....	(¼Max.)	(½Max.)	(¾Max.)	(Max.)
Temperature of water to (deaerator), °F..	(......)	(......)	(......)	(......)
Pressure of steam to (deaerator), lb. per sq. in. abs.	(......)	(......)	(......)	(......)
Total heat content of steam to (deaerator), B.t.u. per lb..	(......)	(......)	(......)	(......)

(b) Introduction of (....) per cent make-up water at the (deaerator), supplied from (.... river) and having the following average analysis:

(............) (............)
(............) (............)

(c) Abnormal condenser leakage amounting to (....) per cent of the water passing through the (deaerator).
(d) (Cooling water at a temperature of 40-80 deg. fahr. will be available in quantities up to 200 gal. per min.).

Description

4. DESIGN AND CONSTRUCTION: All parts of the equipment shall be designed and constructed in accordance with the A.S.M.E. Code for Unfired Pressure Vessels insofar as this code does not conflict with the laws and regulations prevailing at the place of installation. All water passages of closed vent condensers or auxiliary heaters shall be designed for a test pressure of (200) lb. per sq. in. gage. The steam space of (each) (deaerator) shall be designed for a test pressure of (....) lb. per sq. in. gage.

5. CAPACITY: The (deaerators), when operating under specified maximum conditions, shall be capable of delivering feed water containing not more than (.03) c.c. of oxygen per litre, if provided with sufficient steam to heat the water to the boiling point.

6. ARRANGEMENT: The (deaerators) will receive feed water from (.. stage closed heater) and deliver water to (feed pumps) as indicated on Heat Balance Diagram. Heating steam will be supplied from (.. stage of the main turbine) (exhaust steam system).

7. FLOOR SPACE: Floor space (..) ft. by (..) ft. with a clearance height of (..) ft., including all aisle space necessary for operation and maintenance, is available for (each) (deaerator).

8. SHELL(S):
   (a) (Deaerator) shell(s) shall be (wrought iron) (Armco iron) (with riveted joints) (cast iron).
   (b) Water outlet(s) from deaerating equipment shall be large enough to permit water flow (100) per cent in excess of specified maximum without overflow.
   (c) (Each) (deaerator) (storage tank) shall have a hot water storage capacity of (....) gal.
   (d) Where water storage space is in separate tank(s), (this) tank(s), constructed of (wrought iron) (Armco iron), with all openings for (deaerator), overflow, outlet and float chamber connection(s), shall be furnished (and installed) by the (Contractor).

9. SPECIAL EQUIPMENT: (Each) (deaerator) (storage tank) shall be equipped with the following:
   (a) Balanced valve with by-pass, controlled by adjustable (external) float, for admission of make-up water to the feed water system.
   (b) Overflow for water storage space (for loop seal) (with float valve), having a minimum overflow capacity of (....) lb. per hr. under all conditions of operation. (Overflow float and valve shall be of the external adjustable type).
   (c) Safety valve(s) with a discharge capacity of (....) lb. per hr. at a pressure of (....) lb. per sq. in. gage.
   (d) Suitable air ejector equipment, if required by operating steam pressure.
   (e) Water gage glass and fittings to indicate water level in storage section of (deaerator).
   (f) Test kit for the determination of oxygen in feed water. (One required for each installation).

10. PIPING: The fellowing piping, suitable for the pressures handled, shall be furnished (and installed) by the Contractor as part of the deaerating equipment. All piping (2) in. diameter and larger shall be flanged.
   (a) All piping directly a part of the equipment.
   (b) (All interconnecting and by-pass piping between the various parts of the equipment furnished under this specification).

11. PIPE CONNECTIONS: Outlets to which Purchaser's piping connects, (2) in. diameter and larger, shall be flanged. All flanges, flanged fittings and flanged outlets shall be faced, drilled and constructed in accordance with the A. S. A. American Standard for the pressure handled. Welded necks on steel shell(s) shall be of extra heavy pipe with (steel) flanges (screwed and welded) on, face of flange to be not less than (7) in. from crown of sheet. Welded connections less than (2) in. diameter shall be extra heavy couplings retapped after welding.

12. SUPPORTS: All supports for (deaerators), including structural steel other than beams and columns forming part of the building structure, shall be furnished (and installed)by the (Contractor).

13. ACCESSIBILITY: All parts of the equipment shall be provided with a sufficient number of removable heads or doors, manholes and handholes to make the interior of each accessible for inspection, repair or for the removal of internal parts or foreign matter.

14. TOOLS: The Contractor shall furnish one complete set of special tools and wrenches necessary for the operation and maintenance of the equipment.

15. MATERIAL: Any part coming in contact with steam at a temperature above (450) deg. fahr. shall be of (steel, monel or ....).

16. MATERIAL BY PURCHASER: The Purchaser will furnish and install the following:
   (a) Foundations, foundation bolts, washers and grouting.
   (b) (All piping, valves and fittings extraneous to the deaerating equipment.)
   (c) Insulating covering.

17. PAINTING: All exposed castings which will not be insulated shall have (two) coats of filler rubbed smooth and shall be given one shop coat of flat paint. Exposed steel shall be given one shop coat of flat paint. All finished parts shall be slushed over before shipment (and cleaned by the Contractor after erection is completed).

18. ERECTION: The (Contractor) shall be responsible for the erection (and preliminary operation) of the equipment covered by this specification under the general direction of the (Engineers).

Drawings

19. (Two) copies of certified drawings shall be submitted to the (Purchaser or his) Engineers for approval within (....) calendar days after contract is placed. The (Purchaser or his) Engineers will examine these certified drawings only for general design, general dimensions and apparent suitability, and will approve them or return them for changes desired. Such approval will not relieve the Contractor of responsibility to furnish equipment which will perform successfully under the specified conditions. After drawings are approved (four) copies shall be furnished (as soon as possible). After installation is completed (two) more copies of corrected drawings shall be furnished.

20. (Two) copies of sectional views and lists of parts with piece numbers shown thereon shall be furnished the Purchaser to facilitate the ordering of repair parts.

21. (Two) copies of any special operating instructions shall be furnished to the (Engineers) when deaerating equipment is shipped.

Guarantee

22. The Contractor guarantees that the apparatus to be furnished will be free from all defects in design, workmanship and material, and will give successful service under the conditions required and specified. The Contractor agrees to replace f.o.b. (....), without expense to the Purchaser, any part of the apparatus which may prove defective within (....) year(s) after apparatus is placed in operation.

[NOTE: Purchaser may wish to insert here, or in the formal contract, a requirement for a broader guarantee, calling for the Contractor to be responsible for furnishing equipment which will perform successfully under the specified conditions and to make good, without cost to the Purchaser, any defects of whatever kind, even including removal of the entire equipment and replacement thereof by similar or differently designed apparatus, which will perform in successful manner.]

Tests

23. Purchaser's inspector shall have free access to the equipment during the process of its manufacture and construction.

24. After the deaerating equipment has been erected, all pressure parts shall be given a hydrostatic test at the test pressure specified in Paragraph 4, and any and all other tests as may be required by law or ordinance. All apparatus for these tests shall be furnished by the (Contractor).

25. If the Purchaser so desires, an acceptance test shall be run on (one of) the (deaerators) at the expense of the Purchaser and under the rules of the latest A. S. M. E. Test Code. This test shall be made within (180) days after the (deaerators) (is) placed in service. The Contractor will be given an opportunity to have a representative present to see that the equipment is operated properly, and he will be given every opportunity to take observations or to apply any instruments desired, unless a different arrangement is made by mutual agreement. Should this test indicate that the equipment does not meet all guarantees included in the contract, the Contractor shall, at his own expense, make such other tests as may be necessary to show that the contract has been fulfilled.

[NOTE: It may be desirable under certain special conditions to add at this point a bonus and penalty clause or liquidated damages clause.]

ANALYSIS OF PROPOSALS

On receiving bids it will be found that, with the large amount of information furnished by the bidders, the analysis of proposals requires a great deal of time.

With the completion of its work the Specifications Subcommittee wishes to suggest that the analysis of bids may be facilitated, especially if the purchasing of equipment is of frequent occurrence, by having the bidders fill in prepared forms for the information required.

One large member company has used such forms to great advantage. A separate form is required for each type of equipment. The form which they use for boilers is shown in Fig. 1, 2 and 3.

These forms are to be used as follows:

With the specifications for boilers include copies of sheets 101, 102 and 103, shown in Fig. 1, 2 and 3; each bidder is requested to fill in these forms and include them in his formal proposal. Preferably the forms should be on paper that permits blueprinting and for this purpose the information should be filled in by the bidder in India ink or with a reversed carbon back.

The purchaser, upon receipt of bids, trims the tabulation sheets (except one) along the central line and pastes them together so as to form a continuous tabulation as shown in Fig. 4,—this permits of easy comparison of the bids.

In placing an analysis of proposals before an executive it would probably be sufficient to give items No. 1 and 2 of sheet 101, together with comparison of performance characteristics. This information can be arranged in graphic form as shown in Fig. 5.

Sheet 101

ANALYSIS OF PROPOSALS FOR BOILERS
for

....

	BIDDER:				
1	*Summary* Price:				
	a—Delivered and erected in accordance with specifications.				
	b—Allowance for common labor for unloading and erection.				
	c—Allowance for structural steel.				
	d—Allowance for trimmings and pipe.				
	e—				
	f—				
	g—				
	h—Per lb. (-1 ÷ 2-a).				
	i—Per horsepower (1-a ÷ 21).				
2	Weight: a—Net empty boiler and trimmings as quoted in 1-a.				
	b—Full boiler under hydrostatic test.				
	c—Weight of structural steel in 1-c.				
	d—Weight of material in item 1-d.				
3	F. O. B.				
4	Shipping point.				
5	Delivery—No. of working days—order to delivery at plant.				
6	Time required for erection.				
7	Performance: Based upon fuel and operating conditions as given in specification.				
8	Rating.	100%	200%	300%	400%
9	Lb. water evaporated per hour. (actual).				
10	Exit gas temperature from boiler proper.				
11	Exit gas temperature from integral economizer (if used).				
12	Draft loss through boiler proper.				
13	Draft loss through integral economizer.				
14	Draft loss—Total.				
15	Moisture in steam leaving drum.				

FIG. 1.

Sheet 102

ANALYSIS OF PROPOSALS FOR BOILERS

for

....

	BIDDER:	
	Details	
20	Type of boiler.	
21	Size: Rated horsepower.	
22	Sq. Ft. water and gas swept surface in boiler proper.	
23	Sq. Ft. water and gas swept surface in integral economizer.	
24	Total water and gas swept surface	
25	Sq. Ft. subject to direct radiation.	
26	Total surface in tubes only, not including circulators.	
	Tubes:	
27	Number (not including circulators).	
28	Length.	
29	Diameter (O. D.)	
30	Thickness or gage.	
31	Seamless.	
32	Number in width of boiler.	
33	Number in height or depth.	
34	Number of circulators.	
	Drums:	
35	Number.	
36	Diameter.	
37	Length.	
38	Thickness.	
39	Number and size of manholes.	
	Headers:	
40	Number	
41	Construction.	
42	Number of hand-holes.	
43	Staybolts—number, size and spacing.	
	Pressure:	
44	Max. operating drum pressure—ga. (Max. press. allowed for safety valve setting.)	
45	Test pressure —ga.	

FIG. 2.

Sheet 103

ANALYSIS OF PROPOSALS FOR BOILERS

for

....

	BIDDER:				
46	*Details Continued:* Per diem charge for representative after completion.				
	Accessories:	No.	Make	Size	Remarks
47	Water column.				
48	Safety valves.				
49	Steam gages.				
50	Blow-off valves.				
51	Feed stop and check valves.				
52	Tools				
53	Weight of heaviest piece to be erected.				
54	Size of largest piece to be erected.				
55	Are baffles supplied by Bidder?				
56	Are special tile supplied by Bidder?				

FIG. 3.

ANALYSIS OF PROPOSALS FOR BOILERS
for
THE FICTITIOUS POWER CO.

Note: All data hereon are fictitious.

May, 1925

	BIDDER:	BIDDER A.	BIDDER B.	BIDDER C.	BIDDER D.
	Summary				
1	Price:				
	a—Delivered and erected in accordance with specifications	$13,000	$14,200	$14,800	$15,500
	b—Allowance for common labor for unloading and erection.	600	700	800	900
	c—Allowance for structural steel.	700	800	900	1,000
	d—Allowance for trimmings and pipe.	500	600	700	800
	e				
	f				
	g				
	h—Per Lb. (1-a ÷ 2-a).	0.08	0.09	0.12	0.10
	i—Per horsepower (1-a ÷ 21).	16.00	17.65	18.50	19.40
2	Weight:				
	a—Net empty boiler and trimmings as quoted in 1-a.	162,500 lb.	158,000 lb.	123,500 lb.	155,000 lb.
	b—Full boiler under hydrostatic test.	210,000 lb.	198,000 lb.	128,000 lb.	198,000 lb.
	c—Weight of structural steel in 1-c.	8,000 lb.	9,000 lb.	10,000 lb.	11,000 lb.
	d—Weight of material in item 1-d.	1,200 lb.	1,300 lb.	1,400 lb.	1,500 lb.
3	F. O. B.	Plant	Factory	Frt. All'd.	Plant
4	Shipping point.	Albany	San Francisco	Miami	Podunk
5	Delivery—No. of working days—order to delivery at plant.	60 da.	65 da.	70 da.	90 da.
6	Time required for erection.	4 wk.	4 wk.	4 wk.	4 wk.

FIG. 4.

ANALYSIS OF PROPOSALS FOR BOILERS
for
THE FICTITIOUS POWER CO.

Note: All data hereon are fictitious.

May, 1925

	BIDDER:	BIDDER A.				BIDDER B.				BIDDER C.				BIDDER D.			
	Summary Continued:																
7	Performance: Based upon fuel and operating conditions as given in specification.																
8	Rating:	100%	200%	300%	400%	100%	200%	300%	400%	100%	200%	300%	400%	100%	200%	300%	400%
9	Lb. water evap. per hr. (actual).	24,000	48,000	72,000	96,000	24,000	48,000	72,000	96,000	24,000	48,000	72,000	96,000	24,000	48,000	72,000	96,000
10	Exit gas temperature from boiler proper.	570	660	770	900	490	570	670	780	540	620	700	800	560	680	720	820
11	Exit gas temperature from integral economizer (if used).																
12	Draft loss through boiler proper.	.40	.80	1.4	2.2	.50	1.1	1.8	2.8	.30	.65	1.1	1.8	.20	.45	1.00	1.50
13	Draft loss through integral economizer.																
14	Draft loss—Total.																
15	Moisture in steam leaving drum.	.01	.02	.03	.04	.01	.02	.03	.04	.01	.02	.03	.04	.01	.02	.03	.04

FIG. 4-A.

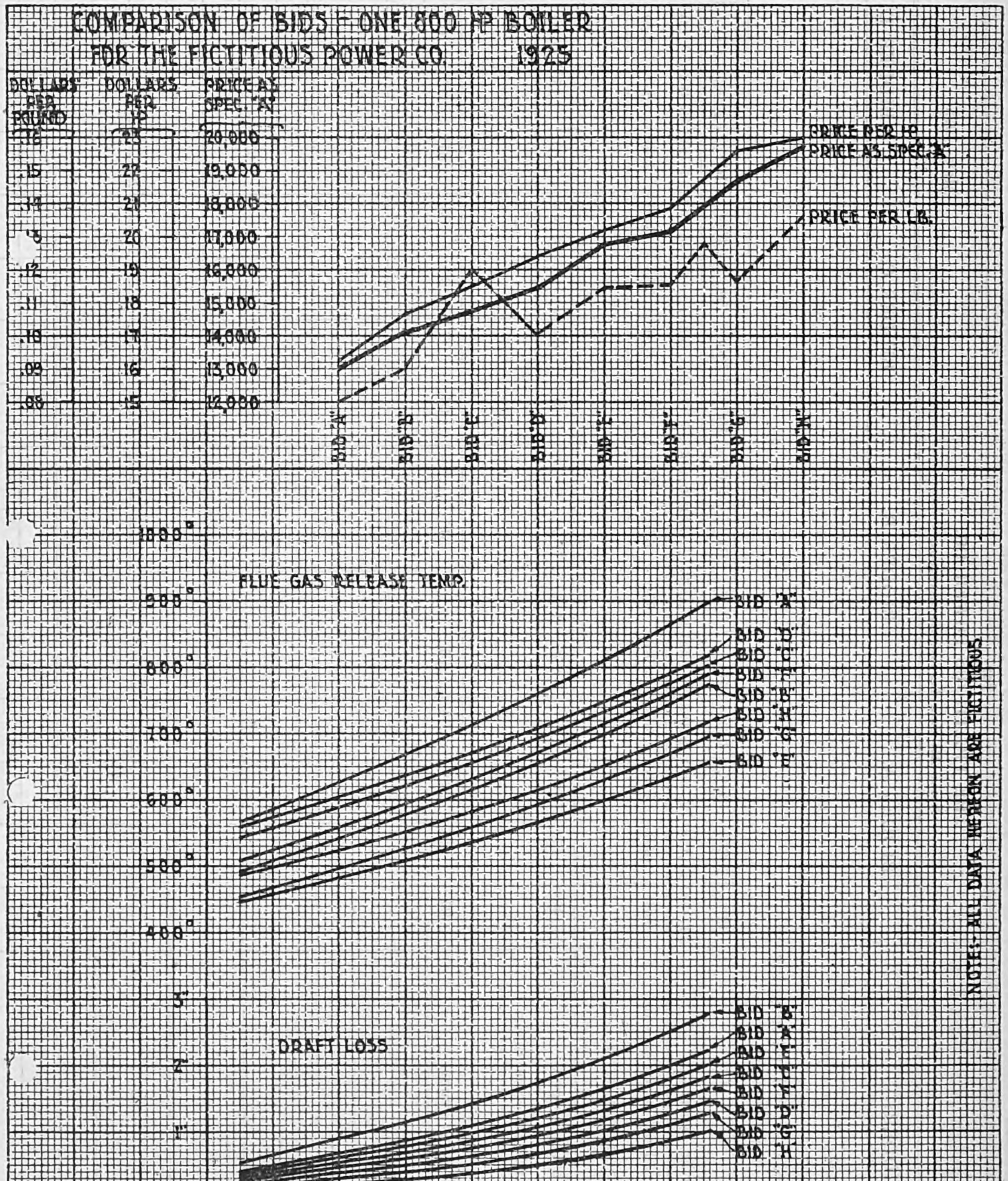
COMPARISON OF BIDS – ONE 800 HP BOILER
FOR THE FICTITIOUS POWER CO. 1925
DOLLARS PER POUND
DOLLARS PER HP
PRICE AS SPEC. "A"
.16
.15
.14
.13
.12
.11
.10
.09
.08
23
22
21
20
19
18
17
16
15
20,000
19,000
18,000
17,000
16,000
15,000
14,000
13,000
12,000
PRICE PER HP
PRICE AS SPEC. "A"
PRICE PER LB.
BID "A"
BID "B"
BID "C"
BID "D"
BID "E"
BID "F"
BID "G"
BID "H"
FLUE GAS RELEASE TEMP.
1000°
900°
800°
700°
600°
500°
400°
BID "A"
BID "D"
BID "C"
BID "F"
BID "B"
BID "H"
BID "G"
BID "E"
DRAFT LOSS
3"
2"
1"
0"
BID "B"
BID "A"
BID "E"
BID "C"
BID "F"
BID "D"
BID "G"
BID "H"
20
30
40
50
60
70
80
90
100
THOUS. LB. WATER EVAP. PER. HR.
100
200
300
400
APPROX. RATING PERCENT
NOTES:- ALL DATA HEREON ARE FICTITIOUS

FIG. 5.

STANDARDS FOR USE IN DESIGN AND OPERATION OF MECHANICAL POWER PLANT EQUIPMENT

There are in more or less general use throughout the country, a large number of standards which have been formulated by various groups interested in the standardization of equipment or commodities. The accompanying Numerical List and Alphabetical Index of Standards have been compiled especially for the use of engineers interested in the design or operation of the mechanical equipment of power plants. In the present instance standards have been selected from those promulgated by several of the national bodies whose standardization work is most generally recognized and which seems to best cover the equipment and material in question.

American Standards Association

This organization was formed in 1918, as the American Engineering Standards Committee, for the purpose of unifying engineering and industrial standards along national lines.

The personnel of the Standards Council consists of representatives of the group of national organizations known as member-bodies. The functions of the Council are to formulate rules for the development of standards and for the constitution of committees; to approve, on behalf of the Association, such standards as it may find to be supported by a consensus, affirmatively expressed, of those substantially concerned with the standard; but not to formulate standards.

Sectional Committees are made up of representatives designated by the various bodies concerned with the project assigned to the committee and of additional specially qualified individuals. The actual formulation of a standard which is later to be approved by the American Standards Association, rests with the Sectional Committee. Sectional Committees may be established under the administrative support and direction of one or more of the bodies principally concerned, known as sponsors, or they may function autonomously with certain limitations.

Most of the departments of the Federal Government, national engineering societies and national industrial associations, as well as many industrial corporations and individual manufacturers, are actively cooperating with the Association. A most comprehensive program has been adopted whereby the standardization work of the many bodies concerned is being broadened and unified into a system of national industrial standards. The fundamental principle is that approval by the A. S. A. shall mean that a real national consensus has been reached.

Those of the standards officially approved and issued by the Association, which are pertinent, have been included in the accompanying list.

American Society for Testing Materials

Since its organization in 1898, this Society has built up a series of standard specifications, standard methods and recommended practices which have been very generally accepted. The Society is most actively identified with the work of the American Standards Association and a number of its standards have already received the approval of and have been issued by the Association.

As there are still many A. S. T. M. standards which have not yet been passed upon by the A. S. A., all those issued by the Society that apply to material required in the design or operation of the mechanical part of a power plant, have been included in the accompanying list.

The American Society of Mechanical Engineers

This Society has formulated and issued a number of rules and codes, as well as various standards, dealing with mechanical equipment. Those pertaining to power plants have been included in the accompanying list.

The Society is cooperating to the fullest extent with the American Standards Association and a number of its standards have already been adopted by the Association.

Federal Specifications Board

This Board, organized in 1921, and operating under the authority of the Bureau of the Budget, is composed of representatives of each of the purchasing units of the U. S. Government, the Chairman of the Board being the Director of the Bureau of Standards, ex officio. Its function is to unify the specifications of the many purchasing branches of the Government and to bring its specifications into harmony with the best commercial practice so as to broaden the field of supply. Cooperative arrangements between the Board and the A. S. A. have been made, whereby the Government specifications are being submitted, at first informally, for criticism by industry and to determine their acceptability to industry, and finally for approval as American Standards.

Those U. S. Government master specifications promulgated by the Board, which apply to mechanical power plant materials, have been included in the accompanying compilation. It is to be noted that in many instances these specifications, in addition to the F. S. B. number, bear also the circular number of the Bureau of Standards.

Bureau of Standards

The Bureau, as reorganized in 1927, now has a branch known as the Commercial Standards Group. This group is composed of (1) the Division of Simplified Practice, organized in 1921, whose function is the reduction of industrial waste through the elimination of unnecessary diversity in sizes, types, styles and other varieties of manufactured products; (2) a new Division of Specifications; (3) a new

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Publication No. 289-50. Serial Report, Prime Movers Committee.

Commercial Standards Unit. The detailed functions of the two new divisions have not yet been announced, but apparently specifications issued by the Federal Specifications Board will be used as a principal means through which the Bureau will enter the field of industrial standardization.

Utilization of Standards

In utilizing these selected standards, it is suggested that, where possible, preference be given to those officially approved and issued by the A. S. A. For this reason, these are listed first under each item in the Alphabetical Index. In cases where no A. S. A. standards have yet been adopted, or where those already adopted do not cover the situation, standards issued by the A. S. T. M., the A. S. M. E. or the F. S. B. can be used.

The following abbreviations are used:

A. S. A. —American Standards Association.
A. S. T. M.—American Society for Testing Materials.
A. S. M. E.—The American Society of Mechanical Engineers.
F. S. B. —Federal Specifications Board.
B. of S. —Bureau of Standards.
B. of M. —Bureau of Mines.
Std. —Standard.
Tent. —Tentative.
Spec. —Specification.
Def. —Definition.
Rec. —Recommended.
Cir. —Circular.

How to Obtain Standards

For the guidance of those desiring to obtain copies of the various standards or more complete information on standardization, the following directions are given:

American Standards Association

Copies of American Engineering and Industrial Standards, officially approved by the A. S. A. are for sale at cost by the A. S. A. are for sale at cost by the American Standards Association, 29 West Thirty-ninth Street, New York, N. Y. A list of these approved standards, with prices, is issued periodically by the Association and can be obtained on application.

The Association has also arranged to act as a central distributing agent for the specifications of the national technical societies, trade associations, and the nineteen foreign standardizing bodies for the convenience of those who may wish to secure copies of these specifications from one rather than several sources.

A Year Book of the A. S. A. is issued annually. This contains a list of all projects which have an official status before the Association as well as various information regarding the work of the Association and standardization in general. The names and addresses of local Association representatives are also given.

American Society for Testing Materials

There is issued, as of September 1st each year, a pamphlet containing a complete list of A. S. T. M. Standards and Tentative Standards, as well as price list of the Society's publications. Copies of this may be had by application to the American Society for Testing Materials, 1315 Spruce Street, Philadelphia, Pa. Standards may be obtained individually at 25 cents per copy, or collectively in book form at prices given in price list.

The American Society of Mechanical Engineers

The A. S. M. E. issues periodical lists of the Society's publications with prices. These lists may be obtained by addressing the American Society of Mechanical Engineers, 29 West Thirty-ninth Street, New York, N. Y.

Federal Specifications Board

An Alphabetical Index and Numerical List of United States Government Master Specifications promulgated by the F. S. B. are issued annually by the Department of Commerce, as Circular of the Bureau of Standards No. 319, and may be obtained by addressing the Superintendent of Documents, Government Printing Office, Washington, D. C.

Specifications bearing only a Federal Specifications Board number are in mimeograph form and can be obtained, free upon request, from the Federal Specifications Board, care of Bureau of Standards, Washington, D. C.

Specifications bearing Bureau of Standards circular numbers or other bureau publication numbers in addition to the F. S. B. numbers are in printed form and must be purchased direct from the Superintendent of Documents. Orders for specifications must state the bureau publication numbers and must be addressed, accompanied by cash or money order, to the Superintendent of Documents, Government Printing Office, Washington, D. C. With a few exceptions noted in the published list, the price of each printed specification is 5 cents per copy.

Bureau of Standards

The Department of Commerce, Bureau of Standards issued, as Miscellaneous Publications No. 65, August 28, 1925, a National Directory of Commodity Specifications. This directory contains classified and alphabetical lists together with brief description of the then existing commodity specifications formulated not only by the public purchasing agencies throughout the United States, but also by the nationally recognized trade associations, technical societies and public utilities.

The directory may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., at the price of $1.25.

The Department of Commerce also issues annually, as Bureau of Standards Miscellaneous Publication No. 83, a Standards Yearbook. This publication deals with the general subject of standardization both in this country and abroad. Copies may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., at the price of $1.00 each.

NUMERICAL LIST OF STANDARDS RELATING TO MECHANICAL EQUIPMENT OF POWER PLANTS

American Standards Association—American Engineering and Industrial Standards

Standard No.
A 14-1923—Ladders, Safety Code.
A 17-1925—Elevators and Escalators, Safety Code.

B 1a-1924—Screw Threads for Bolts, Machine Screws, Nuts and Commercially Tapped Holes.
B 2-1919—Pipe Thread.
B 4a-1925—Tolerances and Allowances for Machined Fits in Interchangeable Manufacture.
B 6b-1927—Tooth Form of Spur Gears.
B 15-1927—Power Transmission Apparatus, Mechanical, Safety Code.
B 16a-1928—Cast Iron Flanges and Flanged Fittings for Maximum Pressures of 125 lb.
B 16b-1928—Cast Iron Flanges and Flanged Fittings for Maximum Pressures of 250 lb.
B 16c-1927—Malleable Iron Screwed Fittings for Maximum Pressures of 150 lb.
B 16d-1927—Cast Iron Screwed Fittings for Maximum Pressures of 125 and 250 lb.
B 16e-1927—Steel Flanges and Flanged Fittings for Maximum Pressures of 250, 400, 600, 900 and 1350 lb.
B 17a-1924—Diameters and Lengths of Cold-Finished Shaftings.
B 17b-1925—Keys, Square and Flat Stock, Widths and Heights.
B 17c-1927—Design of Transmission Shafting, Code.
B 17d-1927—Keys, Plain Taper Stock, Square and Flat.
B 17e-1927—Keys, Gib Head, Taper Stock, Square and Flat.
B 18a-1927—Small Rivets.
B 18b-1927—Wrench Head Bolts and Nuts and Wrench Openings.
B 18e-1928—Round Unslotted Head Bolts.
G 9-1924—Forgings, Carbon-Steel and Alloy-Steel Blooms, Billets and Slabs for, Specifications.
G 12-1923—Bars, Refined, Wrought-Iron, Specifications.
G 13-1923—Plates, Wrought-Iron, Specifications.
H 7-1925—Brass Forging Rod, Specifications.
H 8-1925—Brass Rod, Free-Cutting for Use in Screw Machines, Specifications.
H 10-1924—Ingot Metal, Brass, for Sand Castings, Specifications.
K 3-1921—Manganese Bronze, Methods of Chemical Analysis.
K 5-1922—Alloys of Lead, Tin, Antimony and Copper, Chemical Analysis.
K 8-1923—Liquids, Volatile, Flammable, Method of Test for Flash Point.
K 12-1921—Copper, Methods for Battery Assay.
X 1-1921—Coal, Method of Sampling.
Z 11a-1928—Standard Abridged Volume Correction Table for Petroleum Oils.
Z 11b-1928—Viscosity of Petroleum Products and Lubricants.
Z 11c-1928—Penetration of Greases and Petrolatum.
Z 11e-1928—Cloud and Pour Points of Petroleum Products.
Z 11f-1928—Flash and Fire Points by Means of Open Cup.
Z 11g-1928—Flash Point by Means of the Pensky-Martens Closed Tester.
Z 11l-1928—Neutralization Number of Petroleum Products and Lubricants.
Z 11m-1928—*Sulfur* in Petroleum Oils Heavier Than Illuminating Oil.
Z 11n-1928—Thermal Value of Fuel Oil.
Z 11p-1928—Standard Method of Analysis of Grease.
Z 12a-1927—Installation of Pulverized Fuel Systems, Safety Code.

American Society for Testing Materials—Standards and Tentative Standards

Standard No.
*A 17-21—Std. Spec. for Carbon-Steel and Alloy-Steel Blooms, Billets, and Slabs for Forgings.
A 18-28—Std. Spec. for Carbon-Steel and Alloy-Steel Forgings.
A 27-24—Std. Spec. for Steel Castings.
A 31-24—Std. Spec. for Boiler Rivet Steel.
A 33-24—Std. Methods of Chemical Analysis of Plain Carbon-Steel.
A 33-28T—Tent. Methods of Sampling Rolled and Forged Steel Products for Check Analysis.
A 35-24—Rec. Practice for Annealing of Miscellaneous Rolled and Forged Carbon-Steel Objects.
A 36-24—Rec. Practice for Heat Treatment of Carbon-Steel Castings.
A 37-27—Rec. Practice for Carburizing and Heat Treatment of Carburized Objects.
*A 41-18—Std. Spec. for Refined Wrought-Iron Bars.
*A 42-18—Std. Spec. for Wrought-Iron Plates.
A 43-24—Std. Spec. for Foundry Pig Iron.
A 44-04—Std. Spec. for Cast-Iron Pipe and Special Castings.
A 47-27—Std. Spec. for Malleable Castings.
A 48-18—Std. Spec. for Gray-Iron Castings.
A 53-27—Std. Spec. for Welded and Seamless Steel Pipe.
A 55-24—Std. Methods of Chemical Analysis of Alloy Steels.
A 58-27—Std. Spec. for Carbon-Steel Bars for Vehicle and General Purpose Springs.
A 64-27—Std. Methods of Sampling and Chemical Analysis of Pig and Cast Iron.
A 70-27—Std. Spec. for Boiler and Firebox Steel for Stationary Service.
A 72-27—Std. Spec. for Welded Wrought-Iron Pipe.
A 78-27—Std. Spec. for Steel Plates of Structural Quality for Forged Welding.
A 81-27—Std. Def. of Terms Relating to Wrought-Iron Specifications.
A 83-27—Std. Spec. for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes.
A 84-27—Std. Spec. for Staybolt, Engine-Bolt and Extra Refined Wrought-Iron Bars.
A 85-27—Std. Spec. for Common Iron Bars.
A 86-27—Std. Spec. for Hollow Rolled Staybolt Iron.
A 88-24—Std. Spec. for High-Test Gray-Iron Castings.
A 89-27—Std. Spec. for Steel Plates of Flange Quality for Forge Welding.
A 95-28T—Tent. Spec. for Carbon-Steel Castings for Valves, Flanges and Fittings for High-Temperature Service.
A 96-27—Std. Spec. for Alloy-Steel Bolting Material for High-Temperature Service.
A 105-28—Std. Spec. for Forged or Rolled Steel Pipe Flanges for High-Temperature Service.
A 106-28T—Tent. Spec. for Lap-Welded and Seamless Steel Pipe for High-Temperature Service.
A 107-27—Std. Spec. for Commercial Quality Hot-Rolled Bar Steels.
A 108-27—Std. Spec. for Commercial Cold-Finished Bar Steels and Cold Finishing Shafting.
A 119-28T—Tent. Definitions of Terms Relating to Heat Treatment Operations (Especially as Related to Ferrous Alloys).
A 120-28T—Tent. Spec. for Lap-Welded and Seamless Steel Pipe, Black and Galvanized, for Ordinary Uses.
A 124-28T—Tent. Spec. for the Arbitration Test Bar and Tension Test Specimen for Cast Iron.
B 4-27—Std. Spec. for Lake Copper Wire Bars, Cakes, Slabs, Billets, Ingots and Ingot Bars.
B 5-27—Std. Spec. for Electrolytic Copper Wire Bars, Cakes, Slabs, Billets, Ingots and Ingot Bars.

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* Approved by the American Standards Association.

Standard No.
B 7-27—Std. Spec. for Manganese-Bronze Ingots for Sand Castings.
B 10-18—Std. Spec. for the Alloy: Copper, 88 per cent; Tin, 10 per cent; Zinc, 2 per cent.
B 13-18—Std. Spec. for Seamless Copper Boiler Tubes.
B 14-18—Std. Spec. for Seamless Brass Boiler Tubes.
*B 15-18—Std. Spec. for Brass Forging Rod.
*B 16-18—Std. Spec. for Free-Cutting Brass Rod for Use in Screw Machines.
*B 18-21—Std. Methods of Chemical Analysis of Alloys of Lead, Tin, Antimony and Copper.
B 23-26—Std. Spec. for White Metal Bearing Alloys (known commercially as "Babbitt Metal").
*B 27-19—Std. Methods of Chemical Analysis of Manganese Bronze.
B 30-28T—Tent. Spec. for Brass Ingot Metal, Graded and Ungraded, for Sand Castings.
B 31-21—Std. Spec. for Bronze Bearing Metal in Ingot Form.
*B 34-20—Std. Methods of Battery Assay of Copper.
B 39-22—Std. Spec. for Nickel.
B 41-23—Std. Methods of Chemical Analysis of Nickel.
B 42-24—Std. Spec. for Copper Pipe, Standard Sizes.
B 43-24—Std. Spec. for Brass Pipe, Standard Sizes.
B 44-24—Std. Spec. for Seamless Admiralty Condenser Tubes and Ferrule Stock.
B 45-27—Std. Methods of Chemical Analysis of Brass Ingots and Sand Castings.
B 46-27—Std. Methods of Chemical Analysis of Bronze Bearing Metal.
B 54-27—Std. Spec. for Manganese-Bronze Sand Castings.
B 55-25—Std. Spec. for Seamless 70-30 Brass Condenser Tubes and Ferrule Stock.
B 56-25—Std. Spec. for Seamless Muntz Metal Condenser Tubes and Ferrule Stock.
B 57-27—Std. Spec. for Muntz Metal Condenser Tube Plates.
B 60-28—Std. Spec. for Sand Castings of the Alloy: Copper, 88 per cent; Tin, 8 per cent; Zinc, 4 per cent.
B 61-28—Std. Spec. for Steam or Valve Bronze Sand Castings.
B 62-28—Std. Spec. for Composition Brass or Ounce Metal Sand Castings.
B 65-28—Std. Spec. for Yellow Brass Sand Castings for General Purposes.
B 72-28T—Tent. Spec. for Fire-Refined Copper Other Than Lake.
B 74-28T—Tent. Spec. for Sand Castings of the Alloy: Copper, 80 per cent; Tin, 10 per cent; Lead, 10 per cent.
B 75-28T—Tent. Spec. for Seamless Copper Tubes.

C 16-20—Std. Method of Test for Refractory Materials Under Load at High Temperatures.
C 18-21—Std. Methods of Ultimate Chemical Analysis of Refractory Materials, Including Chrome Ores and Chrome Brick.
C 20-20—Std. Method of Test for Porosity and Permanent Volume Changes in Refractory Materials.
C 24-28—Std. Method of Test for Softening Point of Fire-Clay Brick.
C 25-27T—Tent. Methods of Chemical Analysis of Limestone, Quicklime and Hydrated Lime.
C 27-28—Std. Def. for Clay Refractories.
C 38-27T—Tent. Method of Test for Resistance of Fire-Clay Brick to Thermal Spalling Action.
C 49-24—Std. Spec. for Quicklime and Hydrated Lime for the Manufacture of Silica Brick.
C 50-27—Std. Methods of Sampling, Inspection, Packing and Marking of Quicklime and Lime Products.
C 51-28—Std. Def. of Terms Relating to Lime.
C 53-27—Std. Spec. for Quicklime for Use in Water Treatment.
C 54-27—Std. Spec. for Hydrated Lime for Use in Water Treatment.

Standard No.
C 55-28T—Tent. Spec. for Concrete Building Brick.
C 62-28T—Tent. Spec. for Building Brick (Made from Clay or Shale).
C 64-28—Std. Spec. for Clay Fire Brick for Stationary Boiler Service.
C 67-28T—Tent. Methods of Testing Brick.
C 71-28—Std. Def. of Terms Relating to Refractories.
C 71-28T—Tent. Def. of Terms Relating to Refractories.
C 73-28T—Tent. Spec. for Sand-Lime Building Brick.

D 13-26—Std. Spec. for Gum Spirits of Turpentine and Steam-Distilled Wood Turpentine.
D 15-24—Std. Method of Testing Rubber Products.
D 16-24—Std. Def. of Terms Relating to Paint Specifications.
*D 21-16—Std. Method of Sampling Coal.
D 34-27—Std. Methods of Routine Analysis of White Pigments.
D 46-24—Std. Spec. for Wrapped Air Hose for Use with Pneumatic Tools.
D 49-28—Std. Methods of Routine Analysis of Dry Red Lead.
D 54-24T—Tent. Spec. for Steam Hose.
D 56-21—Std. Method of Test for Flash Point of Volatile Flammable Liquids.
D 60-24—Std. Spec. for Braided Air Hose for Use with Pneumatic Tools.
D 79-24—Std. Spec. for Zinc Oxide.
D 80-24—Std. Spec. for Leaded Zinc Oxide.
D 81-24—Std. Spec. for Basic Carbonate White Lead.
D 82-24—Std. Spec. for Basic Sulfate White Lead.
D 83-24—Std. Spec. for Red Lead.
D 84-27—Std. Spec. for Mineral Iron Oxide.
*D 88-26—Std. Methods of Test for Viscosity of Petroleum Products and Lubricants.
D 91-21T—Tent. Method of Test for Precipitation Number of Lubricating Oils.
*D 92-24—Std. Method of Test for Flash and Fire Points by Means of Open Cup.
*D 93-22—Std. Method of Test for Flash Point by Means of the Pensky-Martens Closed Tester.
D 94-28—Std. Method of Test for Saponification Number.
D 95-28—Std. Method of Test for Water in Petroleum Products and Other Bituminous Materials.
D 96-28—Std. Method of Test for Water and Sediment in Petroleum Products by Means of Centrifuge.
*D 97-28—Std. Method of Test for Cloud and Pour Points of Petroleum Products.
D 121-27—Std. Def. of Terms Relating to Coal and Coke.
D 121-27T—Tent. Def. of Terms Relating to Coal and Coke.
*D 128-27—Std. Method of Analysis of Grease.
*D 129-27—Std. Method of Test for Sulfur in Petroleum Oils Heavier Than Illuminating Oil.
D 151-23—Std. Spec. for Rubber Pump Valves.
D 154-28—Std. Methods of Testing Oleo-Resinous Varnishes.
D 155-23T—Tent. Method of Test for Color of Lubricating Oils by Means of Union Colorimeter.
D 157-28 Std. Method of Test for Steam Emulsion of Lubricating Oils.
D 177-24—Std. Spec. for Wrapped Cold Water Hose.
D 182-25—Std. Spec. for A.S.T.M. Partial-Immersion Thermometer for General Use, —20 to +150 deg. cent., 0 to +300 deg. fahr.
D 183-25—Std. Spec. for A.S.T.M. Partial-Immersion Thermometer for General Use, —5 to +300 deg. cent., +20 to +580 deg. fahr.
D 184-25—Std. Spec. for A.S.T.M. Partial-Immersion Thermometer for General Use, —5 to +400 deg. cent., +20 to +760 deg. fahr.
*D 188-27T—Tent. Method of Test for Neutralization Number of Petroleum Products and Lubricants.
D 189-28—Std. Method of Test for Carbon Residue of Petroleum Products (Conradson Carbon Residue).
D 197-26T—Tent. Method of Test for Fineness of Powdered Coal.

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*Approved by the American Standards Association.

Standard No.
*D 206-25—Std. Abridged Volume Correction Table for Petroleum Oils.
D 215-28T—Tent. Methods of Routine Analysis of White Linseed Oil Paints.
*D 217-27T—Tent. Method of Test for Penetration of Greases and Petrolatum.
D 233-26—Std. Methods of Sampling and Testing Turpentine.
D 234-28—Std. Spec. for Raw Linseed Oil.
D 235-26T—Tent. Spec. for Petroleum Spirits (Mineral Spirits).
D 236-27—Std. Spec. for Destructively Distilled Wood Turpentine.
*D 240-27—Std. Method of Test for Thermal Value of Fuel Oil.
D 260-28T—Tent. Spec. for Boiled Linseed Oil.
D 266-28T—Tent. Spec. for Aluminum Powder for Paints (Aluminum Bronze Powder).
D 267-28T—Tent. Spec. for Gold Bronze Powder.
D 270-27T—Tent. Methods of Sampling Petroleum and Petroleum Products.
D 271-27—Std. Methods of Laboratory Sampling and Analysis of Coal and Coke.
D 271-27T—Tent. Methods for the Determination of Sulfur in Coal and Coke by the Bomb-Washing and Sodium Peroxide Fusion Methods.
D 277-28T—Tent. Spec. for the Toxic Ingredients in Anti-Fouling Paints.
D 286-28T—Tent. Method of Test for the Termination of Autogenous Ignition Temperatures.
D 287-28T—Tent. Method of Test for Gravity of Petroleum and Petroleum Products by Means of the Hydrometer.
D 288-28T—Tent. Def. of Terms Relating to Petroleum.
D 291-28T—Tent. Method of Test for Cubic Foot Weight of Crushed Bituminous Coal.
D 297-28T—Tent. Methods of Chemical Analysis of Rubber Products.

E 2-27—Std. Rules Governing the Preparation of Micrographs of Metals and Alloys, Including Recommended Practice for Photography as Applied to Metallography.
E 3-24—Std. Methods of Metallographic Testing of Iron and Steel.
E 5-27—Std. Methods of Metallographic Testing of Non-Ferrous Metals and Alloys.
E 6-25T—Tent. Def. of Terms Relating to Methods of Testing.
E 7-27—Std. Def. of Terms Relating to Metallography.
E 8-27T—Tent. Methods of Tension Testing of Metallic Materials.
E 9-27T—Tent. Methods of Compression Testing of Metallic Materials.
E 10-27—Std. Methods of Brinell Hardness Testing of Metallic Materials.
E 14-25T—Tent. Rec. Practice for Thermal Analysis of Steel.
E 15-26T—Tent. Rec. Practice for Radiographic Testing of Metal Castings.

The American Society of Mechanical Engineers Codes and Standards

Construction and Operation Codes
- Boiler Construction Code.
- Suggested Rules for Care of Power Boilers.
- Rules for the Construction of Unfired Pressure Vessels.
- Safety Code for Elevators.
- Safety Code for Mechanical Power Transmission Apparatus.
- *Code for Design of Transmission Shafting.
- Code on Instruments and Apparatus, Part 1, General Considerations.

Power Test Codes
- Definitions and Values.
- General Instructions.
- Centrifugal and Rotary Pumps.
- Condensing Apparatus.
- Displacement Compressors and Blowers.
- Evaporating Apparatus.
- Feedwater Heaters.
- Reciprocating Steam-Driven Displacement Pumps.
- Reciprocating Steam Engines.
- Solid Fuels.
- Speed Responsive Governors.
- Stationary Steam Boilers.
- Steam Turbines.
- Fan Section.

Standards
- *Tolerances, Allowances and Gages for Metal Fits.
- *American Standard Screw Threads for Bolts, Machine Screws, Nuts and Commercially Tapped Holes.
- Standardization of Shafting.
  - a. *Shafting Diameters.
  - b. *Square and Flat Stock Keys.
  - c. *Plain Taper Stock Keys.
  - d. *Gib Head Taper Stock Keys.
- *Spur Gear Tooth Form.
- *Small Rivets.
- *Wrench Head Bolts and Nuts and Wrench Openings.
- American Standards for Pipe Flanges and Fittings.
  - a. *Steel Pipe Flanges and Flanged Fittings for maximum working steam pressures of 250, 400, 600, 900 and 1350 lb. per sq. in.
  - b. *Cast Iron Pipe Flanges and Flanged Fittings, all sizes for maximum working saturated steam pressures of 125 and 250 lb. per sq. in.
  - c. *Cast Iron Screwed Fittings, for maximum working saturated steam pressures of 125 and 250 lb. per sq. in.
  - d. *Malleable Iron Screwed Fittings, for maximum working saturated steam pressures of 150 lb. per sq. in.
- Bibliography on Mechanical Springs.

Federal Specifications Board—United States Government Master Specifications

F.S.B. Spec. No.	B. of S. Cir. No.	
2d	†	Lubricants and liquid fuels and methods for sampling and testing.
4b	C82	Linseed oil, raw.
5	C84	Basic carbonate white lead, dry and paste.
6	C85	Basic sulphate white lead, dry and paste.
7b	C86	Turpentine (gum spirits of turpentine and steam-distilled wood turpentine).
8	C87	Zinc oxide, dry and paste.
9	C88	Leaded zinc oxide, dry and paste.
10b	C89	White paint and tinted paints made on a white base, semi-paste and ready mixed.
11	C90	Red lead, dry and paste.
13b	C93	Iron oxide and iron hydroxide paints.
14b	C94	Black paint, semi-paste and ready mixed.
15	C97	Green paint, semi-paste and ready mixed.
16	C98	Volatile mineral spirits for thinning paints.
17	C102	Composite vehicle for thinning semi-paste paints when the use of straight linseed oil is not justified.
18b	C103	Spar varnish, water resisting.
19	C104	Asphalt varnish.
20	C105	Liquid paint drier.
37	C148	Leather belting.
40b	C290	Gas hose.
41b	C307	Pneumatic hose.
48b	C291	Water and wash deck hose.
49b	C268	Steam hose.
50a	C292	Water suction hose (smooth bore).
57	...	Flexible non-metallic tubing.

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†Bureau of Mines Technical Paper No. 323B.

F.S.B. Spec. No.	B. of S. Cir. No.	
59a	C232	General specifications for rubber goods (methods of physical tests and chemical analysis).
63b	C209	Oil hose, suction and discharge.
66	C146	Water-resisting red enamel.
89	...	Manganese bronze ingots (for remelting).
93	...	Corrugated asbestos-copper gaskets.
94b	C243	Asbestos metallic cloth sheet packing.
95	...	Asbestos valve-stem packing.
96c	...	Compressed asbestos sheet packing.
97b	C242	Asbestos metallic cloth gaskets.
98a	C240	Diaphragm packing.
99	...	Fabric condenser-tube packing.
100	...	Fiber packing for lubricating and fuel oil.
101c	...	Flax packing.
102	...	Flexible metallic packing.
103a	C238	Asbestos high-pressure rod packing.
104a	C237	Low-pressure spiral-gland packing.
105	...	Metallic packing (fixed-ring type).
106	...	Plastic metallic packing.
107	...	Semi-metallic packing.
108	...	Solid metallic packing (floating-ring type).
110a	C236	Cloth-insertion rubber packing.
111a	C235	Rubber packings and gaskets (molded, sheet and strip).
112a	C234	Wire-insertion rubber packing.
113a	C233	Tucks packing.
114a	C244	Rubber valves.
120	...	Ingot copper.
126a	...	Foundry pig iron.
137a	C165	Olive-drab paint, semi-paste and ready mixed.
140	...	High-test gray-iron castings (semi-steel).
141	...	Gray-iron castings.
158	...	Hair felt.
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170	...	Steel castings.
172a	...	Bronze castings.
174	...	Welding wire, iron and steel.
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211	...	Magnesia-asbestos plaster.
212	...	Magnesia molded pipe covering and blocks.
238	...	Pipe threads.
239	C200	Heavy rust-preventive compound.
242	...	Welded wrought iron pipe (black and galvanized).
259a	C261	Cotton rags, colored, for wiping machinery (sterilized).
261a	C264	Cotton rags, white, for wiping machinery (sterilized).
262a	C262	Cotton waste, white.
263a	C263	Cotton waste, colored.
264a	C260	Wool waste, colored.
268a	C299	Fire-clay brick.
269	...	Welding rods, non-ferrous, for gas welding.
272	...	Brass castings, naval and commercial.
286	...	Brass castings to be brazed.
287	...	Seamless copper tubing and pipe, standard iron pipe size.
290a	...	Bronze ingots (for remelting).
293	C214	Medium and light rust-preventive compounds.
314	...	Railroad track scales.
316	...	Steel blooms, billets, slabs and bars, for reforging, carbon and alloy.
334a	C298	Fire clay.
335a	C297	Plastic fire-clay refractories.
339	...	General specification for metals.
342a	...	Seamless brass pipe, iron pipe size, standard and extra strong.
347	...	Lapwelded and seamless steel boiler tubes.
349	...	Lapwelded charcoal iron boiler tubes.
370	...	Manganese bronze castings.
371	...	Nickel (for remelting).
374	...	Admiralty metal condenser tubes and tubes for ferrule stock.
378a	...	Malleable iron castings.
388	...	Emery cloth.
391	...	Refined wrought iron bar.
392	...	Brass rods, bars, shapes, plates, sheets and strips, commercial.
393	...	Malleable iron or steel unions.
427	...	Seamless brass tubing.
429	C314	Soda ash.
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486	C335	Hard fiber sheet packing.
487	C334	Asbestos wick and rope packings.
489	...	Cast-iron pipe fittings (threaded).
496	C340	Hydraulic leather packing (vegetable tanned).
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505	C347	Common sand-lime brick.
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552	...	Manganese bronze rods, bars, shapes and plates.
578	...	Copper castings, nickel alloy.

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    A.S.M.E.—Stationary Steam Boilers, Power Test Code.
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A.S.T.M. C16-20—Std. Method of Test for Refractory Materials Under Load at High Temperatures.
A.S.T.M. C18-21—Std. Methods of Ultimate Chemical Analysis of Refractory Materials, Including Chrome Ores and Chrome Bricks.
A.S.T.M. C20-20—Std. Method of Test for Porosity and Permanent Volume Changes in Refractory Materials.
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A.S.T.M. C27-28—Std. Def. for Clay Refractories.
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A.S.T.M. C55-28T—Tent. Spec. for Concrete Building Brick.
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A.S.T.M. C64-28—Std. Spec. for Clay Fire Brick for Stationary Boiler Service.
A.S.T.M. C67-28T—Tent. Methods of Testing Brick.
A.S.T.M. C71-28—Std. Def. of Terms Relating to Refractories.
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F.S.B. 334a—Fire Clay (B. of S. Cir. No. C298).
F.S.B. 335a—Plastic Fire-Clay Refractories (B. of S. Cir. No. C297).
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A.S.T.M. A36-24—Rec. Practice for Heat Treatment of Carbon-Steel Castings.
A.S.T.M. A44-04—Std. Spec. for Cast-Iron Pipe and Special Castings.
A.S.T.M. A47-27—Std. Spec. for Malleable Castings.
A.S.T.M. A48-18—Std. Spec. for Gray-Iron Castings.
A.S.T.M. A88-24—Std. Spec. for High-Test Gray-Iron Castings.
A.S.T.M. A95-28T—Tent. Spec. for Carbon-Steel Castings for Valves, Flanges and Fittings for High-Temperature Service.
A.S.T.M. B54-27—Std. Spec. for Manganese-Bronze Sand Castings.
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A.S.T.M. B61-28—Std. Spec. for Steam or Valve Bronze Sand Castings.
A.S.T.M. B62-28—Std. Spec. for Composition Brass or Ounce Metal Sand Castings.
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A.S.T.M. B74-28T—Tent. Spec. for Sand Castings of the Alloy: Copper, 80 per cent; Tin, 10 per cent; Lead, 10 per cent.
A.S.T.M. E15-26T—Tent. Rec. Practice for Radiographic Testing of Metal Castings.
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A.S.T.M. A124-28T—Tent. Spec. for the Arbitration Test Bar and Tension Test Specimen for Cast Iron.
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A.S.T.M. C50-27—Std. Methods of Sampling, Inspection, Packing and Marking of Quicklime and Lime Products.
A.S.T.M. C51-28—Std. Def. of Terms Relating to Lime.
A.S.T.M. C53-27—Std. Spec. for Quicklime for Use in Water Treatment.
A.S.T.M. C54-27—Std. Spec. for Hydrated Lime for Use in Water Treatment.
F.S.B. 429—Soda Ash (B. of S. Cir No. C314).
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A.S.A. Z12a-1927—Investigation of Pulverized Fuel Systems, Safety Code.
A.S.T.M. *D21-16—Std. Method of Sampling Coal.
A.S.T.M. D121-27—Std. Def. of Terms Relating to Coal and Coke.
A.S.T.M. D121-27T—Tent. Def. of Terms Relating to Coal and Coke.
A.S.T.M. D197-26T—Tent. Method of Test for Fineness of Powdered Coal
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A.S.T.M. D271-27T—Tent. Methods for the Determination of Sulfur in Coal and Coke by the Bomb-Washing and Sodium Peroxide Fusion Methods.
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- Engines
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  - A.S.T.M. A18-28—Std. Spec. for Carbon-Steel and Alloy-Steel Forgings
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  - A.S.M.E ......—*Tolerances, Allowances and Gages for Metal Fits.
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  - F.S.B. 102 —Flexible metallic packing.
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  - F.S.B. 104a—Low-pressure spiral-gland packing (B. of S. Cir. No. C237).
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  - F.S.B. 485 —Metallic encased gaskets (B. of S. Cir. No. C336).
  - F.S.B. 486 —Hard fiber sheet packing (B. of S. Cir. No. C335).
  - F.S.B. 487 —Asbestos wick and rope packings (B. of S. Cir No. C334).
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  - F.S.B. 212—Magnesia molded pipe covering and blocks.
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  - A.S.T.M. D54-24T—Tent. Spec. for Steam Hose.
  - A.S.T.M. D60-24—Std. Spec. for Braided Air Hose for Use with Pneumatic Tools.
  - A.S.T.M. D177-24—Std. Spec. for Wrapped Cold Water Hose.
  - F.S.B. 40b—Gas Hose (B. of S. Cir. No. C290).
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  - F.S.B. 63b—Oil Hose, Suction and Discharge (B. of S. Cir. No. C209).
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- Ladders
  - A.S.A. A14-1923—Ladders, Safety Code.
- Leather (See Gaskets and Packing and Power Transmission Equipment).
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- Magnesia (See Heat Insulation).
- Malleable Iron Castings (See Castings).
- Malleable Iron Pipe Fittings (See Pipe Flanges and Fittings).
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  - A.S.T.M. E2-27—Std. Rules Governing the Preparation of Micrographs of Metals and Alloys, Including Recommended Practice for Photography as Applied to Metallography.
  - A.S.T.M. E6-25T—Tent. Def. of Terms Relating to Method of Testing.
  - A.S.T.M E7-27—Std. Def. of Terms Relating to Metallography.
  - A.S.T.M. E8-27T—Tent. Methods of Tension Testing of Metallic Materials.
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  - A.S.T.M. E10-27—Std. Methods of Brinell Hardness Testing of Metallic Materials.
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- Non-Ferrous Alloys (See Non-Ferrous Metals).
- Non-Ferrous Castings (See Castings).
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  - A.S.A. H7-1925—Brass Forging Rod, Specifications.
  - A.S.A. H8-1925—Brass Rod, Free-Cutting for Use in Screw Machines, Specifications.
  - A.S.A. H10-1924—Ingot Metal, Brass, for Sand Castings, Specifications.
  - A.S.A. K3-1921—Manganese Bronze, Methods of Chemical Analysis.
  - A.S.A. K5-1922—Alloys of Lead, Tin, Antimony and Copper, Chemical Analysis.
  - A.S.A. K12-1921—Copper, Methods for Battery Assay.
  - A.S.T.M. B4-27—Std. Spec. for Lake Copper Wire Bars, Cakes, Slabs, Billets, Ingots and Ingot Bars.
  - A.S.T.M. B5-27—Std. Spec. for Electrolytic Copper Wire Bars, Cakes, Slabs, Billets, Ingots and Ingot Bars.
  - A.S.T.M. B7-27—Std. Spec. for Manganese-Bronze Ingots for Sand Castings.
  - A.S.T.M. B10-18—Std. Spec. for the Alloy: Copper, 88 per cent; Tin, 10 per cent; Zinc, 2 per cent.

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A.S.T.M. *B15-18—Std. Spec. for Brass Forging Rod.
A.S.T.M. *B16-18—Std. Spec. for Free-Cutting Brass Rod for Use in Screw Machines.
A.S.T.M. *B18-21—Std. Methods of Chemical Analysis of Alloys of Lead, Tin, Antimony and Copper.
A.S.T.M. B23-26—Std. Spec. for White Metal Bearing Alloys (known commercially as "Babbitt Metal").
A.S.T.M. *B27-19—Std. Methods of Chemical Analysis of Manganese Bronze.
A.S.T.M. B30-28T—Tent. Spec. for Brass Ingot Metal, Graded and Ungraded, for Sand Castings.
A.S.T.M. B31-21—Std. Spec. for Bronze Bearing Metal in Ingot Form.
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A.S.T.M. B39-22—Std. Spec. for Nickel.
A.S.T.M. B41-23—Std. Methods of Chemical Analysis of Nickel.
A.S.T.M. B45-27—Std. Methods of Chemical Analysis of Brass Ingots and Sand Castings.
A.S.T.M. B46-27—Std. Methods of Chemical Analysis of Bronze Bearing Metal.
A.S.T.M. B72-28T—Tent. Spec. for Fire-Refined Copper Other Than Lake.
A.S.T.M. E5-27—Std. Methods of Metallographic Testing of Non-Ferrous Metals and Alloys.
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Oils (See Petroleum Products and Lubricants).
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A.S.T.M D16-24—Std. Def. of Terms Relating to Paint Specifications.
A.S.T.M. D34-27—Std. Methods of Routine Analysis of White Pigments.
A.S.T.M. D49-28—Std. Methods of Routine Analysis of Dry Red Lead.
A.S.T.M. D79-24—Std. Spec. for Zinc Oxide.
A.S.T.M. D80-24—Std. Spec. for Leaded Zinc Oxide.
A.S.T.M. D81-24—Std. Spec. for Basic Carbonate White Lead.
A.S.T.M. D82-24—Std. Spec. for Basic Sulfate White Lead.
A.S.T.M. D83-24—Std. Spec. for Red Lead.
A.S.T.M. D84-27—Std. Spec. for Mineral Iron Oxide.
A.S.T.M. D154-28—Std. Methods of Testing Oleo-Resinous Varnishes.
A.S.T.M. D215-28T—Tent. Methods of Routine Analysis of White Linseed Oil Paints.
A.S.T.M. D233-26—Std. Methods of Sampling and Testing Turpentine.
A.S.T.M. D234-28—Std. Spec. for Raw Linseed Oil.
A.S.T.M. D235-26T—Tent. Spec. for Petroleum Spirits (Mineral Spirits).
A.S.T.M. D236-27—Std. Spec. for Destructively Distilled Wood Turpentine.
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A.S.T.M. D266-28T—Tent. Spec. for Aluminum Powder for Paints (Aluminum Bronze Powder).
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F.S.B. 7b—Turpentine (Gum Spirits of Turpentine and Steam-Distilled Wood Turpentine) (B. of S. Cir. No. C86).
F.S.B. 8 —Zinc Oxide, Dry and Paste (B. of S. Cir. No. C87).
F.S.B. 9 —Leaded Zinc Oxide, Dry and Paste (B. of S. Cir. No. C88).
F.S.B. 10b—White Paint and Tinted Paints Made on a White Base, Semi-Paste and Ready Mixed (B. of S. Cir. No. C89).
F.S.B. 11 —Red Lead, Dry and Paste (B. of S. Cir. No. C90).
F.S.B. 13b—Iron Oxide and Iron Hydroxide Paints (B. of S. Cir. No. C93).
F.S.B 14b—Black Paint, Semi-Paste and Ready Mixed (B. of S. Cir. No. C94).
F.S.B. 15 —Green Paint, Semi-Paste and Ready Mixed (B. of S. Cir. No. C97).
F.S.B. 16 —Volatile Mineral Spirits for Thinning Paints (B. of S. Cir. No. C98).
F.S.B. 17 —Composite Vehicle for Thinning Semi-Paste Paints When the Use of Straight Linseed Oil Is Not Justified (B. of S. Cir. No. C102).
F.S.B. 18b—Spar Varnish, Water Resisting (B. of S. Cir. No. C103).
F.S.B. 19 —Asphalt Varnish (B. of S. Cir. No. C104).
F.S.B. 20 —Liquid Paint Drier (B. of S. Cir. No. C105).
F.S.B 66 —Water-Resisting Red Enamel (B. of S. Cir. No. C146).
F.S.B. 137a—Olive-Drab Paint, Semi-Paste and Ready Mixed (B. of S. Cir. No. C165).
F.S.B. 239 —Heavy Rust-Preventive Compound (B. of S. Cir. No. C200).
F.S.B. 293 —Medium and Light Rust-Preventive Compounds (B. of S. Cir. No. C214).
F.S.B. 475b—Linseed Oil, Boiled (B. of S. Cir. No. C330).

Petroleum Products and Lubricants

A.S.A. K8-1923—Liquids, Volatile, Flammable, Method of Test for Flash Point.
A.S.A. Z11a-1928—Standard Abridged Volume Correction Table for Petroleum Oils.
A.S.A. Z11b-1928—Viscosity of Petroleum Products and Lubricants.
A.S.A. Z11c-1928—Penetration of Greases and Petrolatum.
A.S.A. Z11e-1928—Cloud and Pour Points of Petroleum Products.
A.S.A. Z11f-1928—Flash and Fire Points by Means of Open Cup.
A.S.A. Z11g-1928—Flash Point by Means of the Pensky-Martens Closed Tester.
A.S.A. Z11 1-1928—Neutralization Number of Petroleum Products and Lubricants.
A.S.A. Z11m-1928—Sulfur in Petroleum Oils Heavier Than Illuminating Oil.
A.S.A. Z11n-1928—Thermal Value of Fuel Oil.
A.S.A. Z11p-1928—Standard Method of Analysis of Grease.
A.S.T.M. D56-21—Std. Method of Test for Flash Point of Volatile Flammable Liquids.
A.S.T.M *D88-26—Std. Methods of Test for Viscosity of Petroleum Products and Lubricants.

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A.S.T.M. D91-21T—Tent. Method of Test for Precipitation Number of Lubricating Oils.
A.S.T.M. *D92-24—Std. Method of Test for Flash and Fire Points by Means of Open Cup.
A.S.T.M. *D93-22—Std. Method of Test for Flash Point by Means of the Pensky-Martens Closed Tester.
A.S.T.M. D94-28—Std. Method of Test for Saponification Number.
A.S.T.M. D95-28—Std. Method of Test for Water in Petroleum Products and Other Bituminous Materials.
A.S.T.M. D96-28—Std. Method of Test for Water and Sediment in Petroleum Products by Means of Centrifuge.
A.S.T.M. *D97-28—Std. Method of Test for Cloud and Pour Points of Petroleum Products.
A.S.T.M. *D128-27—Std. Method of Analysis of Grease.
A.S.T.M. *D129-27—Std. Method of Test for Sulfur in Petroleum Oils Heavier Than Illuminating Oil.
A.S.T.M. D155-23T—Tent. Method of Test for Color of Lubricating Oil by Means of Union Colorimeter.
A.S.T.M. D157-28—Std. Method of Test for Steam Emulsion of Lubricating Oils.
A.S.T.M *D188-27T—Tent. Method of Test for Neutralization Number of Petroleum Products and Lubricants.
A.S.T.M. D189-28—Std. Method of Test for Carbon Residue of Petroleum Products (Conradson Carbon Residue).
A.S.T.M. *D206-25—Std. Abridged Volume Correction Table for Petroleum Oils.
A.S.T.M. *D217-27T—Tent. Method of Test for Penetration of Greases and Petrolatum.
A.S.T.M. *D240-27—Std. Method of Test for Thermal Value of Fuel Oil.
A.S.T.M D270-27T—Tent. Methods of Sampling Petroleum and Petroleum Products.
A.S.T.M D286-28T—Tent. Method of Test for the Determination of Autogenous Ignition Temperatures.
A.S.T.M. D287-28T—Tent. Method of Test for Gravity of Petroleum and Petroleum Products by Means of the Hydrometer.
A.S.T.M D288-28T—Tent. Def. of Terms Relating to Petroleum.
F.S.B. 2d—Lubricants and Liquid Fuel and Methods for Sampling and Testing (B. of M. Tech. Paper No. 323B).
Pipe (See Tubes and Pipe).
Pipe Covering (See Heat Insulation).
Pipe Fittings (See Pipe Flanges and Fittings).
Pipe Flanges and Fittings
A.S.A. B16a-1928—Cast Iron Flanges and Flanged Fittings for Maximum Pressures of 125 lb.
A.S.A. B16b-1928—Cast Iron Flanges and Flanged Fittings for Maximum Pressures of 250 lb.
A.S.A. B16c-1927—Malleable Iron Screwed Fittings for Maximum Pressures of 150 lb.
A.S.A. B16d-1927—Cast Iron Screwed Fittings for Maximum Pressures of 125 and 250 lb.
A.S.A. B16e-1927—Steel Flanges and Flanged Fittings for Maximum Pressures of 250, 400, 600, 900 and 1350 lb.
A.S.T.M. A105-28—Std. Spec. for Forged or Rolled Steel Pipe Flanges for High-Temperature Service.
A.S.M.E. ......—*Steel Pipe Flanges and Flanged Fittings for maximum working steam pressures of 250, 400, 600, 900 and *1350 lb. per sq. in.
A.S.M.E. ......—*Cast Iron Pipe Flanges and Flanged Fittings, all sizes for maximum working saturated steam pressures of 125 and 250 lb. per sq. in.
A.S.M.E. ......—*Cast Iron Screwed Fittings, for maximum working saturated steam pressures of 125 and 250 lb. per sq. in.
A.S.M.E. ......—*Malleable Iron Screwed Fittings, for maximum working saturated steam pressure of 150 lb. per sq. in.
F.S.B. 393—Malleable Iron or Steel Unions.
F.S.B. 489—Cast-Iron Pipe Fittings (Threaded).
F.S.B. 535—Malleable Iron Pipe Fittings (Threaded) (150 lb.).
Pipe Threads (See Threads).
Power Boilers (See Boilers).
Power Test Codes (See Codes, Power Test).
Power Transmission Equipment
A.S.A. B15-1927—Power Transmission Apparatus, Mechanical, Safety Code.
A.S.A. B17a-1924—Diameters and Lengths of Cold-Finished Shafting.
A.S.A. B17b-1925—Keys, Square and Flat Stocks, Widths and Heights.
A.S.A. B17c-1927—Design of Transmission Shafting, Code.
A.S.A. B17d-1927—Keys, Plain Taper Stock, Square and Flat.
A.S.A. B17e-1927—Keys, Gib Head, Taper Stock, Square and Flat.
A.S.M.E. ......—Safety Code for Mechanical Power Transmission Apparatus.
A.S.M.E. ......—*Code for Design of Transmission Shafting.
A.S.M.E. ......—*Shafting Diameters.
A.S.M.E. ......—*Square and Flat Stock Keys.
A.S.M.E. ......—*Plain Taper Stock Keys.
A.S.M.E. ......—*Gib Head Taper Stock Keys.
F.S.B. 37—Leather Belting (B. of S. Cir. No. C148).
F.S.B. 184—Lace Leather (B. of S. Cir. No. C213).
F.S.B. 466—Conveyor Belting (Stitched Duck).
Pressure Vessels (See Unfired Pressure Vessels).
Protective Coatings (See Paints and Protective Coatings).
Pumps
A.S.M.E. ......—Centrifugal and Rotary Pumps, Power Test Code.
A.S.M.E. ......—Reciprocating Steam-Driven Displacement Pumps, Power Test Code.
Pump Valves (See Valves).
Rags and Waste
F.S.B. 259a—Cotton Rags, Colored, for Wiping Machinery (Sterilized) (B. of S. Cir. No. C261).
F.S.B. 261a—Cotton Rags, White, for Wiping Machinery (Sterilized) (B. of S. Cir. No. C264).
F.S.B. 262a—Cotton Waste, White (B. of S. Cir. No. C262).
F.S.B. 263a—Cotton Waste, Colored (B. of S. Cir. No. C263).
F.S.B. 264a—Wool Waste, Colored (B. of S. Cir. No. C260).
Refractories (See Bricks and Refractories).
Rivets
A.S.A. B18a-1927—Small Rivets.
A.S.M.E. ......—*Small Rivets.
Rivet Steel (See Steel).
Rubber Gaskets (See Gaskets and Packing).
Rubber Packing (See Gaskets and Packing).
Rubber Products
A.S.T.M D15-24—Std. Methods of Testing Rubber Products.
A.S.T.M. D297-28T—Tent. Methods of Chemical Analysis of Rubber Products.
F.S.B. 59a—General Specifications for Rubber Goods (Methods of Physical Tests and Chemical Analysis) (B. of S. Cir. No. C232).

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Rubber Valves (See Valves).
Rules (See Codes).
Scales
  F.S.B. 314—Railroad Track Scales.
Screw Threads (See Threads).
Shafting (See Power Transmission Equipment and Steel).
Soda Ash (See Chemicals).
Springs
  A.S.M.E ......—Bibliography on Mechanical Springs.
Spring Steel (See Steel).
Spring Wire (See Non-Ferrous Metals).
Steam Boilers (See Boilers).
Steam Engines (See Engines).
Steam Pumps (See Pumps).
Steam Turbines (See Turbines).
Steel
  A.S.A. G9-1924—Forgings, Carbon-Steel and Alloy-Steel Blooms, Billets and Slabs for, Specifications.
  A.S.T.M. *A17-21—Std. Spec. for Carbon-Steel and Alloy-Steel Blooms, Billets and Slabs for Forgings
  A.S.T.M. A31-24—Std. Spec. for Boiler Rivet Steel.
  A.S.T.M. A33-24—Std. Methods of Chemical Analysis of Plain Carbon Steel.
  A.S.T.M. A33-28T—Tent. Methods of Sampling Rolled and Forged Steel Products for Check Analysis.
  A.S.T.M. A37-27—Rec. Practice for Carburizing and Heat Treatment of Carburized Objects.
  A.S.T.M. A55-24—Std. Methods of Chemical Analysis of Alloy Steels.
  A.S.T.M. A58-27—Std. Spec. for Carbon-Steel Bars for Vehicle and General Purpose Springs.
  A.S.T.M. A70-27—Std. Spec. for Boiler and Firebox Steel for Stationary Service.
  A.S.T.M. A78-27—Std. Spec. for Steel Plates of Structural Quality for Forge Welding.
  A.S.T.M. A89-27—Std. Spec. for Steel Plates of Flange Quality for Forge Welding.
  A.S.T.M. A96-27—Std. Spec. for Alloy-Steel Bolting Material for High-Temperature Service.
  A.S.T.M. A107-27—Std. Spec. for Commercial Quality Hot-Rolled Bar Steels.
  A.S.T.M. A108-27—Std. Spec. for Commercial Cold-Finished Bar Steels and Cold-Finished Shafting.
  A.S.T.M. A119-28T—Tent. Definitions of Terms Relating to Heat Treatment Operations (Especially as Related to Ferrous Alloys).
  A.S.T.M. E3-24—Std. Methods of Metallographic Testing of Iron and Steel.
  A.S.T.M. E14-25T—Tent. Rec. Practice for Thermal Analysis of Steel.
  F.S.B. 174—Welding Wire, Iron and Steel.
  F.S.B. 316—Steel Blooms, Billets, Slabs and Bars, for Reforging, Carbon and Alloy.
  F.S.B. 550—Boiler Staybolt Steel.
Steel Castings (See Castings).
Steel Forgings (See Forgings).
Steel Pipe (See Tubes and Pipe).
Steel Pipe Flanges and Fittings (See Pipe Flanges and Fittings).
Steel Tubes (See Tubes and Pipe).
Thermometers.
  A.S.T.M. D182-25—Std. Spec. for A.S.T.M. Partial-Immersion Thermometer for General Use, —20 to +150 deg. cent., 0 to +300 deg. fahr.
  A.S.T.M. D183-25—Std. Spec. for A.S.T.M. Partial-Immersion Thermometer for General Use, —5 to +300 deg. cent., +20 to +580 deg. fahr.
  A.S.T.M D184-25—Std. Spec. for A.S.T.M. Partial-Immersion Thermometer for Gen-Use, —5 to +400 deg. cent., +20 to +760. deg fahr.
  F.S.B. 472—Industrial Thermometers.
Threads
  A.S.A. B1a-1924—Screw Threads for Bolts, Machine Screws, Nuts and Commercially Tapped Holes.
  A.S.A. B2-1919—Pipe Thread.
  A.S.M.E. ......—*American Standard Screw Threads for Bolts, Machine Screws, Nuts and Commercially Tapped Holes.
  F.S.B. 238—Pipe Threads.
Tolerances (See Gages).
Tube Plates (See Condensers).
Tubes and Pipe
  A.S.T.M A53-27—Std. Spec. for Welded and Seamless Steel Pipe.
  A.S.T.M. A72-27—Std. Spec. for Welded Wrought-Iron Pipe.
  A.S.T.M. A83-27—Std. Spec. for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes.
  A.S.T.M. A106-28T—Tent. Spec. for Lap-Welded and Seamless Steel Pipe for High-Temperature Service.
  A.S.T.M. A120-28T—Tent. Spec. for Lap-Welded and Seamless Steel Pipe, Black and Galvanized, for Ordinary Uses.
  A.S.T.M. B13-18—Std. Spec. for Seamless Copper Boiler Tubes.
  A.S.T.M. B14-18—Std. Spec. for Seamless Brass Boiler Tubes.
  A.S.T.M. B42-24—Std. Spec. for Copper Pipe, Standard Sizes.
  A.S.T.M. B43-24—Std. Spec. for Brass Pipe, Standard Sizes.
  A.S.T.M. B44-24—Std. Spec. for Seamless Admiralty Condenser Tubes and Ferrule Stock.
  A.S.T.M. B55-25—Std. Spec. for Seamless 70-30 Brass Condenser Tubes and Ferrule Stock.
  A.S.T.M. B56-25—Std. Spec. for Seamless Muntz Metal Condenser Tubes and Ferrule Stock.
  A.S.T.M. B75-28T—Tent. Spec. for Seamless Copper Tubes.
  F.S.B. 57 —Flexible Non-Metallic Tubing.
  F.S.B. 162a—Welded Steel Pipe (Black and Galvanized).
  F.S.B. 242 —Welded wrought iron pipe (Black and Galvanized).
  F.S.B. 287 —Seamless Copper Tubing and Pipe, Standard Iron Pipe Size.
  F.S.B. 342a—Seamless Brass Pipe, Iron Pipe Size, Standard and Extra Strong.
  F.S.B. 347 —Lap-Welded and Seamless Steel Boiler Tubes.
  F.S.B. 349 —Lap-Welded Charcoal Iron Boiler Tubes.
  F.S.B. 374 —Admiralty Metal Condenser Tubes and Tubes for Ferrule Stock.
  F.S.B. 427 —Seamless Brass Tubing.
Tubes and Pipe, Cast Iron
  F.S.B. 537—Centrifugally Cast Iron Water Pipe.
  (See also Castings).
Tubes and Pipe, Threads (See Threads).
Turbines
  A.S.M.E. ......—Steam Turbines, Power Test Code.
Unfired Pressure Vessels.
  A.S.M.E. ......—Rules for the Construction of Unfired Pressure Vessels.
Valves
  A.S.T.M. D151-23—Std. Spec. for Rubber Pump Valves.
  F.S.B. 114a—Rubber Valves (B. of S. Cir. No. C244).
Waste (See Rags and Waste)

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Water Treatment (See Chemicals).
Welding Rods (See Non-Ferrous Metals).
Welding, Steel (See Steel).
Welding Wire (See Steel).
Wrench Openings (See Bolts, Nuts and Machine Screws).
Wrought Iron
  A.S.A. G12-1923—Bars, Refined Wrought-Iron, Specifications.
  A.S.A. G13-1923—Plates, Wrought-Iron, Specifications.
  A.S.T.M. *A41-18—Std. Spec. for Refined Wrought-Iron Bars.
  A.S.T.M. *A42-18—Std. Spec. for Wrought-Iron Plates.
  A.S.T.M. A81-27—Std. Def. of Terms Relating to Wrought-Iron Specifications.
  A.S.T.M. A84-27—Std. Spec. for Staybolt, Engine-Bolt and Extra-Refined Wrought-Iron Bars.
  A.S.T.M. A85-27—Std. Spec. for Common Iron Bars.
  A.S.T.M. A86-27—Std. Spec. for Hollow Rolled Staybolt Iron.
  F.S.B. 391—Refined Wrought Iron Bar.
Wrought Iron Pipe (See Tubes and Pipe).
Wrought Iron Tubes (See Tubes and Pipe).

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REPORTS OF INVESTIGATIONS

Investigations by Government Bureaus

Among the Government publications which present the results of scientific and technical investigations and research made by the various Government Bureaus, there are some which should be of particular interest to engineers engaged in the design or operation of the mechanical equipment of power plants. While not coming strictly under the head of standards, a number of these publications, covering investigations by the Bureau of Standards and the Bureau of Mines, are included in separate lists for the convenience of those interested.

Prices of publications of the Bureau of Standards included in accompanying list and available for distribution, are given in Price List 64, Standards of Weight and Measure. This price list, which can be obtained by addressing the Superintendent of Documents, Government Printing Office, Washington, D. C., also gives an alphabetical list, with prices, of a large number of other publications on engineering subjects.

A General List of Publications of the Bureau of Mines, with prices, as well as an Index of Bureau of Mines Publications are issued by the Bureau. Copies can be had by applying to the Superintendent of Documents, Government Printing Office, Washington, D. C. Those publications of the Bureau that deal with the safety and health of workmen in the mineral industries or relate essentially to the conservation of mineral resources are printed for free distribution to residents of the United States and its possessions.

The publications of the Bureau of Standards and those of the Bureau of Mines indicated in accompanying list as obtainable only through the Superintendent of Documents, must be ordered from the Superintendent of Documents, Government Printing Office, Washington, D. C. Prepayment of price is required and should be made in cash (exact amount) or by postal or express money order, payable to the Superintendent of Documents.

Publications of the Bureau of Mines available for free distribution should be ordered by number and title from the Section of Publications, Bureau of Mines, Washington, D. C. No publications are sold by the Bureau and no money for publications should be sent to it.

Publications indicated in the list as out of print can not be supplied by the Bureau of Mines or the Superintendent of Documents. Copies of these publications were widely distributed to public libraries and can probably be consulted there.

Bureau of Standards Publications Relating to Mechanical Equipment of Power Plants

Circulars

8—Testing of Thermometers.
18—Standard Gage for Sheet and Plate Iron and Steel.
38—Testing of Rubber Goods.
42—Metallographic Testing.
69—Paint and Varnish.
73—Copper.
83—Specifications for Manufacture and Installation of Railroad Track Scales.
99—Carbonization of Lubricating Oils.
100—Nickel.
101—Physical Properties of Materials: 1, Strengths and Related Properties of Metals and Certain Other Engineering Materials.
106—Lime, Definitions and Specifications.
109—Sand-lime Brick, Description and Specification.
113—Structure and Related Properties of Metals.
150—Quicklime and Hydrated Lime for Use in Manufacture of Sand-lime Brick.
153—Quicklime and hydrated Lime for Manufacture of Silica Brick.
154—National Standard Petroleum Oil Tables.
Sup.—Abridged Volume Correction Table for Petroleum Oils.
231—Quicklime and Hydrated Lime for Use in Purification of Water.
282—Fire-clay Brick, Their Manufacture, Properties, Uses and Specifications.
333—Specifications for Manufacture and Installation of Two-section, Knife-edge Railroad Track Scales.

Technologic Papers

53—Investigation of Fusible Tin Boiler Plugs.
76—Determination of Volatile Thinner in Oil Varnish.
84—Failure of Brass: 3, Initial Stress Produced by the Burning in of Manganese Bronze.
85—Manufacture and Properties of Sand-lime Brick.
97—Some Unusual Features in Microstructure of Wrought Iron.
112—Standardization of the Saybolt Universal Viscosimeter.
116—Silica Refractories, Factors Affecting Their Quality and Methods of Testing the Raw Materials and Finished Ware.
124—Constitution and Microstructure of Silica Brick and Changes Involved Through Repeated Burnings at High Temperatures.
159—Porosity and Volume Changes of Clay Fire Bricks at Furnace Temperatures.
163—Stresses Caused by Cold-rolling.
176—Slushing Oils.
179—Electric Arc Welding of Steel: 1, Properties of the Arc-fused Metal.

188—Some Properties of White Metal Bearing Alloys at Elevated Temperatures.
201—Friction and Carrying Capacity of Ball and Roller Bearings.
206—Effect of Heat Treatment on the Mechanical Properties of 1 per cent Carbon Steel.
219—Effect of Temperature, Deformation, and Rate of Loading on the Tensile Properties of Low-carbon Steel Below Thermal Critical Range.
243—Stresses in a Few Welded and Riveted Tanks Tested Under Hydrostatic Pressure.
245—Embrittlement of Malleable Cast Iron Resulting from Heat Treatment.
252—Nick-bend Test for Wrought Iron.
254—Emissive Tests of Paints for Decreasing or Increasing Heat Radiation from Surfaces.
257—Development of Method for Measurement of Internal Stress in Brass Tubing.
267—Effect of Hot-rolling Conditions on Physical Properties of Carbon Steel.
274—Use of United States Government Specification Paints and Paint Materials.
279—Testing of Fire-clay Brick with Special Reference to Their Use in Coal-fired Boiler Settings.
281—Malleability and Metallography of Nickel.
285—Release of Internal Stress in Brass Tubing.
289—Comparative Slow Bend and Impact Notched Bar Tests on Some Metals.
296—Flow in Low-carbon Steel at Various Temperatures.
306—Photometric Method for Measuring Hiding Power of Paints.
308—Cement-lime Mortars.
334—Relationships Between Rockwell and Brinell Numbers (in Comparing Hardness of Ferrous and Non-ferrous Metals).
358—Air-hardening Rivet Steels.

Scientific Papers

356—Microstructure of Iron and Mild Steel at High Temperatures.
410—Thermal Expansion of Copper and Some of its Important Industrial Alloys.
426—Thermal Expansion of Nickel, and Monel Metal, Stellite, Stainless Steel, and Aluminum.
562—Density of Hot-rolled and Heat-treated Carbon Steels.
570—Thermal Expansion of Alloys of Stainless Iron Type.

Miscellaneous Publications

15—Some Technical Methods of Testing Miscellaneous Supplies Including Paints and Paint Materials, Inks, Lubricating Oils, Soaps, etc.
62—Brinell Hardness Numbers.

Bureau of Mines—Publications Relating to Mechanical Equipment of Power Plants

Bulletins

*1—The Volatile Matter of Coal. 1910.
*8—The Flow of Heat through Furnace Walls. 1911.
**12—Apparatus and Methods for the Sampling and Analyses of Furnace Gases. 1911.
*18—The Transmission of Heat into Steam Boilers. 1912.
*21—The Significance of Drafts in Steam-Boiler Practice. 1911.
**63—Sampling Coal Deliveries and Types of Government Specifications for the Purchase of Coal. 1913.
*91—Instruments for Recording Carbon Dioxide in Flue Gases. 1916.
97—Sampling and Analysis of Flue Gases. 1915.
*100—Manufacture and Uses of Alloy Steels. 1915.
*116—Methods of Sampling Delivered Coal and Specifications for the Purchase of Coal for the Government. 1916.
*125—The Analytical Distillation of Petroleum. 1916.
*129—The Fusibility of Coal Ash and the Determination of the Softening Temperature. 1918.
*135—Combustion of Coal and Design of Furnaces. 1917.
*145—Measuring the Temperature of Gases in Boiler Settings. 1918.
*155—Oil-Storage Tanks and Reservoirs, with a Brief Discussion of Losses of Oil in Storage and Methods of Prevention. 1918.
*207—The Analytical Distillation of Petroleum and Its Products. 1922.
*209—Fusibility of Ash from Coals in the United States. 1922.
*217—Preparation, Transportation, and Combustion of Powdered Coal, published through the courtesy of the Canada Department of Mines. 1923.
*223—An Investigation of Powdered Coal as Fuel for Power-Plant Boilers. 1923.
242—Explosion Hazards in Industrial Plants Through the Use of Pulverized Coal. 1925.

Technical Papers.

**3—Specifications for the Purchase of Fuel Oil for the Government, with Directions for Sampling Oil and Natural Gas. 1911.
8—Methods of Analyzing Coal and Coke. 1926.
**25—Methods for the Determination of Water in Petroleum and Its Products. 1912.
*26—Methods of Determining the Sulphur Content of Fuels, Especially Petroleum Products. 1912.
**31—Apparatus for the Exact Analysis of Flue Gas. 1913.
**36—Preparation of Specifications for Petroleum Products. 1913.
**49—The Flash Point of Oils, Methods and Apparatus for Its Determination. 1913.
*60—The Approximate Melting Points of Some Commercial Copper Alloys. 1913.
76—Notes on the Sampling and Analysis of Coal. 1914.
**91—A Convenient Multiple-Unit Calorimeter Installation. 1917.
*109—Composition of the Natural Gas Used in 25 Cities, with a Discussion of the Properties of Natural Gas. 1915.
*113—Some Properties of the Water in Coal. 1916.
*114—Heat Transmission through Boiler Tubes. 1915.
133—Directions for Sampling Coal for Shipment or Delivery. 1917.
*140—The Primary Volatile Products of the Carbonization of Coal; A Sequel to Bulletin 1, The Volatile Matter of Coal. 1916.
184—Weights of Various Coals. 1918.
*197—Use of the Hydrogen-Volatile-Matter Ratio in Obtaining the Net Heating Values of American Coals. 1918.
218—Boiler-Water Treatment, by United States Fuel Administration. 1920.
219—Combustion and Flue-Gas Analysis, by United States Fuel Administration. 1919.
*236—Abatement of Corrosion in Central Heating Systems. 1919.
*238—Indicators for Carbon Dioxide and Oxygen in Air and Flue Gas. 1920.
240—Boiler and Furnace Testing. 1920.
320—The Bureau of Mines Orsat Apparatus for Gas Analysis. 1925.
*323B—United States Government Specification for Lubricants and Liquid Fuels and Methods for Testing. (Federal Specifications Board, Specification No. 2d, 1927.)
346—Properties of Typical Crude Oils from the Producing Fields of the Western Hemisphere. 1925.

Investigations by College Engineering Experiment Stations

Some thirty-three engineering colleges connected with State institutions maintain engineering experiment stations which carry on investigations of value

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*Obtainable only through the Superintendent of Documents, Government Printing Office, Washington, D. C.
**Out of print.

to the public. The Engineering Experiment Stations of the University of Illinois, Iowa State College, Ohio State University, Purdue University, University of Washington, University of Kansas, Pennsylvania State College and of several other State universities have made investigations of direct interest to the power industry.

Lists of publications, giving the results of their investigations, are issued by the various Engineering Experiment Stations and may be had on application to their Directors. While available these publications are generally subject to free distribution within certain limitations, or they may be obtained at prices indicated in the published lists.

The following bulletins are among those issued by the several Stations which apply particularly to mechanical power plant equipment. It will be noted that some of these are no longer available for general distribution.

University of Illinois

Bulletin No. 34—Tests of Two Types of Tile-Roof Furnaces under a Water-Tube Boiler. 1909.
Bulletin No. 36—The Thermal Conductivity of Fire-Clay at High Temperatures. 1909.
Bulletin No. *37—Unit Coal and the Composition of Coal Ash. 1909.
Bulletin No. 45—The Strength of Oxyacetylene Welds in Steel. 1910.
Bulletin No. 78—A Study of Boiler Losses. 1915.
Bulletin No. 94—The Embrittling Action of Sodium Hydroxide on Soft Steel. 1917.
Bulletin No. 98—Tests of Oxyacetylene Welded Joints in Steel Plates. 1917.
Bulletin No. *117—Emissivity of Heat from Various Surfaces. 1920.
Bulletin No. 128—The Ignition Temperature of Coal. 1922.
Bulletin No. 139—An Investigation of the Maximum Temperatures and Pressures Attainable in the Combustion of Gaseous and Liquid Fuels. 1924.
Bulletin No. 149—An Investigation of the Efficiency and Durability of Spur Gears. 1925.
Bulletin No. 155—The Cause and Prevention of Embrittlement of Boiler Plate. 1926.
Bulletin No. 168—Heat Transmission Through Boiler Tubes. 1927.
Bulletin No. 177—Embrittlement of Boiler Plate. 1928.
Bulletin No. 180—The Classification of Coal. 1928.
Bulletin No. 181—The Thermal Expansion of Fire-clay Bricks. 1928.
Bulletin No. 183—Tests of the Fatigue Strength of Steam Turbine Blade Shapes. 1928.

Iowa State College

Bulletin No. 54—An Investigation of the Protective Values of Structural Steel Paints.
Bulletin No. 71—The Mechanism for the Graphitization of White Cast Iron and Its Application to the Malleabilization Process.

Ohio State University

Bulletin No. *4—Superheated Steam.
Bulletin No. 31—The Thermal Conductivities of Alloys.
Bulletin No. 34—Effect of Stratification of Furnace Gases on Steam Boiler Losses.

Purdue University

Bulletin No. *1—Flow of Water Through One and One-half Inch Pipe and Valves. 1918.
Bulletin No. 8—Flow of Water Through Spiral Riveted Steel Pipe. 1921.
Bulletin No. 25—Flow of Heat in Pistons. 1925.

University of Washington

Bulletin No. 34—Centrifugal Fans: Performance, Characteristics and Methods of Testing. 1926.
Bulletin No. 45—Loss of Head in Three Types of Water Meters. 1927.
Bulletin No. 46—The Float-and-sink Testing of Fine-Size Coal. 1928.

Pennsylvania State College

Bulletin No. *14—Purchasing Coal by Specification and Methods of Sampling. 1914.
Bulletin No. *21—Empirical Method for Determining the Ultimate from the Proximate Analysis of Coal. 1915.
Bulletin No. *27—The Relative Corrosion of Alloys, 1918.
Bulletin No. 32—Heat Transmission and Efficiency in Steam Boiler Tubes. 1924.

Welding

Until ten or twelve years ago welding was employed principally to repair broken parts of machinery and other metal parts. Today it is accepted by industry as a most important production as well as repair process.

The rapidity with which the welding art developed during the World War was responsible for some unsatisfactory work and consequent delay in the general acceptance of the process. With a realization of the need of standardization for the orderly and conservative development of the several welding methods, the American Welding Society was formed in 1919 for the broad purpose of putting the welding art on a sound, scientific and engineering basis.

The American Welding Society is an organization of individuals and also companies and corporations interested in welding by any process—either as manufacturers of welding equipment and supplies interested in the commercial acceptance of the art, or as users concerned with its efficient application.

The research department of the American Welding Society is known as the American Bureau of Welding. This Bureau acts also as the Welding Research Department of the National Research Council and in addition to representatives from the Society, includes representatives from some twenty other interested scientific and engineering bodies. The Bureau maintains a technical information service and is recognized as an authentic source of welding information.

The American Welding Society, at the request of the A. S. M. E. Boiler Code Committee, is now preparing a general procedure, governing the use of welding in the construction of unfired pressure vessels, which can be used in connection with, or be made a part of, the A. S. M. E. Code for Unfired Pressure Vessels. A joint research committee on pressure vessels has also been organized under the auspices of the American Society of Mechanical Engineers and the American Bureau of Welding. This committee includes representatives from both sponsor organizations, as well as from other interested scientific and engineering societies, from interested welding apparatus manufacturing companies and also from tank manufacturers.

Under the auspices of the American Standards Association there is being prepared a comprehensive code dealing with pressure piping, the American Society of Mechanical Engineers acting as sponsor body. That section of this code which will deal with the use of welding in such work, is being formulated by the American Welding Society. The Society has also appointed a committee to prepare standard nomenclature, definitions and symbols in the welding field.

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*Not available for general distribution.

The principal publication of the American Welding Society is its monthly *Journal* distributed free to members and for sale to the general public. The Journal contains papers giving accurate information on the application of welding in a wide variety of fields, as well as research committee reports and other matter pertaining to the welding art.

Aside from the *Journal,* the Society publishes from time to time bulletins containing reports of its research department, the American Bureau of Welding. A list of these bulletins, as well as of reports and papers dealing with various phases of welding, is included in the August number of the *Journal* which is issued each year as a Year Book. Information regarding the Society or its publications may be obtained by addressing the American Welding Society, 33 West Thirty-ninth Street, New York, N. Y.

A list of some of the American Welding Society's publications of interest in connection with mechanical power plant equipment is appended. References to the "Journal" refer to the *Journal* of the American Welding Society.

American Welding Society Publications Relating to Mechanical Equipment of Power Plants

Bulletins

1—Standards for Testing Welds. 1921.
2—Welding Wire Specifications and Folios. 1921.
3—Report to the American Bureau of Welding on Standards for Arc Welding Apparatus. 1922.
5—An Investigation of Welded Pressure Vessels. 1923.
8—Some Metallurgical Investigations of Welding Wire. 1927.

Manuals

- Arc Welding.
- Gas Welding.
- Resistance Welding.
- Thermit Welding.

Reports

- Elevated Temperature Tests of Welds—Preliminary Report. Journal, Vol. 6, No. 7, 1927.
- Cast Iron Welding. General Consideration. Journal, Vol. 1, No. 8-9, 1922.
- Summary of Information on Arc Welding of Copper, Brass, and Bronze in the Literature up to March, 1923. Journal, Vol. 3, No. 3, 1924.
- Welding Manganese Steel. Journal, Vol. 2, No. 6, 1923.
- Nomenclature Report. Electric Resistance Welding. Journal, Vol. 1, No. 7, 1922.
- Proposed Method for Oxy-acetylene Welding of Oil Storage Tanks. Journal, Vol. 2, No. 6, 1923.
- Report of the Committee for the Electric Welding of Storage Tanks. Journal, Vol. 1, No. 12, 1922.

Papers

- Arc Welding of Cast Iron. Journal, Vol. 1, No. 8, 9 and 11, 1922.
- Cast Iron Welding by the Oxy-acetylene Process. Journal, Vol. 1, No. 8-9, 1922.
- Welding of Manganese Steel. Journal, Vol. 3, No. 5, 1924.
- How to Investigate Welded Tanks. Journal, Vol. 5, No. 5, 1926.
- Review of Electro-percussive Welding. Journal, Vol. 1, No. 7, 1922.
- Butt Welding: Slow Butt Method. Flash Method. Part Flash, Part Slow Butt Method. Journal, Vol. 1, No. 8-9, 1922.
- Spot Welding. Journal, Vol. 3, No. 9, 1924.
- Welding of Non-ferrous and Special Metals by the Resistance Welding Process. Journal, Vol. 4, No. 9, 1925.
- Fusion Tests to Determine the Suitability of Various Materials for Welding Purposes. Journal, Vol. 1, No. 10, 1922.
- Welding Cast Iron by Means of the Thermit Process. Journal, Vol. 1, No. 10, 1922.
- Writing Specifications for Welding Wire. Journal, Vol. 1, No. 11, 1922.

TREATMENT OF FEED WATER

The Treatment of Feed Water Subcommittee has made a survey of the central station field to determine the general practice in regard to the treatment of boiler feed water and the results obtained by the various methods. Forty statements have been received from operating companies, showing that twenty-four use evaporators, nine chemical treatment, three zeolite and four no treatment at all. Included in these statements is one from an operating company that uses evaporators in all its high pressure plants, and another from an operating company that uses zeolite softeners; the latter company operates for the most part relatively small sized low pressure generating stations.

Evaporators

Of the twenty-four plants using evaporators, ten pre-treat the evaporator feed. Of these ten, six use zeolite softeners, while one employs a unit system of evaporators and has a zeolite softener installed ahead of only one of the four units.

One of the plants reports that in the past it used zeolite softeners on the evaporator feed, but has discontinued this practice, and now feeds raw water to the evaporators.

Four plants reported the use of a chemical treatment of the water before going to the evaporators; two, the treatment of harbor or river water with alum and caustic soda as a coagulative, another the use of a "Scaife," lime-soda system, and the fourth a lime, iron sulphate, and barium hydrate treatment.

Nine of the plants using evaporators treat the entire boiler feed water before it enters the boilers, that is the condensate plus the make-up water, stating that it is necessary to add sodium phosphate and soda ash to maintain positive alkalinity. Some of these plants add caustic soda when the boilers are being refilled, and others make weekly tests from every boiler in order to control the sulphate-carbonate ratio and thus prevent embrittlement. One of these plants also reports using Glauber salts.

Two of the plants treat only the evaporator distillate in order to produce the desired alkalinity.

Three of the companies using additional chemical treatment report having difficulty with scaled superheaters, or deposits in the turbine blading when using chemicals in boiler feed water treatment.

The replies from the various companies indicate that the treatment of the make-up water to the evaporators is beneficial in a great many cases where the evaporator feed has properties producing very hard scale, and that the difficulties encountered due to the introduction of treatment of the water are of minor consequence if properly supervised. The same is true where treatment is used to produce positive alkalinity.

The results of the evaporator performance of four of the plants are given by tests which show the solids in the distillate from evaporators. Only one of the reporting companies submits data giving the moisture contained in the evaporated vapor.

Chemical Treatment

Chemical treatment is being used in nine of the plants, in most of which the boiler feed contains only a small amount of scale-forming matter, so that only a small amount of treatment is necessary. One of the plants reports considerable deposits in the superheater and turbine blading; this deposit is removed by washing. Another plant reporting difficulties on account of the carry-over of treatment chemicals states that the problem was solved by the installation of steam purifiers in the boiler drums to remove impurities in the steam, and by employing continuous blow-down, which is an aid in the control of the treatment.

Zeolite Treatment

Two plants of one company using zeolite treatment report generally satisfactory results. One of the plants reports difficulty with a mud deposit on the tanks and zeolite, which is not removed by back washing. Another plant reports difficulty through formation of channels in the zeolite, and that if water velocities are increased to agitate the zeolite the material is carried over.

Corrosion of Non-Ferrous Metals

Several of the companies report the occurrence of corrosion in bleeder heaters and evaporator condensers. Except for the evaporator condensers, the method of treatment seems to bear no relation to corrosion. In all cases corrosion has been remedied by the additional deaeration of the water and venting of the equipment. One company reports that corrosion of the tubes in its evaporator condensers has been corrected by the installation of an open heater on the evaporator feed in order to reduce the amount of gases that would otherwise be discharged to the evaporator condenser.

OPERATING COMPANIES' STATEMENTS

STATEMENT BY THE KANSAS CITY POWER & LIGHT COMPANY, KANSAS CITY, MO.

Northeast Station

"To date, boiler feed makeup for this station has not been treated, since city water has been used, and the estimated saving did not warrant the investment in a treating system. However, as the new 1200 lb. boilers will operate on condensate only, the per cent makeup to the 300 lb. boilers will be increased to a point where it is deemed advisable to treat.

"A Cochrane hot process lime and soda system of 50,000 lb. per hr. capacity is being installed and will be ready for service when the 1200 lb. unit is started."

Publication No. 289-53, Serial Report, Prime Movers Committee.

Grand Avenue Station

"This station is being remodeled from a 185 lb. plant to a 600-185 lb. plant, and in addition to supplying electrical energy, will also supply the commercial heating system steam. As the condensate from the heating system is not returned, the makeup, particularly in winter, will run very high.

"A two unit Cochrane hot process lime and soda system of 470,000 lb. per hr. total capacity is being installed for treatment of the makeup, and provisions are also being made for treatment with tri-sodium phosphate.

"This equipment will go in service about Jan. 1, 1929, when the new 600 lb. unit is started."

STATEMENT BY THE PENNSYLVANIA-OHIO POWER & LIGHT COMPANY

Toronto Plant

"The amount of makeup water varies from 1.5 to 2.0 per cent of the total boiler feed.

"Condenser leakage is kept at a minimum by testing the condensate daily and closing all leaks as soon as practical. The bacteria method of testing for leakage is used. Samples are collected from the condenser hot wells in sterilized bottles. A covered sterilized petri-dish containing 10 c.c. of nutrient agar is inoculated with 1 c.c. of the sample through a sterilized pipette. The corresponding plate is placed in an incubator at 37.5 deg. cent. for 24 hours. The number of bacteria colonies is then compared with the number of colonies for the raw water test to obtain the ratio of leakage.

"The makeup water is supplied by evaporators, whose output is vapor at 2 to 3 lb. gage pressure, and is discharged to the deaerators.

"The evaporators for the first two plant units are the film type, single effect, with 460 sq. ft. of surface and a maximum capacity of 12,000 lb. per hr. Those for the next two plant units are the submerged coil, Weir type, single effect, with 300 sq. ft. of surface and a maximum capacity of 12,000 lb. per hr.

"Ohio River water treated with lime and alum to remove suspended, organic matter and bacteria, is fed to evaporators 1, 3 and 4, but the water for unit No. 2 is also treated by a Permutit water softener.

"The average output of evaporators 1, 3 and 4 is 5500 to 6500 lb. per hr., whereas unit No. 2 delivers about 7500 lb. per hr.

"Evaporators 1, 3 and 4 are 'cracked' with cold water every day and manually cleaned every 6 to 8 weeks, requiring about twenty-seven man hours for each cleaning. Unit No. 2 does not require these cleaning methods.

"Moisture in the evaporator output has not been determined, but the following data shows the mineral constituents of the condensed evaporator steam output in parts per million.

Evaporator Number	Silicon Dioxide	Iron and Aluminum Oxide	Calcium Oxide	Magnesium Oxide	Sodium Oxide	Ignited Sulphates
1	5.6	0.4	4.7	less than 0.1	1.4	20.0
2*	1.6	1.3	1.6	less than 0.1	1.0	8.0
3	3.2	0.7	0.5	less than 0.1	1.8	8.0

*Evaporator feed through a Permutit softener.

An average analysis of Ohio River water after being treated for sanitary purposes is as follows:

Silicon Dioxide	11.6 p.p.m.
Iron and Aluminum Oxide	6.8
Calcium Oxide	32.8
Magnesium Oxide	0.5
Chloride	7.0
Sulphur Trioxide	78.0

Sodium oxide and carbonate not determined.

"Due possibly to the amount of dissociation of water encountered at the saturation temperature (about 440 deg. fahr.), it is necessary to treat the water chemically to prevent corrosion. Samples of water from the blow-off line of the boiler mud drums are taken in an open container daily through a cooling coil at light loads and transferred to an Erlenmeyer flask and corked. This water is titrated for phenolphthalein and methyl-orange alkalinities and the pH value is determined by using La Motte color tubes. When the phenolphthalein alkalinity is below 25 p.p.m. or the pH value is below 8.8, enough soda ash is added to the boiler water to bring it to this point. Under normal conditions one pound of soda ash will increase the alkalinity 6 p.p.m., but sometimes under unusual conditions of makeup water, a greater proportion of soda ash must be added to obtain the desired result.

"Glauber's salts are also added to the boiler water to keep the ratio of sodium sulphate to sodium carbonate above 3.5 in order to prevent caustic embrittlement. The concentration of sodium sulphate remains quite constant, and it is only necessary to make weekly tests. This is done by precipitating the SO_4 ion from the boiler water with barium chloride solution.

"Salts for internal treatment are pumped into the boilers through the water columns.

"For 8 months this year an average of 66.2 lb. of Glauber's salts and 11.6 lb. of soda ash have been added per boiler per month. During this period the boilers have averaged 7.7 k. B.t.u. per sq. ft. per hr., and during the daytime operation 10.1 k. B.t.u. per sq. ft. per hr. The average evaporation per boiler per month was 110,000,000 lb.

"Due to the low concentration of solids in the boiler water (about 200 p.p.m. total solids) it is not necessary to blow down. Due to troubles not associated with water quality or treatment, the boiler water has been changed about every 3 or 4 months, and as these troubles are eliminated this changing will probably be at longer intervals.

"The boiler feed water contains an average of 4.5 p.p.m. total solids.

"No tubes have been lost due to scale or water treatment methods since the method described has been followed. A number of water screen tubes have failed, but as these failures occurred at points on the tubes subjected at times to flame impingement and as the tubes showed no evidence of scale at the time of failure, these losses were not ascribed to boiler feed water or its treatment.

"The first pass and the water screen tubes are turbined every 6 months and the others once a year.

"For about three months one boiler was treated with tri-sodium phosphate. After this period the boiler had to be taken out of service due to failure of superheater tubes. All of the superheater tubes were coated with a thick scale which analysis showed to be mainly silica dioxide, iron oxide and aluminum oxide and no alkali. In spite of this analysis, this trouble was ascribed to solids carried over with the wet steam caused by the use of tri-sodium phosphate since this was the only boiler so treated, and no scale was ever found in the superheater tubes of the other boilers."

STATEMENT BY THE UNION GAS & ELECTRIC COMPANY, CINCINNATI, OHIO

"The Columbia Power Station has been in operation since November, 1925, and all makeup water for this station has been Ohio River water treated with lime and soda ash, with ferrous sulphate as a coagulant, in a cold intermittent water softener. The boilers in this station operate at a drum pressure of 630 lb. gage and a final steam temperature of 725 deg. fahr.

"Six of the boilers are operated at an average rating of 7.7 k. B.t.u. per sq. ft. per hr., and the feed water treatment has been entirely satisfactory for these boilers with regard to scale formation.

"Two boilers are used to screen the reheat coils, and these boilers operate at an average rating of 15 k. B.t.u. per sq. ft. per hr. We have encountered some troubles with scale in these units.

"With this method of feed water treatment it has not been possible to maintain the ratio of sodium sulphate to sodium carbonate recommended to prevent caustic embrittlement.

"Early in the year 1928 we added disodium phosphate continuously to the condenser hot wells in sufficient quantity to maintain a phosphate concentration of 50 p.p.m. in the boiler water. The boiler blow down was also regulated so that the total solids in the boiler water did not exceed 1000 p.p.m.

"This phosphate treatment has been very successful in eliminating scale even in the boilers operating at 15 k. B.t.u. per sq. ft. per hr. average rating. The nature of the boiler water is such that caustic embrittlement is also inhibited.

"A similar system of feed water treatment is used at our West End Station where the boilers are operated at an average rating of 7.3 k. B.t.u. per sq. ft. per hr. at drum pressures of 260 lb. gage and a final steam temperature of 600 deg. fahr. The results of this treatment have been very satisfactory.

"At Columbia Station there has been some difficulty with deposits on the high pressure turbine blading which has reduced the capacity of the units about 10 per cent after a month's operation. An analysis of this deposit shows the following:

	Per cent
Sodium Hydroxide	35.33
Sodium Carbonate	29.95
Sodium Chloride	25.03
Sodium Sulphate	3.30
Magnesium Carbonate	1.28
Calcium Carbonate	1.64
	92.53

"It has been found possible to remove this deposit by passing a small amount of saturated steam through the unit when it is shut down. No deposits have been found in the superheater tubes."

STATEMENT BY THE COMMONWEALTH EDISON CO., CHICAGO, ILL.

"In the 1927-28 Serial Report of this subcommittee (N. E. L. A. Publication No. 278-81) results of tests on the operation of a Wheeler, four effect evaporator were given. The results at that time showed excessive carry-over from the fourth effect.

"To remedy this condition and also to obtain a higher capacity from the evaporator, a second fourth effect was installed, which operates in parallel with the original fourth effect. The vapor from the third effect was thus approximately divided in half, which meant that the vapor velocities leaving the two fourth effects would be correspondingly reduced.

"At first this evaporator was operated with zeolite treated water and later changed to raw filtered water, with the idea that successful operation could be accomplished without the expense of pre-treatment. During the last six months the operation has been entirely with raw water. The resulting scale is removed mostly by routine cracking down, and at this time no deleterious effects have been noted as a result of this practice, which is not in accordance with the original intentions. Cracking down, however, does not entirely prevent the formation of hard scale on the tubes and trays, which means that about every two months it is desirable to open up the effects and auxiliary condenser for more thorough cleaning.

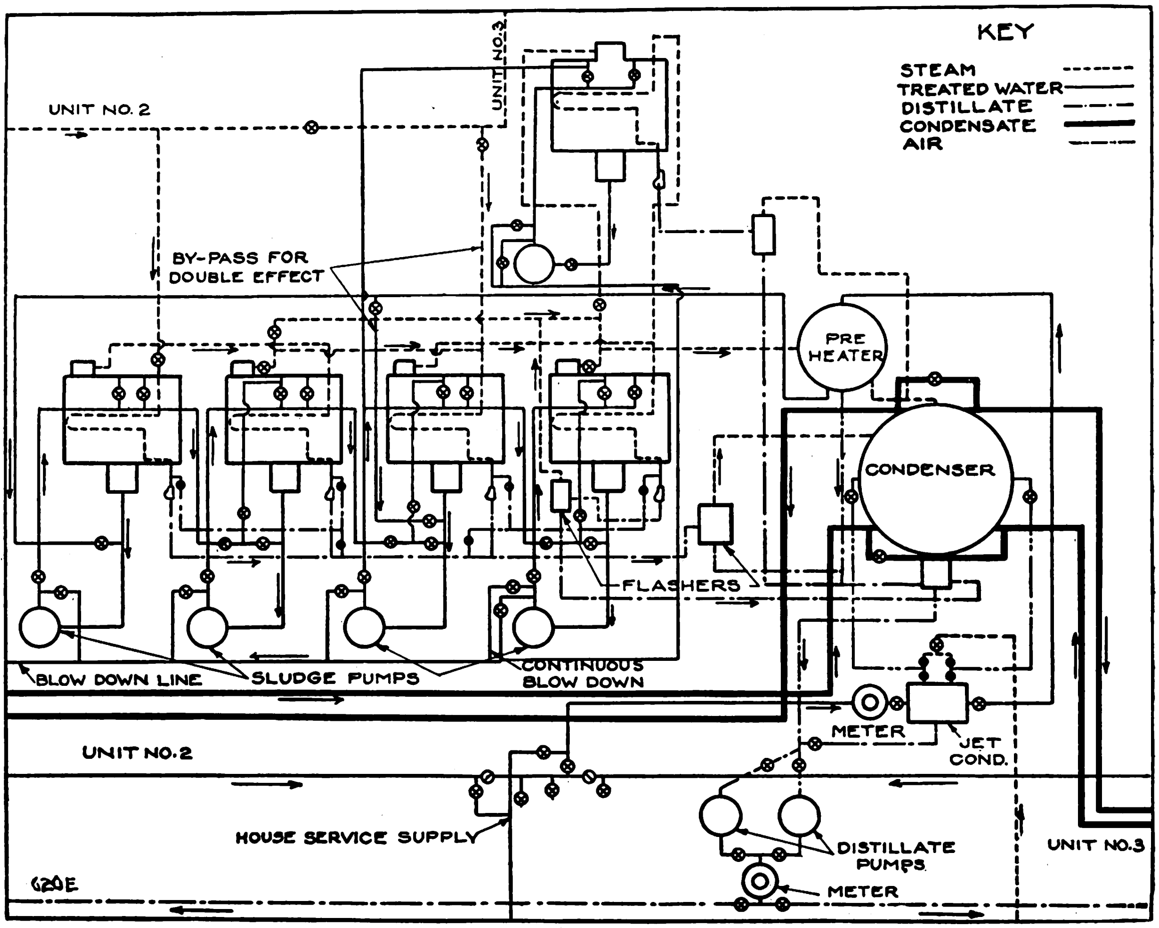

FIG. 1—EVAPORATOR PIPING—CRAWFORD AVENUE PLANT.

TABLE I

WATER ANALYSIS—TEST NO. 14—FOSTER-WHEELER EVAPORATOR—CRAWFORD AVENUE STATION OCTOBER 25, 1928

	P.p.m.	
	Filtered River Water Permutit Treated	Distillate Final Effect
Siliceous matter, SiO_2	0.51	trace
Oxide of iron and alumina ($Fe_2O_3 \div Al_2O_3$)	1.37	0.17
Sodium chloride, NaCl	40.90	1.54
Sodium sulphate, Na_2SO_4	39.85	1.54
Sodium bicarbonate, $NaHCO_3$	118.50	0.51
Calcium carbonate, $CaCO_3$*	0.34	0.34
Magnesium carbonate, $MgCO_3$†	0.34	0.17
Organic and volatile	22.60	1.37
Total solids	224.41	5.64
*Exists in the water as bicarbonate, $Ca(HCO_3)_2$	0.51	0.51
†Exists in the water as bicarbonate, $Mg(HCO_3)_2$	0.51	0.34

"The results of two tests on this equipment are given, one using Zeolite treated water and one using raw filtered water. Considerable improvement appears in the quality of the product over that obtained from the original installation. Although the evaporator effects were cleaned previous to tests, no particular increase in capacity was obtained, due probably to scale formation on the evaporating surfaces between cracking down operations.

"The second evaporator installation at Crawford Avenue Station is a Griscom-Russell single effect integral with the heat cycle of turbine No. 5 as indicated in Fig. 2. The manufacturer rates the equipment as having a normal capacity to evaporate 31,000 lb. of raw water per hr. when supplied with steam at 48 lb. per sq. in. abs. pressure and a maximum capacity of 44,600 lb. of raw water when supplied with steam at 76.5 lb. per sq. in. abs.

"This evaporator is of the bent tube submerged type, two evaporator shells and one evaporator condenser. Steam is supplied from the second I.P. bleed point (High Pressure element exhaust). The drainage is led to drainage of the second I.P. bleeder heater and flashed down in the first I.P. bleeder heater. The evaporated water is passed to the auxiliary condenser and returned to the main condensate line.

TABLE II

WATER ANALYSIS—TEST NO. 13—FOSTER-WHEELER EVAPORATOR—CRAWFORD AVENUE STATION OCTOBER 22, 1928

	P.p.m.	
	Filtered River Water Not Permutit Treated	Distillate Final Effect
Siliceous matter, SiO_2	0.51	0.34
Oxide of iron and alumina, ($Fe_2O_3 \div Al_2O_3$)	1.71	0.68
Sodium chloride, NaCl	30.60	1.0
Calcium sulphate, $CaSO_4$	51.90	3.08
Calcium carbonate, $CaCO_3$*	54.45	trace
Magnesium carbonate, $MgCO_3$†	40.65	2.74
Organic and volatile	17.95	0.86
Total solids	197.77	8.70
*Exists in the water as bicarbonate, $Ca(HCO_3)_2$	88.10	....
†Exists in the water as bicarbonate, $Mg(HCO_3)_2$	70.60	4.79

TABLE III

EVAPORATOR TESTS, CRAWFORD AVENUE STATION—COMMONWEALTH EDISON CO.—UNIT NO. 2

Evaporator Made by—FOSTER WHEELER CO.		
Type—QUADRUPLE EFFECT—FILM		
Test No	13	14
Date	10–22–28	10–25–28
Duration, hr	2	2
Load on unit No. 2, 1000 kw	56.25	54.0
Load on unit No. 3, 1000 kw	40.00	34.7
Barometer, in. hg	29.163	29.54
Total raw water metered, lb	90,900	......
Total raw Permutit water metered, lb	......	83,200
Total distillate metered, lb	107,500	104,400
Blowdown rate 1st-4th effect, lb. per hr	2,200	1,250
Blowdown rate 2nd-4th effect, lb. per hr	2,200	2,380
Blowdown temperature, 1st-4th effect, °F	134	136
Blowdown temperature, 2nd-4th effect, °F	132	136
Temperature raw water to jets, °F	66.8	58.9
Temperature raw water from jets, °F	88.8	82.6
Temperature raw water leaving preheater, °F	116.1	117.2
Steam pressure (header) lb. per sq. in. abs	30.0	29.5
Steam temperature (header) °F	245.6	243.5
First Effect:		
Steam chest pressure, lb. per sq. in. abs	27.7	27.1
Steam chest temperature, °F	245.6	243 5
Distillate temperature, °F	200.5	198.9
Vapor pressure, lb. per sq. in. abs	15.15	15.97
Vapor temperature, °F	214.8	216.6
Feedwater temperature, 1st to 2nd effect, °F	202.7	203.0
Second Effect:		
Steam chest pressure, lb. per sq. in. abs	15.2	15.82
Vapor pressure, lb. per sq. in. abs	7.33	7.0
Vapor temperature, °F	189.0	187.5
Distillate temperature, 1st to 2nd effect, °F	198.1	196.3
Feedwater temperature, 2nd to 3rd effect, °F	186.6	185.0
Third Effect:		
Steam chest pressure, lb. per sq. in. abs	8.83	8.62
Vapor pressure, lb. per sq. in. abs	3.58	3.55
Vapor temperature, °F	157.7	158.1
Distillate temperature, 1st, 2nd and 3rd effect, °F	189.7	187.8
Feedwater temperature, 3rd to 4th effect, °F	157.6	156.8
First Fourth Effect:		
Steam chest pressure, lb. per sq. in. abs	4.67	3.86
Vapor pressure, lb. per sq. in. abs	1.86	2.04
Vapor temperature, °F	135.7	138.5
Distillate temperature, 4th effect, °F	133.5	137.7
Second Fourth Effect:		
Steam chest pressure, lb. per sq. in. abs	4.67	3.86
Vapor pressure, lb. per sq. in abs	1.81	2.05
Vapor temperature, °F	135.9	139.2
Distillate temperature, 4th effect, °F	142.8	145.7
Temperature distillate from flasher, °F	169.0	168.3
Temperature, final distillate, °F	130.4	133.3
Steam pressure at jets, lb. per sq. in. abs	169.1	164.6
Cond. temp. to aux. cond. unit No. 3, °F	101	98
Cond. temp. from aux. cond. unit No. 3, °F	118.5	120
Cond. temp. to aux. cond. unit No. 2, °F	86	96
Cond. temp. from aux. cond. unit No. 2, °F	101.7	109
Pressure in aux. condenser, lb. per sq. in. abs	1.76	2.72
Permutit water evaporation, lb. per hr	......	37,970
Raw water evaporation, lb. per hr	40,950	......
Steam used, lb. per hr	12,800	14,230
Distillate delivered, lb. per hr	53,750	52,200
Lb. of raw water evaporated per lb. of steam	3.2	......
Lb. of Permutit water evaporated per lb. of steam	......	2.67
Water Analysis, Total Concentration in P.p.m.:		
Distillate, 1st effect	8.39	1.71
Distillate, 2nd effect	7.52	5.14
Distillate, 3rd effect	7.70	6.84
Distillate, 1st, 4th effect	6.84	4.79
Distillate, 2nd, 4th effect	10.60	4.96
Distillate, final	8.72	5.64
Permutit water	......	224.41
Raw water	197.77	......
Sludge, 1st effect	213.50	272.20
Sludge, 2nd effect	236.20	322.00
Sludge, 3rd effect	352.80	655.50
Sludge, 1st, 4th effect blowdown	832.50	......
Sludge, 2nd, 4th effect blowdown	1001.00	2184.00

NOTES: Evaporator cleaned October 18, 1928—cracked down 7 a. m. October 19, 1928. Evaporator out of service October 20, 1928, to inspect and clean floats and float valves—evaporator cracked down 7 a. m. October 22, 1928. Test 13 run 1—3 p. m.

Evaporator cracked down October 24, 1928, and started using Permutit water 2 p. m. October 24, 1928. Evaporator cracked down 7 a. m. October 25, 1928. Test 14 run 1—4 p. m.

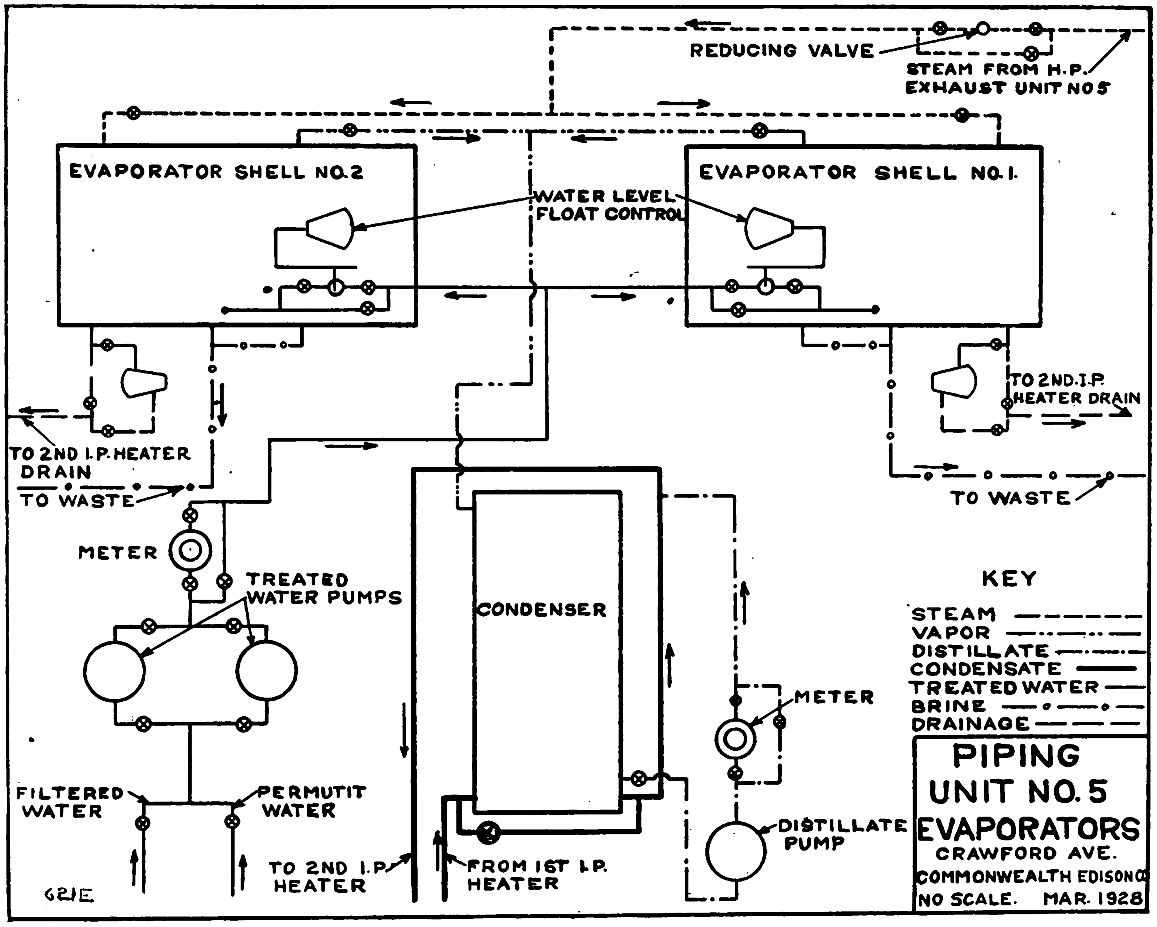
REDUCING VALVE
STEAM FROM H.P. EXHAUST UNIT NO 5
EVAPORATOR SHELL NO.2
EVAPORATOR SHELL NO.1.
WATER LEVEL FLOAT CONTROL
TO 2ND I.P. HEATER DRAIN
TO WASTE
TO 2ND.I.P. HEATER DRAIN
TO WASTE
METER
TREATED WATER PUMPS
CONDENSER
KEY
STEAM
VAPOR
DISTILLATE
CONDENSATE
TREATED WATER
BRINE
DRAINAGE
METER
DISTILLATE PUMP
FILTERED WATER
PERMUTIT WATER
TO 2ND I.P. HEATER
FROM 1ST I.P. HEATER
6215
PIPING UNIT NO. 5 EVAPORATORS
CRAWFORD AVE.
COMMONWEALTH EDISON CO
NO SCALE. MAR. 1928

FIG. 2—FLOW DIAGRAM EVAPORATOR—CRAWFORD AVENUE PLANT.

TABLE IV

WATER ANALYSIS—TEST NO. 1—GRISCOM-RUSSELL EVAPORATOR TESTS—CRAWFORD AVENUE STATION
APRIL 26, 1928

	P.p.m.		
	Filtered River Water (Not Permutit Treated)	Distillate	Brine
Silica, SiO_2	6.15	0.51	14.02
Oxide of iron and alumina ($Fe_2O_3 \div Al_2O_3$)	4.79	0.34	2.91
Sodium chloride, NaCl	16.10	0.86	268.50
Sodium sulphate, Na_2SO_4	....	....	82.10
Calcium sulphate, $CaSO_4$	30.80	0.51	160.00
Calcium carbonate, $CaCO_3$*	63.45	1.71	....
Magnesium sulphate, $MgSO_4$	....	....	52.50
Magnesium carbonate, $MgCO_3$†	34.55	2.05	37.95
Organic and volatile	45.00	4.45	110.60
Total solids	200.84	10.43	728.58
*Exists in the water as bicarbonate $Ca(HCO_3)_2$	103.0	2.74	trace
†Exists in the water as bicarbonate $Mg(HCO_3)_2$	59.9	3.59	65.90 Contains a small amount of carbonate

TABLE V

WATER ANALYSIS—TEST NO. 2—GRISCOM-RUSSELL EVAPORATOR—CRAWFORD AVENUE STATION
SEPTEMBER 24, 1928

	P.p.m.		
	Filtered River Water (Not Permutit Treated)	Distillate	Brine
Silica, SiO_2	3.76	0.34	2.05
Oxide of iron and alumina ($Fe_2O_3 \div Al_2O_3$)	2.74	0.86	1.54
Sodium chloride, NaCl	29.23	trace	545.20
Sodium sulphate, Na_2SO_4	trace	trace	178.80
Calcium sulphate, $CaSO_4$	27.70	0.34	321.70
Calcium carbonate, $CaCO_3$*	70.00	trace	11.47
Magnesium carbonate, $MgCO_3$†	41.00	1.54	41.00
Organic and volatile	9.75	3.08	362.60
Total solids	184.18	6.16	1,464.36
*Exists in the water as bicarbonate $Ca(HCO_3)_2$	113.1	....	18.65
†Exists in the water as bicarbonate $Mg(HCO_3)_2$	71.20	6.00	71.20

"For the past six months this evaporator has been operated with raw filtered water without deleterious effect. Some difficulty has been encountered in removing cracked scale, due to inadequate blow down arrangement. Larger and independent blow downs are expected to remedy this situation.

"Two raw water tests were run on this equipment with the results and averages as shown in Tables IV and V.

"The capacity of this system is at present limited in normal operation by the temperature of the returned distillate. As this distillate is returned to the main condensate line before the boiler feed pump, too high a temperature, occasioned by operating at too high shell pressures, would cause flashing at the pump suction.

"This evaporator is cracked down every 48 hr.

TABLE VI

EVAPORATOR TESTS—CRAWFORD AVENUE STATION
COMMONWEALTH EDISON CO.—UNIT NO. 5

Make of evaporator—GRISCOM-RUSSELL
Type of Evaporator—Submerged tube—Single Effect

Test No.	1	2
Date of test	4-26-28	9-24-28
Duration of test, hr	1	2
Load of unit No. 5 (Printometer) 1000 kw	66.68	93.72
Pressure at second I.P. Bleed Pt., lb. per sq. in. abs.	61.58	86.6
Temperature at second I.P. Bleed Pt., °F	328	364.3
Barometer, in. hg	29.64	29.20
Raw water metered, lb	31,571	62,800
Evaporator Shell No. 1:		
Steam pressure, lb. per sq. in. abs	40.58	50.6
Steam temperature, °F	314	357.4
Drainage temperature, °F	266	277
Vapor pressure, lb. per sq. in. abs.	22.58	29.6
Vapor temperature, °F	235	.....
Evaporator Shell No. 2:		
Steam pressure, lb. per sq. in. abs	39.58	49.3
Steam temperature, °F	313.4	351.4
Drainage temperature, °F	267	276.2
Vapor pressure, lb. per sq. in. abs.	22.58	29.6
Vapor temperature, °F	234	250.1
Evaporator Condenser:		
Vapor temperature, °F	235.4	250.4
Vapor pressure, lb. per sq. in. abs.	22.58	30.2
Temperature circulating water in, °F	191	202.1
Temperature circulating water out, °F	229.7	237.0
Temperature distillate, °F	227.4	237.1
Raw water pressure, lb. per sq. in. abs	77.58	230
Raw water temperature, °F	48	63.5
Raw water evaporated, lb. per hr	31,570.7	31,400
Steam supplied (calculated) lb. per hr	37,600	36,800
Lb. raw water per lb. steam	0.84	0.85
Water Analysis, Total Solids in P.p.m.:		
Raw water	200.0	185.0
Brine	728.5	1464.0
Distillate	10.28	6.16

Conclusions

"The operation of both types of evaporators with raw untreated water for the past six months indicates that this practice under our conditions is quite practical. It means, however, that some cleaning program other than the routine cracking down is necessary to maintain the desired evaporator capacities. It is the intention to install sufficient evaporator capacity at the Crawford Avenue Station to satisfy the whole station makeup, which at present is not the case. The transition from one method of feed water treatment to another is largely the result of a desire to eliminate as much chemical treatment as possible, provided this can be done without deleterious effects."

STATEMENT BY THE DETROIT EDISON CO., DETROIT, MICH.

Beacon Street Heating Plant

"The zeolite system installed in this plant was fully described in a paper entitled 'Zeolite Water Treatment in a Large Central Heating Plant,' by Messrs. White, Walker, Partridge and Collins, presented at the 1927 convention of the American Waterworks Association. At that time the system had been in use only a few months, and consequently but little operating experience had been accumulated. However, the system has continued to give generally satisfactory performance, and due to its simplicity only a moderate amount of attendance is required.

"The acid treatment has successfully maintained safe conditions as regards caustic embrittlement. Some trouble has been experienced with the lead pumps handling the dilute acid mixture (a 4.5 per cent solution of sulphuric and a 0.5 per cent solution of phosphoric acids) and apparently some replacements of parts will always be necessary.

"The boilers have been operated at high steaming rates with no scale formation. Trouble has been experienced with corrosion which we attribute to the low pH value of the water occasioned by the presence of a considerable amount of $NaHCO_3$ and some CA_2. There is also a varying amount of oxygen present. This corrosion began immediately above the bed of zeolite and was evidenced in the cold and hot boiler feed piping, feed water heater, and, to some extent, in the boilers. It appeared as blisters containing green ferrous carbonate, which upon oxidation was changed to ferric oxide. A shallow pit would be found under each blister.

"This trouble has recently been successfully overcome by several different expedients applied to different parts of the system. In the cold water tanks and pipes protective coatings of several kinds have been tried with apparent success, although it is too early to make any definite statement. Cement lined pipe and pipe coated internally with bitumastic paint is being tried. In the feed water heater experiments with cadmium plating of the trays are giving promise of good results.

"Corrosion in the hot boiler feed lines and in the boilers has, we believe, been eliminated by the simple expedient of recirculating sufficient blow-off water back into the water space of the heater. This water, obviously, is rather highly caustic, hence all the free carbon dioxide in the initial water is converted into sodium carbonate, and the sodium bicarbonate is also converted to sodium carbonate, thus making the water sufficiently alkaline that it is non-corrosive to the metal.

"The small amount of phosphoric acid, about six p.p.m. of water treated, is added in order to precipitate any calcium present as calcium phosphate, which forms a thin coating on the boiler metal and helps, we believe, to inhibit corrosion. Some calcium is always present (about one or two p.p.m.) because of its non-removal by the zeolite.

"Two protective coatings, Nitrose and Apexior, have been used and are apparently successful in producing a rather permanent protective coating in the drums. It is felt, however, that the recirculation of the blow-off water is adequate to prevent further corrosion in the boilers and hot pipe lines. This experience emphasizes the fact that, with water containing considerable sodium bicarbonate and free carbon dioxide, corrosion is likely to occur even though the O_2 content is exceedingly low.

"The zeolite system operates on automatic control, and the engineer in charge is warned by an electric signal when a filter bed has softened a predetermined amount of water.

"The Leeds & Northrup conductivity meter, which records the conductivity (and, therefore, the corresponding concentration) of the blow-off water from each boiler, has given considerable trouble due to the short life of the water cells, but a new design of cell recently obtained may be an improvement. The hydrogen ion recorder, which was intended to show the pH value of the acidified water and of the water entering the boiler is not at the present time regarded as a suitable operating instrument."

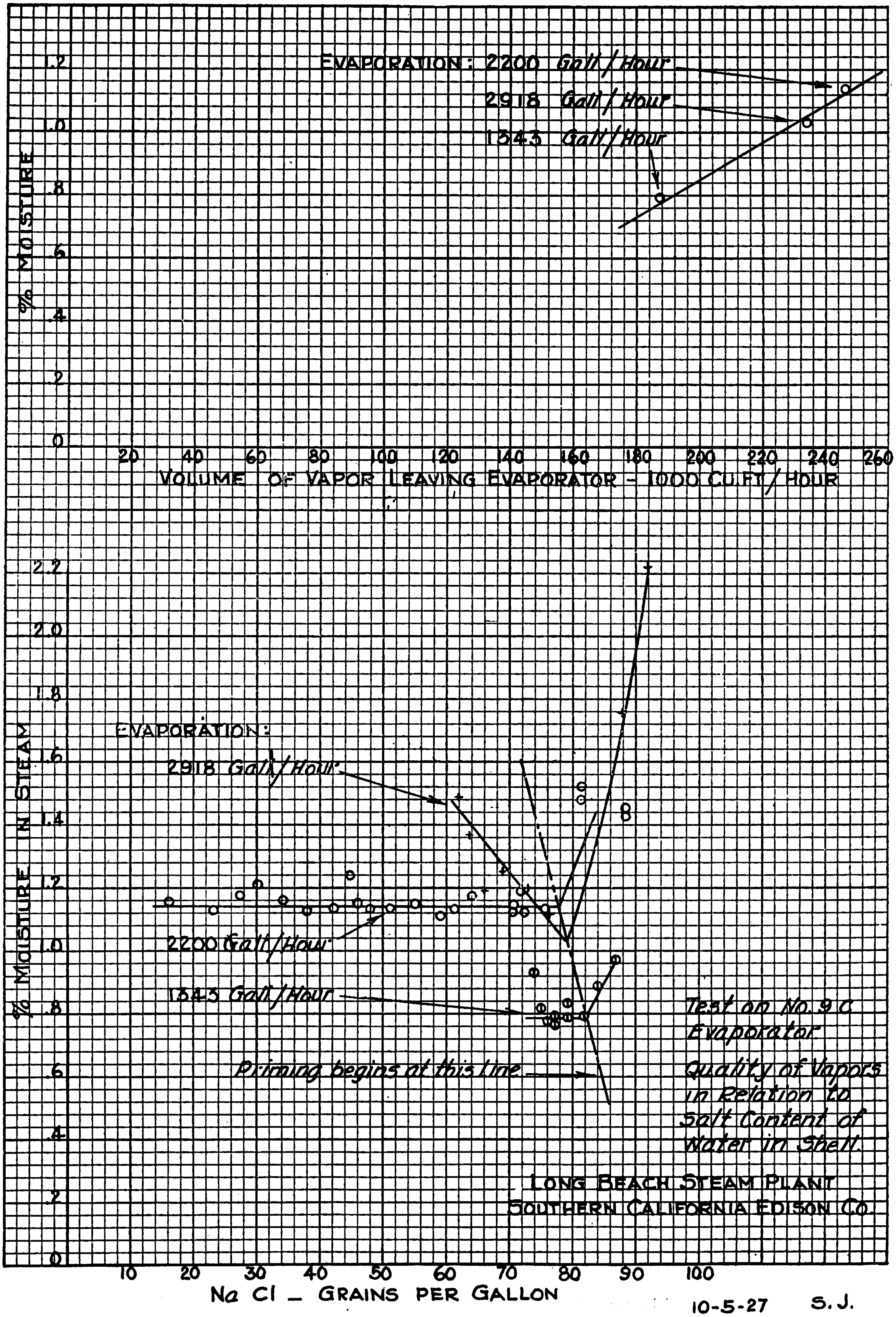

FIG. 3—TEST ON NO. 9 C EVAPORATOR—LONG BEACH STEAM PLANT.

STATEMENT BY THE CONSOLIDATED GAS, ELECTRIC LIGHT & POWER CO., BALTIMORE, MD.

"Table No. VII gives the results of tests made on deaerating heater No. 6 at the Westport Station."

STATEMENT BY THE SOUTHERN CALIFORNIA EDISON CO., LOS ANGELES, CAL.

"Fig. 3 gives the moisture content in the vapor from the evaporators at the Long Beach steam plant."

TABLE VII

TESTS ON HEATER NO. 6, MAY 8 AND 10, 1928—WESTPORT STATION

Item No.	Orifice in vent line	1 in.		2 in.		
	Test No.	1	2	3	4	5
1	Duration of test, hrs	2	2	2	2	2
2	Barometer, in. hg	30.18	30.11	30.00	29.98	30.01
3	Quantity of water admitted to heater, lb. per hr	149,670	302,690	105,800	200,400	300,400
4	Inlet water temperature, °F	139.95	136.77	143.5	140.5	138.9
5	Outlet water temperature, °F	214.77	213.87	214.3	214.0	213.1
6	Rise through heater, outlet-inlet, °F	74.82	76.10	70.8	73.5	74.2
7	Steam pressure at inlet, lb. per sq. in. abs	15.68	15.86	15.70	15.65	15.62
8	Steam temperature corresponding to abs. pressure, °F	215.80	215.20	215.3	215.1	215.0
9	Steam temperature as measured, °F	270.81	293.88	267.7	276.1	266.9
10	Superheat, °F	55.01	78.68	52.4	61.0	51.9
11	Oxygen content entering, c.c. per liter	0.21810	0.32280	0.40480	0.21780	0.28620
12	Oxygen content leaving, c.c. per liter	0.06510	0.05760	0.00000	0.00698	0.00838
13	Oxygen removal, %	70.144	82.162	100.000	96.795	97.073
14	Amount of steam vented, lb. per hr. (from calculations)	237.7	214.2	990.3	939.6	908.9
15	Temperature difference, °F. (sat. temperature corresponding to back pressure and outlet water temp.)	1.03	1.33	1.00	1.10	1.90
16	Pressure drop through control valve, lb. per sq. in	......	12.57	22.92	19.20	15.92

MANUFACTURERS' STATEMENTS

STATEMENT BY THE ELECTRO-CHEMICAL ENGINEERING CORP., CHICAGO, ILL.

"The Electro-Chemical Polarization Process for preventing corrosion in steam boilers, feed water heaters, condensers, etc., utilizes an electric current of low voltage, which is passed through the water as an electrolyte from submerged anodes that are insulated from the metallic portion of the boiler or appurtenances. The current used is approximately two to three milliamperes per sq. ft. of protected surfaces, the source being a two or three volt direct current.

"An arsenical compound is added to the water at definite periods, depending upon the nature of the service, and this is plated out on the heating surfaces. The object of this arsenic plating is to effect polarization of the cathodic boiler metal, which is accomplished because of the high discharge potential of hydrogen upon arsenic. Depolarization of this hydrogen film by the oxygen dissolved in the boiler feed water is prevented by constantly plating out an excess of nascent hydrogen by means of the imposed electric current passed from the anodes.

"This combination has proved very successful in stopping corrosion in locomotive boilers in various parts of the country. Definite, effective results have been reported as being realized in locomotives operating on very corrosive waters from Texas to Montana and Maine, indicating that the nature of the water does not alter the effectiveness of the method. Several installations applied to locomotive boilers using corrosive waters that ordinarily destroy the boiler material within the normal shopping period have been permitted to pass through the shops without requiring the usual renewal of materials. Indications are that this cycle will be duplicated at the next shopping of such locomotives. Great savings are manifested with this kind of performance. We believe that the future of this method of corrosion prevention is very promising."

STATEMENT BY THE NATIONAL ALUMINATE CORP., CHICAGO, ILL.

"One of the most recent developments in the treatment of water for boiler feed is the use of K.W.S. sodium aluminate. It has been repeatedly demonstrated in the past few years that the use of this alkaline coagulant has a number of distinct advantages:

1. In chemical water softeners to replace acid coagulants, such as ferrous sulphate or aluminum sulphate.
2. For use as a coagulant for internal treatment of boilers or evaporators.
3. For pre-softening and clarification preceding Zeolite.
4. For use in conjunction with acid coagulants for electrification only.

"One of the chief difficulties in the proper operation of chemical water softeners is the complete removal of the finely divided suspended matter thrown out of solution by the lime and soda ash treatment. Such material frequently must be removed by filters, and in fact at times is only partially removed by this medium. It has become quite general practice, therefore, to use some form of coagulant in conjunction with lime and soda ash to precipitate such matter in the settling tank itself, thus better preserving the filter medium, saving wash water, and minimizing the possibility of such matter passing through the filter. The disadvantage of other coagulants for this purpose is that they react with the lime and give calcium sulphate as part of their reaction. This must be softened with soda ash, and gives as a result excess sodium sulphate which in turn increases the total solids in the boiler feed.

"With sodium aluminate the reaction takes place best with the magnesium in the water, giving magnesium aluminate, a very flocculent precipitate. Thus coagulation is obtained by direct reaction of the coagulant on the natural incrusting salts in the water, rather than requiring additional softening chemicals for reaction. Thus essentially, no excess soluble salts are formed due to the use of sodium aluminate.

"On certain turbid waters under 171 p.p.m. of hardness this has permitted a reduction of as high as 40 per cent in blow down requirement. In addition to its coagulating properties, however, even more important advantages are found in the speed of reaction of sodium aluminate. This permits of faster softening reaction, which increases plant capacity and produces a more stable resultant water, practically eliminating after reaction. This is due chiefly to its powerful and definite reaction on magnesium salts. Generally it is possible to produce a water of lower hardness with less excess treatment, or if need be produce a water which can be handled without difficulty with higher excess treatment.

"For internal treatment in a boiler or evaporator, the chief advantage of the use of sodium aluminate is in its coagulating power. Of course, the softening power is of distinct advantage also, but its chief function is to coagulate the finely divided particles thrown out by chemicals and heat, and thus inhibit scale formation and carry-over.

"For economical reasons it is generally advisable to use auxiliary softening reagents, such as soda ash, to finish the softening reactions. Only sufficient sodium aluminate is used to obtain proper coagulation. With this use of sodium aluminate it is, of course, just as necessary to check boiler water analysis as it is to check that of water from softening plant equipment, and special equipment and methods to check boiler water hardness, alkalinities, concentration, and for sulphate to total alkalinity ratio for prevention of embrittlement, have been designed for this purpose. Such equipment and methods are especially adapted to power plant use so that both the method and equipment are simple enough, so that power plant operators will not have to be chemists to understand the fundamental principles involved. With this method control is sufficiently positive, and results are, therefore, more nearly assured. Little time is required for such tests.

"For pre-treatment of water preceding zeolite, sodium aluminate in conjunction with lime, or with lime and soda ash, will give a clear water of lower total alkalinity, and with lower phosphate alkalinity or causticity reading. This is desirable to prevent incrustation of zeolite mineral.

"In straight water clarification (filtration), it is found that with the use of a very small amount of sodium aluminate in conjunction with an acid coagulant, subsidence is much faster and reaction is more positive, independent of the condition of the water itself. Also on waters of low pH value, coagulation can be obtained with a higher resultant pH and with lower CO_2 content, as compared to the use of an acid coagulant alone."

STATEMENT BY THE PERMUTIT CO., NEW YORK, N. Y.

Zeolite Softeners

"A few of the larger high pressure installations of zeolite softeners that have been contracted for during 1928, are given in Table VIII.

"A saving is obtained in operating costs (for chemicals) by using zeolite treatment, due to the fact that salt to regenerate zeolite in many localities is less expensive than the soda ash required to treat the same water. The city of Sewickley, Pa., is now installing a zeolite plant to treat 690,000 lb. per hr. Several power plants with existing hot or cold lime soda plants have replaced them with zeolite because of the improved quality of the effluent and lower operating costs.

Natural Brine and Sea Water Used for Regeneration

"Progress has been made in utilizing natural brines or sea water to regenerate zeolite. After considerable experimentation, the effects of the calcium and magnesium impurities in such natural brines on the capacity of the zeolite, and on the manner of applying regeneration, have been determined. Several large zeolite plants, two of which soften 34,700 and 52,000 lb. per hr., respectively, are successfully using sea water for this purpose, while one plant of 173,000 lb. per hr. capacity successfully uses natural brine from wells. Central power plants, located where natural brine wells are in existence or where sea water is available, should investigate this possibility because treatment is thereby obtained without any cost for chemicals, and only the fixed charges on the investment are left.

Zeolite Plants Preceding or Replacing Evaporators

"In some cases the difficulties and costs of scale removal, and heat losses by radiation and blow down of evaporators, have been reduced by installing zeolite ahead of the evaporators and using a continuous blow-off arrangement. This has eliminated scale problems and part of the losses of heat by blow-off. It is noteworthy that two transatlantic liners, the *Aquitania* and *Majestic,* have recently announced

TABLE VIII

RECENT ZEOLITE INSTALLATIONS FOR HIGH PRESSURE BOILERS

Installation	No. of Boilers	Type Boiler	Sq. Ft. H.S.	Per Cent Makeup	K.B.t.u. per Sq. Ft. per Hr.	Per Cent Rating	Steam Pressure Lbs. per Sq. In.
1	4	Kidwell	10,000	33	10.1	300	250
2	2	Kidwell	10,000	30	11.8	350	450
3	2	Erie City	8,070	50	7.6	225	250
	5	Waste heat	4,500	50	2.6	78	250
4	3	Heine	6,000	30	6.7	200	400
5	3	Heine	10,000	28	10.1	300	450
	4	B. & W	4,000	......	......	......	175
	2	Erie	5,000	......	......	......	175
6	3	Crossdrum	10,000	50 to 100	12.6 to 21.9	375 to 650	450
7	6	Bigelow Hornsby	12,000	6.0	......	......	300
8	3	B. & W	17,500	......	8.4 to 13.5	250 to 400	400
9	8	B. & W	15,000	......	......	......	400
10	7	B. & W	15,000	4	......	......	300
11	1	Combustion Engineering	......	15	......	......	450
12	1	Combustion Engineering	60,000	......	5.0	150	450
13	3	B. & W	12,910	25 to 45	7.6	225	275
	2	W. W	12,910	25 to 45	11.8	350	275
	2	Combustion Engineering, per hr. ea.	150,000 lb.	25 to 45	......	......	275

their discontinuance of evaporators and the installation of zeolite plants to treat the fresh water make-up which they carry in their tanks from port to port.

"Distilled water, even if oxygen free, may be corrosive, because when it is heated to boiler pressure and temperature, its pH value decreases appreciably. This requires the addition of alkali. Furthermore, condenser leakage frequently introduces scale-forming constituents into the boiler feed water, and for this reason alkali is usually added. For practice in the addition of this alkali, see the Navy Department 1922 Manual of Engineering Instructions, Chapter 6, and for the usual stationary practice, see *Power,* June 9, 1925, page 899. If alkali is added to the feed water, in order to overcome its acidity at high temperatures and to counteract scale-forming constituents from condenser leakage, then it also may become necessary to add sulphates if the so-called sulphate-carbonate ratio is to be maintained. After this treatment the final feed water is not superior to zeolite softened water, which usually contains natural alkalinity to take care of these conditions. Boilers fed with condensate from leaky condensers and distilled make-up water must be blown down to remove the hardness-forming constituents introduced through the condenser leaks. Heat losses will result if the heat of the blow-off water is not recovered, but if apparatus for recovering this heat is installed, the same apparatus can recover all the heat in the blow-off water in the event that the make-up water is derived from a zeolite softener instead of an evaporator.

"It is difficult to blow-off intermittently such amounts as will keep the concentration between certain limits and yet avoid excessive waste of heat. Intermittent blow-off is rapidly being abandoned, and continuous boiler blow-off is becoming recognized as the best practice, just as continuous feeding has replaced intermittent feeding. If continuous boiler blow-off is used, the only effect of evaporators is to reduce the amount of water thus continually blown off, and since the heat of this blow-off stream is recovered by heat exchangers, the greater economy of zeolite plus such continuous blow-off, as compared with evaporators, will become apparent.

Permutit Continuous Blow-Off Apparatus

"A number of power plants have contracted for such blow-off apparatus in 1928, among which may be mentioned those listed on Table IX, attached. We have designed an excess flow check valve, which closes as soon as the rate of flow exceeds the predetermined rate. This is a safety feature to prevent the boilers from emptying in case any of the pipe lines should fail.

"The rate of flow controller, see Fig. 4, is so designed that a constant depth of boiler salines (after cooling in the

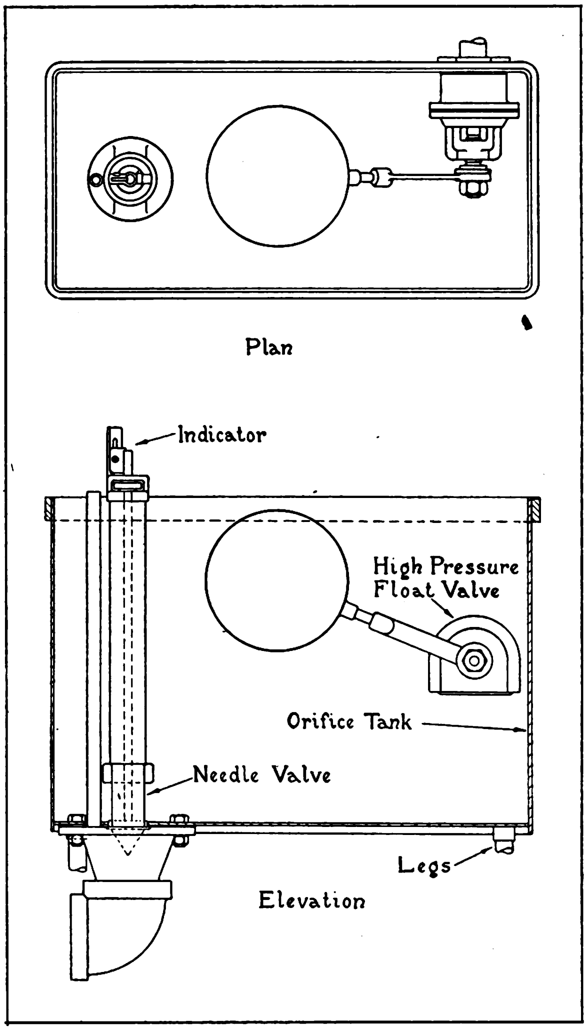

FIG. 4—PERMUTIT CONTINUOUS BLOW-DOWN CONTROL.

TABLE IX

TYPICAL PERMUTIT CONTINUOUS BOILER BLOW-OFF INSTALLATIONS

Installation	No. of Boilers	Lb. per Hr. Average Evap. per Boiler	K.B.t.u. per Sq. Ft. per Hr.	Per Cent Rating	Lb. Pressure	Type of Boilers	Lb. per Hr. Blow-Off per Boiler	Number of Heat Exchangers	Number of Rate Controllers
1	3	18,000	6.7	200	180	Stirling	960	1	3
2	6	55,000	5.8	175	175	Bigelow Hornsby	2,000	2	6
3	2	110,000	10.1	300	450	Edgemoor Crossdrum	3,500	1	2
4	3	40,000	5.0	150	200	Edgemoor	1,800	1	3
5	3	140,000	13.5	400	390	B. & W. Crossdrum	5,000	1	3
6	1	112,000	10.1	300	300	Badenhausen	10,000	1	1
7	3	200,000	13.5	400	450	B. & W. Crossdrum	10,000	1	3
8		300,000	13.5	400	250	Ladd	20,000	1	1
9	4	27,000	5.0	150	175	Stirling	370	1	4
10	4	30,000	6.7	200	200	Wickes Horizontal	1,000	1	4
11	2	175,000	1.18	350	200	Heine V Type	6,000	1	2
12	5	11,000	4.0	120	150	B. & W. Heine & Kieler	350	2	5
13	7	90,000	8.4	250	200	B. & W. Crossdrum	10,000	2	7
14	3	90,000	10.1	300	240	Edgemoor Crossdrum	2,400	1	3

TABLE X

ACID AND PHOSPHATE FEED INSTALLATIONS

Installation	Daily Capacity Gal.	Lb. Acid Daily	No. and Make of Boilers	Sq. Ft. H.S.	Per Cent Make Up	K.B.t.u. per Sq. Ft. per Hr.	Per Cent Rating	Steam Pressure	Remarks
1	240,000	144	5 B. & W.	5,000	6	....	....	575	2 grav. feeds H_2SO_4
			12 B. & W.	16,000	....	....	......	....	....
			11 B. & W.	17,000	....	....	......	....	....
2	144,000	87	7 B. & W.	15,000	4	....	......	300	2 grav. feeds H_2SO_4
3	144,000	87	20 B. & W.	5,600	5	5.0	150	250	2 grav. feeds H_2SO_4
			20 B. & W.	12,200	....	....	......	....	....
4	230,000	116	4 B. & W.	4,200	100	3.3	100	195	1 grav. feeds H_2SO_4
5	3,500,000	2,100	8 B. & W.	15,000	100	3.3	100	400	1 grav. feeds H_2SO_4
6	108,000	65	4 B. & W.	10,000	5	....	......	300	2 grav. feeds H_2SO_4
			4 B. & W.	14,080	....	....	......	....	....
7	180,000	108	3 B. & W.	14,000	5	....	......	350	1 grav. feeds H_2SO_4
8	290,000	300	5 B. & W.	7,230	100	....	......	200	1 grav. feeds H_2SO_4
9	1,730,000	870	3 B. & W.	10,000	50-100	12.6	375	450	Helical rotor feed
			Crossdrum	......	....	21.9	650	....	....
10	72,000	55	5 Titus	1,500	70-90	....	......	90	Pressure feed
11	860,000	330	4 Stirling	7,780	90	6.7	200	300	Pressure feed
12	549,600	220	4 Stirling	8,400	75	6.7	200	375	Sodium bisulphite
13	1,150,000	23	1 Combustion Engineering	150	150	15.1	450	....	....
			35 Other boilers	150	60-160	4.4–15.1	130-450	....	Phosphate
14	36,000	30	4 Heine	4,000	25	6.7	200	100	Phosphate
			2 Heine	1,250	....	....	......	....	....

heat exchanger) is maintained over an adjustable orifice. A specially designed high pressure float valve maintains a constant level. These float valves are in actual use, withstanding a boiler pressure of 450 lb. per sq. in. Because of the low depth in this box, the controlling orifice in its bottom is necessarily large. This avoids the difficulties which would be experienced with small orifices for the regulation of the rate of flow. The high pressure float valve is self-cleansing to a considerable extent, because if any small particles enter the ports when in a throttled position, a reduction in flow causes the level to drop in the box, which opens the ports of the float valve wider and allows the particles to come through. Furthermore, by controlling the rate of flow after the heat exchanger, the blow-off water does not flash into steam and these controllers can, therefore, be placed in any room without provision for the removal of the vapors that would otherwise rise from them. This permits easy inspection, and since each boiler has its own controller (see Col. 9 of Table IX), the operator can see at a glance which boilers are being blown off correctly.

Acid Feeds

"The danger which is sometimes feared with acid feeds, installed to provide a predetermined sulphate-carbonate ratio in the feed water, is the feeding of an excess of acid. We have developed a new type of acid feed which fulfills the following specifications:

1. If any part fails, it results in stopping the feeding of acid, and optical signals inform the operator.
2. The acid is stored and measured in concentrated form and is then automatically and continuously diluted in the apparatus itself on its way to the water to be treated. Accordingly, it occupies a minimum of space and does away with the process of intermittently diluting acid manually, which must be done slowly and carefully.
3. The feed water is measured by a meter in the supply pipe, and this meter actuates the acid pump through electrical and mechanical connections, in proportion to the actual amount of water fed. If no water passes into the boiler, then the meter does not move and cannot actuate the acid feed. In addition, optical signals then inform the operator of the condition of the apparatus. An installation of one of these feeds, handling 600,000 lb. per hr., is now being made, and is referred to with others, in Table X.

"In 1928 there came to our attention only two cases of boiler failure where zeolite treated water was used, and these were ascribed by others to so-called 'caustic embrittlement.' We had an opportunity to examine samples of the boiler material from both these cases. One was a boiler purchased second-hand during war times; the cracked drum was found to contain many rivet holes that did not match; signs of the use of drift-pins were in evidence, indentations under the rivet heads indicated the use of excessive riveting pressures, etc. Only one boiler failed in this plant out of a battery of four using the same water.

"In the other case a number of water tubes cracked circumferentially in certain rows of the boiler. It could not be explained why caustic soda should have concentrated in these rows.

"Metallurgical reports on samples of steel from the tubes showed that the steel was not above reproach. Furthermore, incipient cracks started on the fire side of the tubes, and only where the rolling in of the tubes had produced excessive deformations.

Continuous Blow-Off Plus Acid Feed

"This combination permits an added factor of safety against acid corrosion of feed lines and economizers. Part of the alkaline boiler blow-off water is continually added to the acid treated water after aeration or in the bottom of the heater. The acid reacting with the alkalinity forms CO_2. This is partially liberated in the aeration chamber installed with our acid feeds. The remaining CO_2 is then removed in the heater. The alkaline blow-off stream then enters the water and raises the pH value of the feed water to any desired limit. See Fig. 5.

Sodium Phosphate Feeds

"We have developed a simple phosphate feed where maintenance of a phosphate-carbonate ratio is desired instead of a sulphate-carbonate ratio. This feed has no moving parts, requires no pumps, and works hydraulically. See Fig. 6.

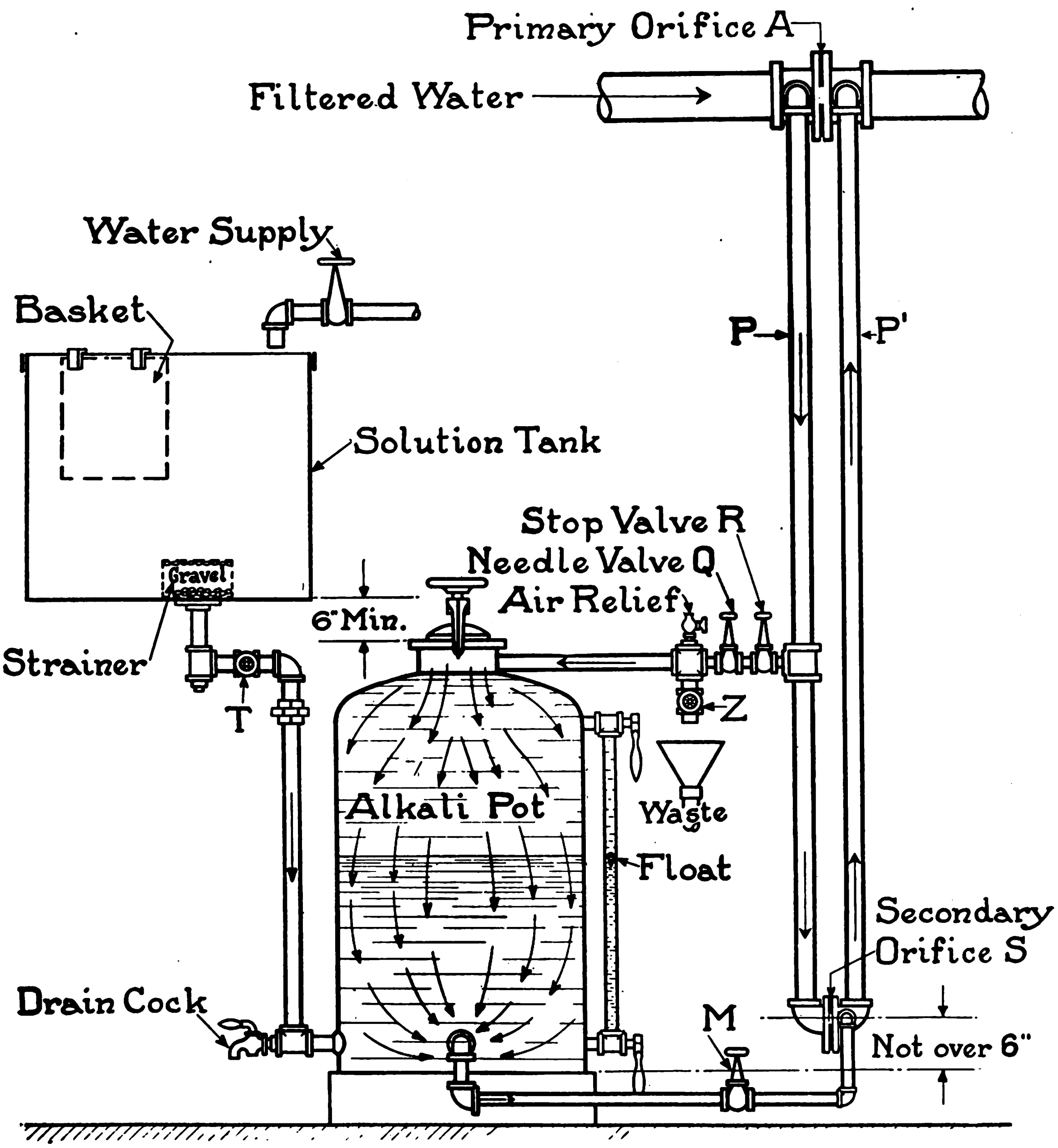
Primary Orifice A
Filtered Water
Water Supply
Basket
Solution Tank
P
P'
Stop Valve R
Needle Valve Q
Air Relief
Gravel
6" Min.
Strainer
T
Z
Alkali Pot
Waste
Float
Secondary Orifice S
Drain Cock
M
Not over 6"

FIG. 5—ZEOLITE TREATMENT WITH CONTINUOUS BOILER BLOW-OFF AND ACID FEED.

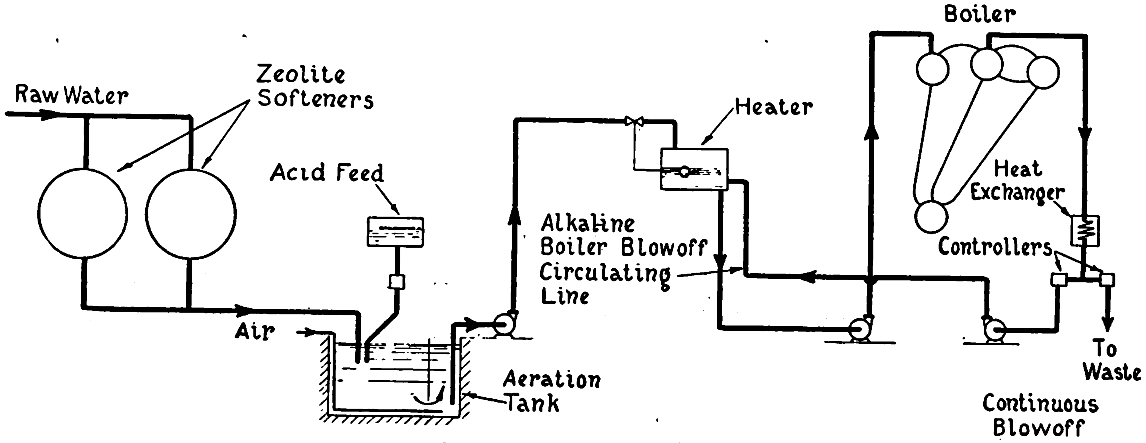
Boiler
Raw Water
Zeolite Softeners
Heater
Acid Feed
Heat Exchanger
Alkaline Boiler Blowoff Circulating Line
Controllers
Air
Aeration Tank
To Waste
Continuous Blowoff

FIG. 6—PERMUTIT ACID FEEDER.

It operates as follows: the di- or tri-sodium phosphate is dissolved in the solution tank, and is then drained into the feeder pot. The glass float in the column attached to this pot floats in the solution but sinks in water, and, therefore, indicates the position of the top surface of the phosphate solution. When the contents of the pot have been used up, the float is low and indicates the need of recharging. The actual feeding is accomplished from the pot by displacement. Primary orifice 'A' causes a pressure drop in proportion to the flow, and forces some water through Primary Shunt Line 'P' and its return 'P'' thus creating a pressure drop across Secondary Orifice 'S.' This in turn forces water into the top of the pot, displacing the chemical solution which passes through 'P'' into the raw water. The design and location of the primary and secondary orifices and the proportioning of the pot and pipe sizes make it possible to feed the chemical in amounts that are always proportional to the rate of flow of the water to be treated."

OPERATING CODE MANUAL

The apparent need for a manual of this type, outlining rules of operating procedure in both the boiler and turbine rooms of steam-generating plants, has led the Prime Movers Committee to revise and republish in convenient form all of the previous reports of the Subcommittee on Operating Code Manual.

The rules contained in the previous reports were based on the comments and criticisms to questions contained in questionnaires drafted from rules extracted from the Station Operating Handbook of the Philadelphia Electric Company.

As it is impossible to formulate one set of rules to fit all cases, no attempt is made to stress adherence to the sequence of the different operations, it being understood that modifications are necessary, depending upon the best judgment of the particular problems and upon the installed equipment in each individual plant.

However, the use to which an operating code may be placed lies entirely in the hands of the individual engineers. It is very probable that in emergency cases such rules will of necessity be overstepped or entirely ignored, but their very existence and the familiarity of the operator with them for normal operation will cause them to serve as a guide and promote good judgment in cases of emergencies.

The value of a code of this kind is not measured by the exactness with which the rules embodied are carried out, but rests, rather, upon the fact that these rules in their general make-up include all possible necessary phases of any particular operation.

SECTION I—BOILER PLANT

A—GENERAL OPERATION

1—Boilers

In order to avoid duplication wherever possible, this part of the code covering the general operation of boilers has been so formulated as to apply both to stoker fired and to pulverized fuel fired boilers. To assist in fixing the application of a rule to the specific type of installation, the following nomenclature has been adopted: (1) Rules which apply to both stoker and pulverized fuel installations have no marking other than the number of the rule itself, such as "101," Rule 2. (2) Rules which apply solely to stoker fired boilers have the letter "S" following the rule number, such as "101," Rule 6-S. (3) Rules which apply solely to pulverized fuel fired boilers have the letter "P" following the rule number, such as "103-P."

The rules for stoker fired boilers have been drawn up particularly for underfeed stoker installations, but it should be readily apparent wherein these rules should be modified in particular cases to cover other types of stoker firing.

[Note: Blank spaces (......) to be filled in by plant engineers to suit their individual plant operation.]

100. Inspection Before Taking Over the Shift

At the beginning of each shift, before taking over the shift, the Water Tender or Boiler Operator must proceed as follows:

1. Blow down the water column and gage glass on each boiler and test the gages by opening the gage cocks to determine the water level.

This should be done by the Water Tender or Boiler Operator, but anyone else detailed may blow down duplicate columns under supervision of the Water Tender or Boiler Operator.

2. Observe fires, ratings and instruments; then judge if fuel feed is correct for maintaining same, or for correcting furnace conditions or ratings.

Attached to each boiler should be a chart of instructions developed for proper operations under normal conditions. If it is impossible to adhere to these instructions, the Boiler Engineer should be informed.

3. Examine the gage board to see that all instruments are in operation.

4. The Water Tender or Boiler Operator leaving the shift must report to his relief any unusual or special conditions pertaining to the apparatus and fires. Special attention must be given in this report to the condition of the automatic feed water regulators and hand operated feed water valves.

5. On taking over the shift, the Water Tender or Boiler Operator assumes full responsibility for further operation.

101. General Operation

1. After assuming responsibility for the shift, the Boiler Operator or Water Tender must not leave the boiler room floor under any consideration without notifying the Shift Superintendent or Boiler Engineer. In any event, the Water Tender or Boiler Operator is responsible for boilers assigned at all times and must not leave the floor in time of trouble or impending trouble.

2. Maintain about .... to .... gages of water in each boiler when steaming.

3. All boilers should be operated at or near the same rating, except when specific characteristics of individual boilers demand a departure from this rule.

4. Draft and fuel feed should be set, using instructions posted by supervisory force on bulletin board as a guide, altering them, if necessary, to suit existing conditions.

Publication No. 289-58. Serial Report, Prime Movers Committee.

5. Always maintain the draft over the fire as stated on the chart. Exception is made to this only for a short time before dumps in stoker fired stations having no means of putting air on the extension grates and in emergency cases.

6-S. All extension grate dampers should be opened according to the general instructions of the Boiler Engineer.

7. Fires should be inspected by the Water Tender or Boiler Operator from the front, side and rear doors from time to time, and when instruments indicate irregularities to determine their condition.

This should be done by the aid of colored glasses made for this purpose.

8-S. When dumping time approaches all fires must be inspected, and those fires which have unburned coal on the dump plates should, if possible, be burned down in the rear before dumping.

If there is so much coke on the dump plates that it is impossible to properly burn it down, this coke should, if possible, be winged back on the fire with a bar.

Where extension grates are installed, the rear of the fire may be burned down by opening the extension grate dampers. Where these are not installed, the rear boiler damper should be opened wider than usual.

9-S. Dump each fire as rapidly as possible, but allow sufficient time between boilers so that the steam pressure will not be affected.

10-S. With boilers equipped with clinker crushers, care must be taken to see that large clinkers do not form in such a position that they will not go through the rolls. This type of clinker should be hooked around with a bar so that its length is parallel with the clinker crusher.

The ash should be held in such amount as permits of best furnace operation.

11. Blow down the boiler from both the main and surface blow-off (when provided) according to the instructions of the Boiler Engineer.

The main blow down should be made with the boiler banked, if possible, or steaming capacity checked.

12. The blow-off valves of the economizers should be operated according to instructions of the Boiler Engineer.

13. The procedure in blowing down main blow-offs is as follows:

(1) Open plug cocks with lever wrench.
(2) Open main blow-off valves slowly.
(3) Close main blow-off valves slowly.
(4) Close plug cocks with lever wrench.

[NOTE: While blowing down, the Water Tender should watch the level of the water in the gage glass.]

14. The following items should be entered on the Boiler Room Log Sheet (Form ......) by the designated person.

(a) The number of hours each boiler was steaming, banked and out;
(b) The time of dumping;
(c) The number of hours the fans were in operation;
(d) The reading of the stoker counters at midnight;
(e) The amount of blow-down.

102-S. Putting a Boiler on the Line—Stoker Fired

1. Remove all danger or "Out of Service" signs placed on valves and equipment controls, and inspect all boiler setting doors to see that they are tightly closed.

2. See that blow-off valves are all closed. Where a safety stop gate valve is connected to the blow-off line, see that this valve is open.

3. Open all vent valves.

4. Close all drain valves.

5. See that valves controlling water column and pressure gages are in operating condition and open.

6. See that water column blow down valves are closed.

7. Open the water feed valves to the boilers slowly for one or two turns. (On boilers equipped with separate economizers, see that the valves between the boilers and economizers and economizer vents are open.)

8. Fill the boiler to about ....

9. Operate superheater drains according to instructions of Boiler Engineer.

10. Start the stoker and fill the grate about .... way down with coal.. This requires about .... revolutions of the stoker.

11. See that the change-over valve on the water back lines is set for raw water.

12. Open the feed and discharge valves on the water backs.

13. See that "tell tales" are open and discharging water, and that the drains are clear.

14. Open the stack damper to give about .... in. draft in furnace.

15. Dig holes in the coal over the tuyeres and put a shovelful of fire in each hole or use wood and oil-soaked waste.

16. Cover the fire with "green" coal and start stoker slowly.

17. When fire is hot enough to insure proper coking, start both the induced and forced draft fans slowly.

[NOTE: Have the electrician inspect the motor-driven forced and induced draft fans before starting.]

18. Adjust the stack damper to .... in. draft over the fire.

19. Apply .... in. blast on the forced draft.

20. Close all vents on the boiler as soon as total elimination of gas and air from boiler is insured.

21. Note that the pressure gage is operating.

22. Turn on the spray of the clinker crusher pit as soon as hot ash begins to accumulate.

23. Raise .... lb. pressure on the boiler, and unlock automatic non-return valve.

24. At .... lb. pressure, drain feed water regulator if it is of the thermostatic type.

25. Increase the speed of the fans, for both induced and forced draft, to such a degree as may be required.

26. Bring the boiler gage pressure gradually up to .... lb.

27. See that the drain valves between the main and automatic non-return valves are open.

28. Open the main stop valve by-pass valve and blow out all water from the line between the automatic non-return valve and the main stop valve.

29. Close the drain valves.

30. Open the trap line valve above the automatic non-return valve.

31. Open the main stop valve and close the by-pass on the same.

32. Increase the stoker speed and air blast until the boiler begins to steam. Keep the fire as light as possible.

The rate of increasing the blast and stoker speed is determined by how fast the boiler must be put on the line.

33. Set the change-over valve on the water back line for condensate.

34. Blow down water columns to check the water level and test safety valves when boiler is on line.

35. Cut in automatic boiler feed control.

103-P. Putting a Boiler on the Line—Pulverized Fuel

1. Proceed according to "102-S," Rules 1-9 inclusive.

2. Have coal in pulverized coal bunkers. (For unit system have coal in green coal bunkers, and pulverizing mill ready for operation.)

3. See that stack damper is open.

4. Start the induced draft fan slowly.

5. Start the primary air fans and adjust speed to give .... inches pressure.

6. Adjust the secondary air door opening and the induced draft fan speed to give .... in. furnace draft.

7. Light .... burners.

[NOTE: The following procedure in lighting burners is suggested.]

(1) Open the dampers (gates) above the coal feeder.
(2) Light the torch and insert it in the burner.
(3) Close the main switch on the feeder motor.
(4) Open the primary air damper on the feeder.
(5) Start the feeder motor by operating the push-button control.
(6) Throw in the feeder motor clutch.

8. Close all vents on the boiler as soon as total elimination of gas and air from the boiler is insured.

9. Note that the pressure gage is operating.

10. Add burners according to the individual plant schedule.

[NOTE: The rate at which burners are to be added is determined by the time allowed for putting the boiler on the line, giving due consideration to the extent of the furnace repairs which may have been made while the boiler was down.]

11. Proceed according to "102-S," Rules 23-30 inclusive, until the boiler is on the line.

12. Proceed according to "102-S," Rules 32, 33 and 34.

104-S. Putting a Boiler on the Line from a Banked Condition—Stoker Fired

1. Blow down the water column and gage glass; test the gages by opening the gage cocks, and see that there is not over .... in. of water in the gage glass when putting a boiler on the line.

2. Open the superheater drains wide and allow them to remain open until superheater is thoroughly drained and the boiler is on the line.

3. Wing the ashes back on the clinker crusher, or drop the dump plates.

4. Close the dump plates.

5. Put the long stroke on the lower ram, where hand dump plates are used.

6. Shut off the draft on the extension grate.

7. Operate the water feed valves so as to maintain from .... to .... gages of water in the boiler, until the steaming rate is such that the feed water regulators will operate satisfactorily.

8. Open feed water valves wide.

[NOTE: With a short bank, it is not necessary to adhere to the above rules; however, it is necessary to maintain not more than one gage of water.]

105-P. Putting a Boiler on the Line from a Banked Condition—Pulverized Fuel

1. Blow down the water column and gage glass; test the gages by opening the gage cocks, and see that there is not over .... in. of water in the gage glass when putting a boiler on the line.

2. Open the superheater drains wide and allow them to remain open until the superheater is thoroughly drained and the boiler is on the line.

3. Start the induced and primary air fans.

4. Light .... burners, and add more burners according to individual plant schedule, until boiler goes on the line.

5. Operate the water feed valves so as to maintain from .... to .... gages of water in the boiler, until the steaming rate is such that the feed water regulators will operate satisfactorily.

6. Open the feed water valves wide.

106-S. Dumping

1. Cut off the forced draft.
2. Open the back dampers wide.
3. Stop or reduce speed of stoker.
4. Open the ash spray valve.
5. Dump the plates in sections.
6. Reduce the rate of water feed, if necessary.
7. Clean the fires, being careful not to throw good coal down with ashes.

(If there is much coke over the top of the clinker, close the dumps before hooking out the clinker.)

8. Raise the dump plates.
9. Adjust the forced and stack drafts for load.
10. Start the stoker.
11. Shut off the ash spray valve, after ashes are thoroughly wet.

107-S. Clinker Crushers

1. Operate the clinker crusher in accordance with the condition of the fire, by adjusting its operation to keep .... ft. of ashes over the crusher.

2. Inspect the clinker crushers at regular intervals for heating.

3. The crusher doors should be set to the proper opening by the Boiler Engineer when the boiler is off and should not be changed without his knowledge or the knowledge of the Water Tender or Boiler Operator.

Any change made in the opening must be sanctioned by the Boiler Engineer or Shift Superintendent.

4. The Boiler Engineer should make inspection at specified intervals.

108. Soot Blowers on Boilers and Economizers

1. Notify boiler operator that tubes are to be blown.

2. See that the drains on the soot blower supply manifold are open.

3. Crack the main steam valve and blow the water out of the manifold.

4. Close the drain.

5. Open the main steam valve wide.

6. Open the soot blowers in rotation, beginning with the first pass.

7. As the unit is being blown, rotate the blower slowly and steadily between the stops provided on the main wheel or on the hand wheel.

8. After blowing, close the main steam valve to the manifold.

9. Open the drain on the manifold and leave it open.

10. Notify boiler operator that blowing is completed.

109. Soot Blowers on Induced Draft Fans

1. The fan should be running at lowest speed when soot blowers are opened.

2. See rules 1, 2, 3, 4, 5, 8 and 10, of "108."

110-S. Clinkers on Side Walls

1. Bank the fires, if possible.

2. Wing the coal off the clinker with a scraper or bar.

3. Break the clinker from the side wall with a bar and clean the clinker off as far down as the grate.

Push the clinker to the rear of the fire, being careful not to mix green coal with clinkers.

111. High Water

1. Cut off the forced draft.

2. Stop the fuel feed.

3. Close the feed water valve.

4. Try the gage cocks to make sure that the water is high.

5. Open the superheater drains and surface blow-off valves, if easily accessible.

6. Open the blow-off valves and blow down water level to safe working conditions.

7. Partly close the back damper. Leave sufficient draft to clear the gases.

8. Maintain practically a banked condition and blow down until the water level has been lowered to between .... and .... gages.

9. If a feed water regulator is in service, close the feed valve to the regulator and operate the feed valve by hand until the trouble has been located.

10. When normal water level is reached, put the boiler in service similar to procedure in "104" or "105."

112. Low Water

FIRST OF ALL—Try to remedy cause. Then, if conditions become dangerous, proceed as follows:

1. Close the feed water valve to the boiler.

2. Cut off the forced draft.

3. Partly close the back damper, leaving sufficient draft to clear the gases.

4. Stop the fuel feed.

5. Where possible, drop the dump plates.

6. Drown the fire and allow the boiler to cool.

7. As the steam pressure drops below header pressure, shut the main stop valve.

8. Close the trap line valve above the automatic non-return valve.

9. Lock the automatic non-return valve.

10. After the boiler is cool, open all vents between automatic non-return valve and the boiler.

11. Inspect the boiler and subject it to a hydrostatic test.

113. Priming and Foaming

1. Close the feed valve.

2. Bank the boiler.

3. Open the surface blow-off valve and blow down until the water level is lowered about one gage.

4. Start as from a banked condition.

5. If foaming is not stopped by this method, shut down the boiler and wash it out.

114-S. Hot Stoker Rams—Upper Ram

1. Break the arch over the ram with air agitators or by hand, or, should there be an obstruction, dig the coal out of the hopper and remove it.

2. Feed green coal to the ram.

Lower Ram (Caused by Fire Being Too Thin)

1. Increase the stoker speed.

2. Reduce the drafts when possible.

3. Put the long stroke on the ram.

Lower Ram (Caused by Clinkers)

1. Put the long stroke on the ram, alternating with the normal stroke to break up the clinker.

2. Put U-pins on the end of the lower ram driving bar outside of the driving link to draw the ram farther out of the fire.

3. Dislodge the clinker with bars from the side doors.

4. Reduce the air blast, if it is possible to hold steam.

5. If this fails, take the boiler off the line and remove the clinker.

115-S. Holes in the Fire

1. Increase the stocker speed, cutting out the sections in which the fire may become too heavy.

2. Decrease the forced draft to light sections of the fire, if possible.

3. When a hole is near the front wall, open the extension damper in the section in which the hole occurs.

4. See that coal is feeding into the rams at which holes occur and, if it is not, use wooden rods to force the coal to the rams.

5. If a hole is in the rear, put on the long stroke and close the extension damper.

116. Broken Gage Glass

1. Close the upper and lower gage glass cut-off valves, the lower one first.

2. Open the gage glass free blow-off valve.

3. Replace the glass and washers.

4. Open the upper and lower gage glass cut-off valves, the upper one first.

5. Close the gage glass free blow-off valve.

All opening and closing of valves in this operation must be done from the floor level and the face must be shielded from a possible jet of steam or water or from broken glass.

117. Testing Safety Valves

1. All safety valves must be tested at specified intervals.

2. Pressure should be exerted upon the lever until the valve releases. If the valve sticks, or if too great a force is necessary to open it, it should be reported to the Boiler Engineer.

118-S. Breaking of Shear Pin on Stoker

1. Pull out the clutch on the section of the stoker in which the shear pin is broken.

2. Determine whether or not the speed shaft can be turned forward with an 18-in. pipe wrench.

3. If the shaft cannot be turned, find the obstruction and remove it.

4. Examine the stoker for damage.

5. Examine the bushing in the clutch and see that the cutting edge is sharp, that the face of the bushing is flush with the face of the clutch, and that the set screw is turned down to its lowest position in the groove and not binding.

6. Replace the shear pin and start the stoker again.

119. Shutting Down a Boiler for Banking

1. Cut off the forced draft.

2. Stop both the induced and forced draft fans.

3. Cut off the fuel feed. In case of a light stoker fire at the time of banking, let the stoker turn about .... revolutions to give a bed of green coal and repeat this operation approximately every hour during the banking period.

4. Close the damper of the stack draft until the opening is just sufficient to clear the furnace of gases.

5. Close the main feed water valve to the boiler.

120. Taking a Boiler Off the Line

1. Cut off the coal supply.

2. Set the change over valve on the water back line for raw water.

3. Run the coal feed pipes and hopper empty.

4. Cut off the fuel feed.

5. Shut off feed water valves, keeping the water in sight above the nut on the gage glass.

6-S. After the coal in the furnace is burned out, cut off all forced draft.

7-P. Shut off primary air fan.

8-S. Shut off the spray line in clinker crusher pit.

9. Stop both the induced and forced draft fans.

10. As the steam pressure drops, shut the main stop valve.

11. Close the trap line valve above the automatic non-return valve.

12. Lock the automatic non-return valve.

13. Open the vent valves on the superheater and open the drain valves between the main stop and automatic non-return valves.

14. Close the stack damper.

15. Shut off the water-back feed and discharge valves after the water-back soot chamber has been cleaned.

16. Empty the boiler through the blow-off valves when the setting has cooled.

The superheater drain valves on other boilers must be closed while this is being done.

17. When the boiler is empty, see that the safety stop valve in the blow-off line is closed and close all blow-off or guard valves and cocks.

18. Hang danger or "Out of Service" signs on the main stop, main feed, blow-off valves and control board.

2—Coal Handling Equipment

201. Crushers and Breakers—Starting

1. Lubricate.
2. See that the conveyor handling the crusher or breaker discharge is operating.
3. Start the motor drive.
4. Admit coal to the crusher or breaker.

Crushers and Breakers—Stopping

1. Stop the coal feed.
2. Run the crusher or breaker empty.
3. Stop the motor.
4. Close the lubricators.

202. Green Coal Conveyors—Starting

1. See that succeeding conveyors are operating and that bins are ready to receive coal.
2. Open lubricators where necessary.
3. See that current is on magnetic pulley.
4. Start motor drive.
5. Observe proper working of entire conveyor.
6. Admit coal into conveyor from source.

Green Coal Conveyors—Shutting Down

1. Stop coal feed.
2. Empty entire conveyor.
3. Stop motor.
4. Close lubricators.
5. Inspect for improper bearing, etc.

3—Pulverized Fuel Auxiliaries

301. Rotary Direct Fired Driers—Starting

1. Inspect drier for open doors, workmen or tools inside and general condition of equipment. Prepare torch for lighting fire.
2. Lubricate.
3. Start drier drive motor.
4. Start fan and adjust air flow.
5. Start coal feed and adjust same.
6. Light torch, put into furnace and start fuel feed.
7. Remove torch after combustion is well established.
8. Readjust air flow and coal feed to give desired moisture removal.

Rotary Direct Fired Driers—Shutting Down

1. Stop fuel feed to furnace.
2. After furnace cools, stop green coal flow.
3. Stop fan after drier is entirely empty.
4. Stop drier.
5. Stop lubrication.

302. Steam and Waste Gas Driers—Starting

1. Close off all air or flue gas dampers to driers out of service.
2. Open gates above driers and allow to fill with coal.
3. Cut in steam or flue gas slowly to driers about one-half hour before starting mills according to size of driers. Start drier exhauster fan at same time.
4. Put air washer, cyclone separators or other dust removal equipment in service on drier discharge air or flue gas.
5. Check traps for leakage on drains from steam driers.

Steam and Waste Gas Driers—Shutting Down

1. Shut off steam or flue gas to driers about one-half hour before shutting down mills or long enough to run all dried coal out of drier proper.
2. If mill is to be out of operation for more than 24 hours, empty drier before stopping mill.
3. Keep exhauster fan running until mills are shut down.
4. Shut down air washer, cyclone separator, etc., on drier outlet air or flue gas.

303. Pulverizing Mills (Central Bin and Feeder System)—Starting

1. Make general inspection of mill, including lubrication, making sure that sufficient oil is in reservoirs and that journal bearings are full of grease.
2. Open valve at bottom of collector.
3. Start pulverized coal transport system from collectors to bunkers.
4. Start mill exhauster fan.
5. Open slide in coal feed to mill.
6. Start mill, adjust to load.
7. Maintain uniform feed.

Pulverizing Mills (Central Bin and Feeder System)—Shutting Down

1. Stop coal feed by releasing clutch or throwing off feeder belt to allow mill to nearly empty itself of coal.
2. Stop mill.
3. Allow exhauster to continue running for two or three minutes after mill has been shut down, then shut down exhauster.
4. Close valve on base of collector.

304. Screw Conveyors—Starting

1. Make general inspection.
2. Lubricate.
3. Open valve at discharge from conveyor.
4. Start conveyor.

Screw Conveyors—Shutting Down

1. After making sure that no coal is entering conveyor, close valve to supply line.
2. Empty conveyor.
3. Stop motor.
4. Shut valve at discharge from conveyor.

305. Transport Pump—Starting

1. Start air compressor.
2. Make general inspection of bin above pump, transport line discharge, etc.
3. Check setting of switching valves.
4. Blow out transport line with compressed air, by sections if necessary.
5. Admit compressed air to pump.
6. Make general inspection of pump.
7. Lubricate.
8. Start driving motor.
9. Open gates above screw slowly.

Transport Pump—Shutting Down

1. Close gates above screw or completely empty hopper over pump.
2. Allow screw to empty.
3. Blow out lines.
4. Stop motor.
5. Stop lubrication.
6. Allow air to flow out of pipe, adding more compressed air if necessary.

306. Pulverized Fuel Bunkers—Before Conveying Coal to Bunkers

1. Inspect high and low bin signals or indicators for proper operation.
2. See that bunker vents are unrestricted.
3. See that no covers are loose or manholes uncovered.
4. If bunker is empty, inspect feeders to see that caps are on all clean-out holes and no openings around feeders.

307. Pulverized Fuel Bunkers—When Bunker Is to Be Taken Out of Service

1. If bunker is to be out of service for more than four days, all coal should be fed out.
2. Insert blank in coal supply line joint directly over bunker.
3. Clean out all feeders.

308. Feeders—Starting

1. Make general inspection.

2. Start lubrication.
3. Start primary air fans.
4. Adjust primary air to .... in. pressure.
5. Open the dampers (gates) above the feeder.
6. Insert lighted torch in the burner.
7. Close the main feeder motor switch.
8. Open the primary air damper on the feeder.
9. Start the feeder motor with the clutch out.
10. Throw in the feeder-motor clutch.

Feeders—Stopping

1. Close gate over feeder screw.
2. Stop feeder, after running the hopper empty.
3. Stop lubrication.
4. Close primary air damper.
5. Shut down primary air fan.
6. Open the main feeder switch.

309. Mills and Burners (Unit System)—Starting

1. Furnace operator should make a thorough inspection of mill.
2. Check for proper operation of magnetic separator.
3. Start lubrication.
4. Start mill with coal supply closed.
5. Regulate boiler damper or induced draft fan to give an under pressure in combustion chamber.
6. Light and insert ignition torch through port provided.
7. Start coal feed to mill at a rate determined by experience for best ignition.
8. Remove ignition torch as soon as burners are properly lighted.
9. Increase feeder speed as required.

Mills and Burners (Unit System)—Shuting Down

1. Stop coal feed to mill.
2. Allow all coal to run out of mill.
3. Stop mill.
4. Stop lubrication.

Precautions; Care and Maintenance

There are many precautions to be observed to insure the safe operation and proper care of coal pulverizing and preparation equipment. The National Fire Protection Association has prepared a set of regulations for the installation of pulverized fuel systems which will not be repeated in this report. These regulations also contain certain precautions to be observed in operation.

Following are suggested rules to be observed during operation and for the ordinary care and maintenance of the pulverizing equipment.

351. Conveying System

1. In case of transport line becoming plugged, blow air into line through each air connection, starting at the bunker end. Continue this until line is clear.
2. High and low bin signals on bunkers should be tested every 8 hr.
3. Do not feed pulverized coal into a bunker until two hours have elapsed from the time the high bin signal operates.
4. Bunker vents should be examined and cleaned once each week.
5. If lights are provided on screw conveyors to indicate conveyors are operating, these should be carefully watched so that stoppage of screw conveyor will be noted immediately. The whole conveying and preparation system should then be shut down at once.
6. Air ports in coal pumps should be kept clean. Cleaning of these once a day will improve pump operation.
7. Covers should never be removed from screw conveyors while conveyor is in operation.
8. Examine hopper over coal pump once each week, cleaning out if necessary.
9. Blow tanks should be closed tightly at all times when not in operation by closing the dust-tight gate, flapper valve, shut-off valve, valve in emergency line and air-operated cocks. If pressure builds up in blow tanks, leaky valves or cocks should be repaired.
10. If it is necessary to admit air into the blow tank with a slight amount of coal still remaining, air should not be admitted through the air jet piping, but through the large pipe provided at the top of the tank. The air jet should not be used until skirt pipe has been raised and shot has been started.
11. When the blow tank is shut down for a period of longer than 24 hours, the tank should be thoroughly inspected internally through the manhole to ascertain whether or not any fire or smouldering coal is in the tank. All blow tanks should be taken out of service at least once a week and accumulations of coal which cannot be removed by the regular transport system removed by hand.

352. Rotary Direct Fired Driers

1. The coal should be dried by heating the coal as little as possible.
2. If drier ceases to rotate for any length of time, fuel feed should be stopped.
3. Care should be taken to prevent any overloads which ultimately might cause stoppage.

353. Steam and Waste Gas Driers

1. Driers should be emptied twice a week and cleaned thoroughly with air.
2. Outlet air or gas duct should be cleaned with air every second day.
3. Driers should be inspected for steam leaks once each week.
4. Frequent inspections should be made during operating period for fires.
5. If drier is full of coal and mill is not operating, heat should be kept from coal in drier.
6. Drier and ducts should be inspected for fire when mill is not operating and drier is standing full of coal. Inspection of outlet duct should always be made before starting up drier.
7. Steam traps on steam heated driers should be maintained in good operating condition.
8. With waste gas driers, coal should be entirely run out before shutting down mill; coal and gas gates should be tightly closed.
9. Fire or hot coals should never be allowed to

remain in drier or under coal spout, and under no conditions allowed to enter mill.

354. Pulverizing Mills, Exhausters and Collectors

1. Do not allow mill to run empty.
2. Make routine inspection of puff doors and wearing parts for leakage.
3. Clean out mill wind box once each day or more often if necessary.
4. If automatic feeders are provided, these should be set so that mill does not choke and motor is not overloaded.
5. Check weekly for capacity and fineness of product.
6. In case of unusual sound in mill, stop mill and inspect for cause.
7. On mills where explosion dampers are provided, these should be kept open when mills are not in operation. This is to take care of any accumulation of gas in mill or cyclone. Also, vent should be closed to drier duct while mill is down.
8. No hand holes should be opened when equipment is in operation.

355. Bunkers

1. Bunkers serving boilers to be out of service for more than 100 hr. should be emptied and feeders cleaned out.
2. Bunkers serving boilers to be out of service for less than 100 hr. coal gates above feeders should be closed and coal feeders run out before laying off boilers.
3. Bunker vents should be checked once each day and cleaned once each week.
4. Information as to when a boiler is banked should be given to operator responsible for filling bunkers, so that no more coal will be added to that bunker until boiler again begins steaming.
5. Do not open man-hole or inspection openings in pulverized coal bunkers while fuel is being discharged into these bunkers.

356. Lighting Fires (Unit System)

1. Care should be taken to keep clear of burners and other openings in furnace front in case of fire and smoke puffs when coal ignites.
2. Care should be taken to prevent visitors or employees from standing or passing in front of boiler when it is being lighted.
3. After burners have been lighted, all boiler instruments should be checked to see that they are operating properly.

357. General

1. Records should be kept of all troubles and replacements.
2. Proper periods should be established for general inspection of equipment. Inspections should be made regularly and logs maintained of these inspections.
3. All moving parts should be periodically lubricated. These periods should be established and equipment lubricated regularly.
4. Pulverized coal dust should not be permitted to leak from equipment or piping.
5. Leaks developing in any pulverized fuel equipment should be stopped and repaired at once.
6. Building and equipment should be kept clean at all times.
7. No maintenance work should be started on any equipment until the jumpers have been pulled and the motor switch tagged.
8. Records should be kept of all unusual operation and operating conditions.
9. Allow no fire, open flame, torches, burning or welding in the crushing, drying or pulverizing plant.

4—Fans

401. Forced Draft Fans—Starting

1. Inspect the entire unit's oiling system, seeing that supply of lubricant is ample, and, if of gravity or pressure feed, see that oil is feeding properly to all bearings.
2. Turn on cooling water to bearings.
3. If fan is steam driven, open drains and exhaust valve, warm up unit.
4. If fan is motor driven, have motor inspected by electrician, start unit slowly, making proper use of starting equipment.
5. Adjust dampers for forced draft operation.
6. Bring the unit up to speed.
7. Inspect the unit for vibration and, if noticeable, notify the engineer in charge of shift. If vibration is excessive, shut down unit, notifying engineer in charge of shift.
8. Close the drains.
9. Make final inspection of oiling system.
10. If main oil switch should trip for cause other than throwing from starting to running position before motor is up to speed; if fuse should blow; or, if circuit breaker should open, have inspection made by electrician and trouble corrected before starting again.

Forced Draft Fans—Shutting Down

1. Shut down the turbine or motor.
2. Adjust the dampers for operation with the fan unit shut down.
3. Shut off oiling system.
4. If turbine driven, close exhaust valve.
5. Turn off water cooling system.

402. Induced Draft Fans—Starting

1. Inspect the entire unit's oiling system, seeing that supply of lubricant is ample, and if of gravity or pressure feed see that oil is feeding properly to all bearings.
2. Turn on cooling water to bearings.
3. If fan is steam driven, open exhaust valve and drains, warm up unit.
4. If fan is motor driven, start unit slowly, making proper use of starting equipment.
5. Adjust dampers for induced draft operation.
6. Bring the unit up to speed.
7. Inspect the unit for vibration and, if noticeable, notify the engineer in charge of shift; if excessive, shut down unit, notifying the engineer in charge of shift.
8. If main oil switch should trip for cause other

than throwing from starting to running position before motor is up to speed, if fuse should blow, or if circuit breaker should open, have inspection made by electrician and trouble corrected before starting again.

9. Close the cylinder drains.
10. Make final inspection of oiling system.

Induced Draft Fans—Shutting Down

1. Shut down turbine or motor.
2. Adjust dampers for operation with the fan unit shut down.
3. Shut off oiling system if of pressure or gravity feed.
4. If turbine driven, close exhaust valve.
5. Turn off water cooling system.

5—Boiler Feed Pumps

501. Boiler Feed Pumps—Centrifugal Type—Starting

1. See that valve on pressure gage line on discharge side of pump is open.
2. See that the suction and discharge valves are open.
3. If unit is steam driven, open drains and exhaust valves, warm up unit.
4. Turn on water to packing gland seals.
5. See that all valves to pressure regulator are closed.
6. See that cooling water is on bearing.
7. Inspect the entire unit's oiling system, seeing that supply of lubricant is ample, and, if of gravity or pressure feed, see that oil is feeding properly to all bearings.
8. Start the turbine or motor slowly and gradually bring up to working pressure.
9. Close all drains.
10. See that the proper pressure is on the equalizing pipes to balance the thrust.
11. Open steam and water line valves to pressure regulator.
12. Adjust the regulator to give the proper differential between the feed pressure and the steam pressure.
13. When pumps that are not equipped with a load equalizing device are run in parallel, the load may be equalized by slowing down the speed of the pumps which are taking the most load.
14. Open spray line valve if the pump becomes steam bound.

Boiler Feed Pumps—Centrifugal Type—Shutting Down

1. Shut down turbine or motor and see that pump comes to rest.
2. Close spray line valve if open.
3. Shut off oiling system if of pressure or gravity feed.
4. Close turbine exhaust valve and open the drain.
5. Close suction and discharge valves.
6. Shut off cooling water from bearings and seals.
7. Close steam line to pressure regulator.
8. Adjust water line valve to pressure regulator according to regular practice.

502. Boiler Feed Pumps—Plunger Type—Starting

1. Open steam cylinder drains and exhaust valve, warm up unit.
2. See that suction and discharge valves are open.
3. See that the feed line pressure gage valve is open.
4. See that the lubricator is full of oil and feeding properly.
5. Oil valve gear.
6. Bring up the pump speed for the desired pressure.
7. Close the drains.

Boiler Feed Pumps—Plunger Type—Shutting Down

1. Close the throttle valve.
2. Close the exhaust valve.
3. Turn off lubricator.
4. Close suction and discharge valves.

6—Feed Water Heaters

601. Putting a Heater on the Line—Open Type

1. See that water drains are open.
2. See that vents on heater are open and remain open.
3. Open the exhaust valve slowly.
4. Close drain valves.
5. Open water inlet valve slowly and fill to overflow.
6. See that the gage glasses are open and in operation.
7. Partly open the discharge valve to boiler feed pump suction line.
8. See that float valves are operating freely.
9. See that the water seal is open and working properly.
10. When the operating temperature is reached, open wide the water inlet and discharge valves.
11. See that the proper amount of pressure is obtained on the exhaust line header.
12. Open all trap discharge lines that lead to heater.
13. See that the valve on the connection between the heater and the float tank of the weir recording apparatus is open.
14. See that the heater divides the load equally and that the meter mechanism is operating properly.

602. Taking a Heater Off the Line—Open Type

1. Close the exhaust valve.
2. Partly close the water feed valve and allow water to reach minimum level.
3. Divert all trap discharges entering heater to other heaters or free blow.
4. Divert feed pump suction.
5. Close water supply valve.
6. Close the discharge valve to the pump suction line.

603. Putting a Heater on the Line—Closed Type

1. See that all vents are open.
2. Open the water inlet valve slowly and, when air has been eliminated, close vents.

3. Open the discharge valve to boiler feed pump suction line.
4. Open the valve in the equalizing line to the condenser.
5. See that the steam trap is in operating condition and closed.
6. See that all drain lines from the steam piping are open.
7. Open the steam inlet valve slowly.
8. Open all trap discharge lines that lead to the heater.
9. See that the heater relief valves are sealed.
10. If there is a check valve in the steam line to the heater, see that this valve is in operating condition and open.
11. See that the high water alarm is operating.

604. Taking a Heater Off the Line—Closed Type

1. Close the steam inlet valve slowly.
2. Divert all trap discharges entering the heater to other heaters or free blow.
3. Close the valve in the equalizing line to the condenser.
4. Divert the boiler feed pump suction.
5. Close the water supply valve.
6. Close the discharge valves to the pump suction line.

7—Evaporators

701. Putting an Evaporator Into Service

1. See that the water supply lines and exhaust steam lines to the evaporator heater are in operating condition.
2. Start the evaporator feed pumps.
3. See that all blow down valves are closed and that the vent of each shell is open.
4. Fill each shell to the running water level, as indicated by the mark on the shell (....) in. above the center line of the manifold.
5. Open the vents on the traps on both high and low pressure coils.
6. Open wide the vapor valve on the first effect.
7. Open the vapor valve on the second effect.
8. Open slowly the high pressure steam valve to the first effect coils, noting that the reducing valve maintains (....) lb. gage pressure.
9. Maintain (....) steam temperature by adjusting the boiler feed water supply to the de-superheater.
10. See that the trap is functioning on the steam separator.
11. Close the vents on the shells when the steam appears.
12. Slowly build up pressure in the shell of the first effect to (....) lb. by increasing the live steam to the coils of the first effect until (....) lb. at (....) deg. fahr. is maintained at the entrance of the coils.

702. Taking an Evaporator Out of Service

1. Close the high pressure steam valve to the first effect coils.
2. Close the water line to the de-superheater.
3. See that the float valves shut off the water after evaporation stops.
4. Close the vapor valve on the second effect shell.
5. Shut down the evaporator feed pump.
6. If the heater is to be taken out of service, see second section of rules for feed water heaters.

703. Cracking Down Evaporators—First Effect

1. Close the hand valve on the automatic feed water valve control.
2. Close the steam valve to the coil and blow down the first effect evaporator shell completely through the blow-down line.
3. Close the blow-down valve.
4. Open the vent valve.
5. Fill the first effect evaporator with cold filtered raw water to the top of the gage glass.
6. Close the vent valve.
7. Close the vapor valve on the first effect.
8. Open suddenly the steam valve to the first effect coil.
9. Close the steam valve when the cracking ceases, and see that the pressure does not exceed (....) or (....) lb. in the shell.
10. Blow down completely the shell to the waste discharge.
11. Close the blow-down valve.
12. Open the hand valve on the automatic feed water valve control.
13. See that the shell fills with hot water to the normal running level.

704. Cracking Down Evaporators—Second Effect

1. Close the hand valve on the automatic feed water valve control.
2. Close the vapor valve on the second effect.
3. Open the vent on the low pressure shell.
4. Blow down the shell completely through the blow-down valve.
5. Close the blow-down valve.
6. Fill the second effect evaporator with cold filtered raw water to the top of the gage glass.
7. Close the vent valve.
8. Admit steam suddenly to the second effect coils through the steam line connected to the vapor line. Do not exceed (....) lb. pressure.
9. Close the steam valve when the cracking ceases, and see that the pressure does not exceed (....) lb. on the shell.
10. Blow down completely the shell to the waste discharge.
11. Close the blow-down valve.
12. Open the hand valve on the automatic feed water valve control.
13. See that the shell fills with hot water to the normal running level.

705. Putting Evaporators in Service After Cracking Down

1. Open the vapor valves.
2. Proceed to put in operation according to rules for "Putting an Evaporator into Service."

B—ROUTINE CARE AND MAINTENANCE

1—Boilers

1001. General

1. Before entering a boiler, see that all safety rules have been complied with.

2. Men working on boiler should report any leakage, or any indication of leaks, in joints or where tubes enter the header.

1002. External Cleaning

1. Blow the soot from the boiler and superheater tubes and exposed surfaces of drums with compressed air or dry steam.

2. Clean the tubes of all clinker formation and remove the clinker, when and where necessary, from the walls of the furnace, taking care not to injure the brick work.

3. Clean the combustion and soot chambers.

4-s. Clean the branch air duct and under-grate air compartments, and examine dampers.

5. Inspect and repair brick work, arches and baffles.

6-s. Clean air openings in grate surfaces and replace castings where necessary.

7-s. Clean the water back heater compartment.

8. Thoroughly clean and paint all exterior surfaces of boiler when necessary, applying a paint that is suitable for this service.

9. Inspect all valves periodically, and overhaul if necessary.

10. Inspect and repair piping when necessary.

11. Examine bolts in flanges periodically.

1003. Internal Cleaning

1. Boiler tubes must be bored according to the schedule made by the constituted authority.

2. See all rules for "Taking a Boiler off the Line."

3. Remove scale with cone cutter. Boring schedule should be such as to never necessitate use of hammer.

4. See that the proper handhole or manhole caps are removed to permit ready removal of loosened scale.

5. Block, screen, or disconnect the blow-down pipes at the mud drum to prevent scale from going into blow-down piping.

6. Insert the machine in the end of the tube before starting.

7. Start the machine.

8. After the machine has entered tube about 1 ft., water should be fed into the tube behind the cutter.

9. Machine should be fed backward and forward at all times, making a gradual advance through the tube.

10. Repeat the operation until the tube is clean.

11. Use follower to determine proper gage.

12. Oil the boring machine when necessary, using a mineral oil.

13. See that no excess oil drips from the machine.

14. After all the tubes have been bored clean, wash out the tubes with water, or blow out with compressed air.

15. Remove the scale from the drum or header base.

16. Take down the dry pipes, when necessary, and clean all of the openings and holes. Also make sure the internal feed pipes are clean.

17. Clean interior surface of all drums.

18. Clean the superheater when necessary.

Owing to sharp curves and the presence of a core in some types of superheater tubes, it is difficult to get anything that will pass through them. A piece of cable stubbed on the end should be pushed through the tubes not having a core. The tubes should then be blown out with compressed air.

19. After all the internal surfaces have been scaled, wash out with water.

20. Put into working order the blow-down pipes as affected by rule (5).

21. Examine manhole and handhole gaskets, and replace when necessary.

22. Examine the tube handhole covers, bolts, etc., for cracks and replace those defective.

23. When boiler is closed, fill with water at about 90 deg. fahr. preparatory to a hydrostatic test.

24. When making the hydrostatic test "blank off" the automatic non-return valve and clamp down the safety valves.

25. After completing hydrostatic test, drain to normal water level and remove blanks and clamps.

26. Inspect the water column fittings and connections at least annually, and overhaul if necessary.

27. When gage glasses are replaced, see that there is no metal to glass contact or twisting strain, and that the glands are replaced directly in line.

28. Inspect all valves on the boiler and blow-down lines at least annually and overhaul if necessary.

29. Inspect all safety valves at least annually and overhaul if necessary.

30. Inspect pipe and drum covering annually and repair if necessary.

1004. Preparation for Inspection

1. Boilers must be taken off the line once a year for insurance inspection.

2. Before starting to clean a boiler for inspection, see that all safety rules and all rules for "Taking a Boiler off the Line" have been complied with.

3. Following the rules under "External Cleaning" and "Internal Cleaning."

1005. Economizers

1. Economizers should be considered as boilers and given the same inspection and cleaning. See rules for "External Cleaning," "Internal Cleaning" and "Preparation for Inspection."

2. When an economizer is uncapped, all tubes should be carefully inspected for internal pitting.

1006. Stokers

1. Clean the external mechanism daily.

2. Gear boxes should be inspected periodically, and lubricant renewed when necessary.

3. Brush chains clean and oil daily.

4. Chains and all bearing oil holes should be pro-

tected from dirt and accidental contact by workmen with a suitable housing.

5. Inspect and oil the line shaft when necessary.
6. Examine the clutches and bushings periodically.

1007. Stoker and Fan Motors

1. Lubricate and clean the bearings periodically.
2. If ball bearing motors are used, repack bearings periodically.
3. Motors should be thoroughly cleaned periodically as directed by constituted authority.

2—Boiler Auxiliaries

2001. Fans

1. Clean the induced and forced draft fans, dampers, housings and flues periodically.
2. Always complete cleaning before the fan is restored to service, in order to avoid unbalancing.
3. Inspect the bearings and couplings, the fan runners, and the stay rods for wear and corrosion periodically when out of service.
4. Change the bearing lubricant periodically.
5. The parts subject to wear and corrosion should be painted, or treated, to prevent or retard such action if once started.

2002. Feed Water Heaters

1. Overhaul the control valves and float mechanisms on the heaters periodically.
2. Oil valve stems and float mechanisms as conditions require.
3. Inspect the heaters periodically and clean when necessary.
4. On closed heaters, test for tube leakage periodically by:
    (1) Opening the heater drain with the steam shut off.
    (2) Raising water pressure to (....) lb. and observing the drain for leakage.

2003. Evaporators

1. Remove the coils from the shells periodically and inspect for scale formation.
2. If the scale has not been completely removed by the daily cracking down process, remove the coils from the headers and clean tubes and headers according to rules made by the constituted authority.
3. Test coil joints for leakage.
4. Inspect the evaporator auxiliary heaters as under "Feed Water Heaters."
5. Inspect interior of shell for corrosion and clean and paint when necessary.
6. Examine the blow-down valves periodically for leakage.
7. Test the safety valve periodically: first effect at (....) lb. gage pressure, second effect at (....) lb. gage pressure.
8. Overhaul all feed and steam control valves periodically.

2004. Soot Blowers

1. Inspect the external operating mechanism to see that it is not broken or fouled. This inspection is to be made during operation.
2. See that the drain on steam line is clear and kept open when blowers are not in use.
3. See that the vents are open.
4. Check position of steps or cams with respect to nozzles and reset, if necessary, when the boiler is down for external cleaning.
5. Examine boiler tubes, baffles and arches for steam cutting every time the boiler is down.
6. Inspect elements and bearings and repair when necessary, when boiler is down for external cleaning.

3—Instruments

3001. Draft Gages—Oil Type

1. Check daily for zero and add oil when necessary.
2. On becoming sluggish and dirty, tubes should be cleaned with kerosene and blown out with air. Pipe connections should also be blown out.
3. Test lines periodically for leakage.
4. Check gage periodically with standard gage.

Draft Gages—Diaphragm or Floating Bell Type

1. Check for zero daily.
2. Check the scale periodically with standard gage.

3002. Pressure Gages

1. Check in place monthly with standard test gage, or oftener if necessary.
2. Calibrate annually with deadweight tester, or oftener if necessary.

3003. CO_2 Recorders

1. Blow out the sampling lines daily, and see that they are kept free from soot.

[NOTE: Where ceramic filters are used at the sampling point, do not allow air pressure to act on these filters. Ceramic filters should be removed and cleaned every 90 days, or oftener if necessary.]

2. Replace the filtering material when necessary.
3. Check for zero daily.
4. Check for leaks weekly.
5. On chemical type recorders, replace the absorbent when necessary.
6. On electrical type recorders, check the balance of the electrical system on air weekly.
7. Check for accuracy daily, with Orsat, and report results to the properly constituted authority.
8. Clean the machine externally daily.
9. Clean internally as required.

3004. Flowmeters

1. Clean the meter externally daily.
2. Blow out the pressure differential-producing element and the lines to the manometer monthly, or oftener if necessary.
3. Check for leaks monthly.
4. Inspect, check for zero, and run a water column calibration every two months, or oftener if necessary.
5. Check the level of the condensers and the slope of the lines for possible air pockets periodically.

6. Inspect the recording pen, and clean or replace monthly.

7. Clean the manometer body and refill yearly, or oftener if necessary.

8. Clean the meter mechanism yearly, or oftener if necessary.

3005. Venturi Meters

1. Blow out the lines to the manometer monthly, or oftener if necessary.

2. Vent the meter at the manometer weekly.

3. Follow rules "3004-1, 3, 4, 6, 7, 8."

3006. V-Notch Meters

1. Check the zero monthly with weir measurement meter, the tank being out of service.

2. Check the external meter mechanism weekly.

3. Check the clock and integrator monthly.

4. Lubricate when necessary.

5. Inspect the float monthly for leaks and sediment, and clean same.

6. Inspect the weirs for corrosion and change in level monthly.

7. Areas affected by corrosion or wear should be treated by some means to maintain accuracy.

8. Repack float valve stem periodically.

SECTION II—PRIME MOVER PLANT

A—GENERAL OPERATION

1—Turbines

101. Inspection Before Taking Over Shift

1. The engineer coming on must receive a report covering all matters pertaining to the operating conditions of all apparatus from the retiring engineer.

2. The engineer must vertify this report by personal inspection of all apparatus.

3. The engineer must see that he has sufficient force on hand to operate his shift before the men on the previous shift are allowed to leave.

4. The engineer should see that sufficient apparatus is available for expected load.

5. The engineer or instrument man must take all meter readings and change all charts on the (. . . .) shift. The engineer shall verify the design and date on all charts before their removal.

102. Procedure Before Starting

1. Notify boiler room as to steam requirements.

2. Remove all bolts, tools, etc., which may have been left on or near the machine, and if any repairs have been made while machine was down examine position of all valves on entire unit.

3. Make a general inspection to see that the machine and auxiliaries are in proper condition for operation, and that duplicate auxiliaries (where provided) are in readiness for emergency use.

4. When a gravity lubricating system is used, see that sufficient oil is in the system and that oil in proper quantities is being supplied to all bearings.

103. Vertical Turbines—Starting

1. Notify switchboard operator that machine is ready to be warmed up.

2. After receiving affirmative reply, start high pressure accumulator pumps and bring accumulator pressure to (. . . .) lb.

3. See that oil is being supplied to main bearings of turbine and generator, and that overflow sights, alarms, etc., are in working order.

4. See that strainers in governor oil line are clean and that the governor oil pump air chamber is charged with sufficient air for cushioning.

5. Start governor oil pump and see that it is operating under correct pressure, supplying oil in sufficient quantities to all bearings throughout the system.

6. Turn on water to all water seals.

7. Start circulating pump and air pump, giving proper attention to the priming of the circulating pump and the removing of air from the water side of condenser.

[NOTE: If equipped with barometric condenser, rule to cover specific equipment and practice should be made by the constituted authority and inserted here.]

8. Examine all gages and see that steam gages show proper pressure; step gages show proper pressure; governor oil gages show proper pressure and vacuum gages show proper vacuum.

9. If the step gage does not show the proper pressure, make the necessary adjustments to attain this pressure, checking same with test gage.

10. Start the hotwell pump.

[NOTE: Hotwell pump should be started when high water alarm signal operates, with discharge throttled to hold proper level of water above pump while starting.]

11. Turn on steam to turbine seals.

[NOTE: Steam should be applied to seals just before starting up, so that no stresses will be set up by localized heating of stationary shaft.]

12. Open the throttle quickly until the first stage pressure gage registers (. . . .) lb. pressure and maintains this pressure.

13. As soon as the machine turns over, reduce throttle opening to the point where the spindle revolves at from 100 to 200 r.p.m.

[NOTE: Vacuum during warming up process to be such that temperature through low pressure portions of turbine will approximate temperature of operating conditions.]

14. If specific practice is to trip throttle during starting up operations, rule to cover this feature should be made by the constituted authority, and inserted here.

[NOTE: It is recommended that this rule be related to the above rules 12 and 13, so that tripping is effected when the valve has a small opening, as it is most conducive to sticking at this time.]

15. See that all turbine drains are open.

[NOTE: Open drains when same will not seriously interfere with vacuum. In case draining and sealing are effected through the same line, rule to cover specific practice and equipment should be made by the constituted authority and inserted here.]

16. Listen for internal rubbing until turbine goes into service.

17. Time required for warming up machine will be (....) min. per 100 kw. capacity.

18. During the warming up process, as the vacuum rises, make necessary adjustments of steam supplied to the seals.

19. Close turbine drains when machine is sufficiently warmed up.

20. Turn on water to oil cooling coils.

[NOTE: Water valve to oil cooler should be cracked slightly after turbine is started to keep water circulating through cooler to prevent a sudden change of temperature in the cooler.]

21. When unit is warmed up, notify switchboard operator that machine is ready for operating speed.

22. After receiving affirmative reply, open the throttle until the first stage pressure registers (....) lb. and maintain this pressure until the machine comes up to speed, which will be indicated by the closing of the admission valves by the governor and a reduction of the first stage pressure below normal starting pressure.

22-a. As the machine comes up to speed watch for vibration and do not operate on critical speeds longer than necessary.

[NOTE: This rule to be made specific by the constituted authority in accordance with turbine manufacturer's node data.]

23. Open the throttle wide, noting that no increase takes place in the first stage pressure, or in the turbine speed as shown by the speed indicator.

24. Close the throttle valve until it is sufficiently in advance of the governor to carry the synchronizing load.

25. Notify the switchboard operator that the machine is ready for "load."

26. After receiving affirmative reply, synchronize the machine as quickly as possible and apply load up to (....) kw.

27. See that vacuum is at a maximum.

28. Build up load on the machine at the rate of approximately (....) kw. per min.

[NOTE: As the load comes on, the opening of the throttle valve should be gradually increased and kept in advance of the governor.]

29. When machine is carrying approximately (....) kw., open the throttle wide and regulate the amount of steam supplied to the seals.

30. Make general inspection of all gages and oil temperatures from all bearings.

31. Watch the step bearing gages and see that they are maintained at the proper pressure.

Vertical Turbines—Shutting Down

1. After being notified by the switchboard operator that the load is to be taken off the machine, observe the first stage pressure, and when this pressure recedes to (....) lb., admit steam to the top seal.

2. After being notified by the switchboard operator to "stop" the machine, close the throttle slowly.

[NOTE: If specific practice is to close throttle with hand trip while shutting down, rule to cover this operation should be made by the constituted authority, and inserted here.]

3. Shut down the auxiliary pumps, except oil and step pump.

4. Break vacuum when machine is approximately (....) per cent below operating speed.

5. After vacuum has been destroyed, shut off steam and water to all seals.

[NOTE: In case bottom seal prevents oil leaking into condenser, do not shut off steam to same until machine comes to rest.]

6. After the machine has come to rest, shut down oil and step pump, shut off the oil supply to all bearings, and the water to oil cooler.

7. See that all admission valves have been opened by the governor.

8. Make a general inspection of the turbine.

9. Lubricate admission valves with a high grade cylinder oil mixed with a small quantity of graphite.

104. Horizontal Turbines—Starting

1. Notify switchboard operator that machine is ready to be warmed up.

2. After receiving the affirmative reply, start the auxiliary oil pump and see that it is operating under correct pressure.

3. Start the circulating pump and air pump, giving proper attention to the priming of the circulating pump and the removing of air from the water side of condenser.

4. See that oil is circulating to all main bearings —check oil filter operation.

5. See that governor is being supplied with oil.

6. Rule to cover any trying out of speed control mechanisms while machine is stationary should be made by the constituted authority and inserted here.

7. Examine all gages and see that steam gages show proper pressure; vacuum gages show proper vacuum and oil and water gages show proper pressure.

8. Start the hotwell pump.

[NOTE: Hotwell pump should be started when high water alarm signal operates, with discharge throttled to hold proper level of water above pump while warming up the turbine.]

9. Turn on steam to turbine seals.

[NOTE: Steam should be applied to seals just before starting up, so that no stresses will be set up by localized heating of stationary shaft.]

10. See that all turbine drains are open.

[NOTE: Open drains when same will not seriously interfere with vacuum. In case draining and sealing are effected through the same line, rule to cover specific practice and equipment should be made by the constituted authority and inserted here.]

11. Open the throttle quickly until the first stage pressure gage registers (....) lb.

12. As soon as the spindle starts rolling, close

the throttle to point where machine's speed is at desired rate for warming up the unit.

[NOTE: Vacuum during warming up process to be such that temperature through low pressure portion of turbine will approximate temperature of operating conditions.]

13. If specific practice is to trip throttle during starting up operations, rule to cover this feature should be made by the constituted authority and inserted here.

[NOTE: It is recommended that this rule be related to the above rules No. 11 and 12, so that tripping is effected when the valve has a small opening, as it is most conducive to sticking at this time.]

14. Listen for internal rubbing until turbine goes into service.

15. With spindle revolving, turn on water to water seals.

16. Turn on cooling water to oil cooler and main bearings.

[NOTE: Water valve to oil cooler should be cracked slightly after turbine is started to keep water circulating through cooler to prevent a sudden change of temperature in cooler. A close watch on oil temperatures will determine further regulations to oil cooler circulating water, and the time to turn on cooling water to main bearings.]

17. When unit is warmed up, notify switchboard operator that machine is ready for operating speed.

18. After receiving affirmative reply, open the throttle until the first stage pressure registers (....) lb., and maintain this pressure until the machine comes up to speed, which will be indicated by the closing of the admission valves by the governor and a reduction of the first stage pressure below normal starting pressure.

18-a. If the machine is equipped with an oil pump operated off the turbine shaft, see that this pump goes into service as the machine comes up to speed and that the auxiliary oil pump slows down to a very slow, but continuous, speed.

18-b. As the machine comes up to speed, watch for vibration and do not operate on critical speeds longer than necessary.

[NOTE: This rule to be made specific by the constituted authority, in accordance with turbine manufacturers' node data.]

19. Open the throttle wide, noting that no increase takes place in the first stage pressure, or in the turbine speed as shown by the speed indicator.

20. Close the throttle valve until it is sufficiently in advance of the governor to carry the synchronizing load.

21. Notify the switchboard operator that the machine is ready for "load."

22. After receiving affirmative reply synchronize the machine as quickly as possible and apply load up to (....) kw.

23. See that vacuum is at a maximum.

24. Build up load on the machine at the rate of approximately (....) kw. per min.

[NOTE: As the load comes on, the opening of the throttle valve should be gradually increased and kept in advance of the governor.]

25. When machine is carrying approximately (....) kw., open the throttle wide and regulate the amount of steam supplied to the seals.

26. Make general inspection of all gages and oil temperatures from all bearings.

Horizontal Turbines—Shutting Down

1. After being notified by the switchboard operator that load is to be taken off the machine, stand by to regulate the sealing system as the load decreases.

2. Start the auxiliary oil pump by hand, to see that it will start properly.

3. After being notified by the switchboard operator to "stop" the machine, close the throttle slowly.

[NOTE: If the specific practice is to close the throttle with hand trip or oil relay while shutting down, rule to cover this operation should be made by the constituted authority and inserted here.]

4. See that the auxiliary oil pump starts as the machine slows down, and that proper pressure is maintained.

5. Break vacuum when machine is approximately (....) per cent below operating speed.

6. Shut off steam and water to seals, and open drains to see that valves are not leaking.

[NOTE: Do not shut off all the steam to seals until vacuum is destroyed because of the harmful effect resulting from cold air being drawn through the seal glands.]

7. After machine stops, shut off the oil and water supply to the main bearings and oil cooler.

[NOTE: Temperatures will be a guide in shutting off the water to water cooled bearings.]

8. Shut down the auxiliary oil pump.

9. See that the admission valves have been opened by the governor.

10. Open atmospheric relief valve drains.

11. Make a general inspection of the turbine.

12. Check the exhaust casing temperature for steam leakage past the throttle valve.

13. Lubricate admission valves with a high grade cylinder oil and a small quantity of graphite.

14. When the condenser circulating pumps are shut down, note that the condenser low water alarms operate.

105. Periodic Overspeed Tests on Turbines

These tests are to be made under the personal supervision of the shift supervisor.

1. Bring the turbine up to speed with field on the generator.

[NOTE: Time for bringing the machine up to speed should not be changed from ordinary practice for these tests.]

2. See that the machine remains at normal speed under control of the governor.

3. Close the throttle, and when the speed of the machine has dropped below normal make necessary adjustment so that machine will not be under control of the operating governor.

[NOTE: Rule to cover specific equipment and procedure to be made by the constituted authority and inserted here.]

4. Open the throttle and allow the machine to accelerate until the automatic overspeed device operates, and note the speed and frequency at which this takes place.

5. Do not relinquish hand control of the machine until it is certain that the throttle has entirely closed under the action of the automatic overspeed device, as indicated by immediate decrease in speed and first stage pressure.

6. If automatic overspeed device does not operate when the overspeed reaches approximately (....) per cent, trip the throttle by hand, overhaul overspeed mechanism and put in first class working order, as proved by further tests, before unit is put in service.

[NOTE 1: In case specific practice is to reduce overspeed during these tests by means other than tripping throttle, rule to cover this feature should be made by the constituted authority and inserted here.]

[NOTE 2: Provision should be made for adequately cushioning the throttle valve to prevent excessive wear on the valve seat.]

106. Test Made at Reduced Speed

1. If the turbine has been running, slowly close the throttle valve by hand and allow the turbine to come to rest.

2. Remove the handhole plate on the governor pedestal, and place on the emergency trip the weight provided for the purpose.

[NOTE: If the machine has stopped in such a position that the weight cannot be attached, open the throttle sufficiently to turn the turbine shaft, and trip the throttle immediately when the shaft starts to move. Repeat if necessary until machine stops in position where weight may be attached.]

3. Replace the handhole plate.

4. Bring the turbine up to speed slowly and note with tachometer and frequency meter the speed and frequency at which the emergency trip operates.

The control mechanism should be set so that the machine would operate at normal speed without the weight on the emergency trip.

5. After the throttle valve has operated properly under the action of the automatic overspeed device, operate the handwheel to the closed position and reset the throttle trip.

6. If the emergency trip does not operate before the machine has reached normal speed, close the throttle.

7. Allow the machine to come to rest.

8. Remove the handhole plate and remove the weight from the emergency trip. Overhaul the mechanism, putting same into satisfactory operating condition, as proved by further tests.

9. When tests are complete, remove weight and replace handhole plate.

2—Reciprocating Engines

201. Corliss Engines—Starting

1. Notify switchboard operator that machine is ready to be warmed up.

2. After receiving affirmative reply, see that all drains from the cylinder are open.

3. See that the drain and trap above the throttle valve are open.

4. See that the main exhaust valve is open.

5. If a compound engine, see that the receiver is drained.

6. See that the wrist plate is unlatched from the eccentric rod hook.

7. See that oil is running to the bearings of the engine.

8. See that the crank and cross head pit drains are open and free.

9. See that the cranks, cross heads and other movable parts are not obstructed by any foreign material.

10. See that the wrist pins, crank pins, eccentric straps and wrist plate pins are tight.

11. See that the valve gear nuts, etc., are tight.

12. See that the crank is in such a position that the engine will start readily.

13. See that the governor belt, when used, is in good condition and free from oil.

14. Examine all gages.

15. Oil the governor spindle and see that the dash pot has the necessary amount of oil.

16. Start the circulating, air and hotwell pumps, and get partial vacuum in the condenser.

[NOTE: Regulate hotwell pump so that proper water level is maintained above pump suction.]

17. See that the governor is hooked up on the safety pin.

18. Place the bar in the wrist plate of the engine.

19. Open the by-pass valve, or crack the throttle, admitting steam alternately to each end of the cylinder, warming it up and getting all the water out of the valve chest and cylinder.

[NOTE: Shifting of valve gear to permit steam to enter alternate ends of cylinder shall be done with throttle or by-pass valve closed, due to the wear and tear on the crank pins and boxes when this operation is performed under steam pressure.]

20. Open the throttle valve further until the engine revolves slowly, then engage the wrist plate with the eccentric rod hook.

21. See that the lubricator and oiling system are in operation.

22. Notify the switchboard operator that the machine is ready for operating speed.

23. After receiving affirmative reply, open the throttle slowly and close the by-pass valve, noting that the engine comes up to proper speed.

24. See that the safety pin of the governor is in a correct position to operate, should the governor belt break.

25. Close the drains.

26. Signal "Load" to the switchboard operator.

27. As the load comes on, bring the vacuum up to normal.

Corliss Engines—Shutting Down

1. After receiving the signal "Stand By" from the switchboard operator, answer it.

2. After receiving and answering the signal "Stop"

from the switchboard operator, close the throttle slowly until the engine comes almost, but not quite, to a stop.

3. Reverse the safety pin of the governor so that the governor will not drop to the lowest point.

4. Place the bar in the wrist plate.

5. Disconnect the wrist plate from the eccentric rod.

6. Operate the wrist plate by hand with the bar so that the engine will stop with the crank in starting position.

7. Move the wrist plate to central position so that the exhaust valves are closed.

8. If the engine has a double eccentric, trip the steam valves by hand when the wrist plate is in a central position, so that the steam valves may be closed and lapped.

[NOTE: A test should be made periodically by leaving the governor safety pin in the running position when shutting the throttle valve, to see that the safety device is in working order.]

9. Shut down the circulating, air and hotwell pumps.

[NOTE: If jet condenser is used, close off injection water just before closing throttle valve and allow air or wet vacuum pump to run until engine stops, thus obviating, to some extent, the possibility of water being forced by atmospheric pressure through air or wet vacuum pump into low pressure cylinder in the event of displaced or defective valves in the pump.]

10. Shut off the oiling system.

11. Open the drains.

3—Auxiliaries

301. Small Turbines on Auxiliaries—Starting

1. Inspect the reduction gear to see that no water has accumulated in the case, and that there is enough, but not too much, oil.

2. See that the exhaust valve is open.

3. See that the relief valve on the turbine casing is in operating condition.

4. Inspect the oiling system and the oil strainer, if it is accessible.

5. See that all drains are open.

6. If an emergency trip is provided, see that it is set.

7. See that the overload nozzle valves are closed.

8. If condensate has accumulated in the auxiliary steam line, drain it off.

9. Open the throttle slightly and run the unit at a low speed.

10. Sound the turbine.

11. Inspect the oiling system before and after starting to see if it is functioning properly.

12. Open and adjust the proper supply of water to the oil cooler and bearing water jacket, if any.

13. Bring the turbine up to speed gradually.

14. Close all drains when the turbine is up to speed.

15. If turbine glands are of the water sealed or steam sealed type, see that they are properly sealed.

16. Test the governor by pushing it to the closed position to see if this will cause the turbine to slow down.

17. Overload nozzles are to be used only when necessary.

Small Turbines on Auxiliaries—Shutting Down

1. See that load is off the turbine whenever practicable.

2. Close the throttle valve.

3. Do not shut off the oiling system until unit comes to rest.

4. Close exhaust valve every time machine is shut down.

5. Open the drains.

Small Turbines Periodic Overspeed Test

1. See that the load on the turbine has been removed, when practicable.

2. Apply a tachometer to the shaft and note that normal speed is maintained by the governor at no load.

3. Continue to observe the speed by means of the tachometer and force the governor arm against the spring, allowing the turbine to speed up, not exceeding 2 per cent above the speed at which the manufacturer recommends setting the emergency trip.

4. Note the speed at which the overspeed device trips the throttle, and, if this speed is more than 2 per cent above the speed at which the manufacturer recommends setting the emergency trip, locate cause and make any necessary adjustments to governor mechanism and safety devices.

5. Be sure tripping mechanism is correctly adjusted before putting machine into service.

302. Slide Valve Engines on Auxiliaries—Starting

1. Open the exhaust valve.

2. Open necessary valves on auxiliaries connected to the engine.

3. See that the drains and cylinder cocks are open.

4. See that the lubricator is acting properly and inspect the oiling system before and after starting.

5. Open the throttle valve enough to admit steam to warm up cylinder without turning engine.

6. Bring the engine up to speed gradually and inspect the operation of the governor and safety devices.

7. Close the drains.

Slide Valve Engines on Auxiliaries—Shutting Down

1. Close the throttle and stop the engine in the starting position.

2. Shut off the oiling system when the unit comes to rest.

3. Close all valves on auxiliaries connected to engine.

4. Close the valves on the lubricator.

5. Open the drains before closing the exhaust valve, if non-condensing.

6. Exhaust valve should be closed and drains open.

303. Small Motors on Auxiliaries

Synchronous Motors—Starting

1. See that load is off motor, if possible.

2. Inspect the oiling system.
3. If possible, throw field switch to short circuit the field windings; otherwise, see that field switch is open.
4. Close the starting switch and note that the rotor turns over.
5. After the motor comes up to maximum speed on the starting switch, open the starting switch and immediately close the running switch.
6. After the motor comes up to maximum speed on the running switch, see that all the field resistance is cut in, close the field switch and adjust the field for the minimum or the prescribed leading armature current.
7. Inspect the oiling system and note if it functions properly.

Synchronous Motors—Shutting Down

1. See that all load is off motor, if possible.
2. Open the running switch.
3. Cut all field resistance in.
4. Open the field switch.

Induction Motors Started by Compensator—Starting

1. Inspect the oiling system.
2. See that the compensator handle is in the "Off" position.
3. Close the motor main switch.
4. Throw the compensator handle to the starting position and note that the rotor turns over, or watch ammeter if it is impossible to see motor.
5. When the motor comes up to maximum speed on the starting position, throw the compensator handle to the running position quickly.
6. Inspect oiling system and note if it is functioning properly.

Induction Motors Started by Compensator—Shutting Down

1. Trip compensator.
2. Open the motor main switch when compensator handle is in "Off" position and motor has begun to slow down.

Motors Started from Automatic Control Panel—Starting

1. Inspect oiling system.
2. See that the controller is in the "Off" position.
3. Close the motor main switch.
4. Move the controller handle to the required starting position.
5. Note that the starting operations are in proper sequence, and that the motor comes up to the required speed.
6. Inspect the oiling system and note that it is functioning properly.
7. Inspect the slip rings if motor is of the slip ring type.

Motors Started from Automatic Control Panel—Shutting Down

1. Move the controller handle to the "Stop" position.
2. Open the motor main switch, wherever practicable.

[NOTE: If motor main switch is knife type, open switch when rotor has stopped turning.]

304. Circulating Pumps—Starting

1. Inspect the condenser for open doors and see that the vent on the tail pipe is open unless syphon is provided.
2. See that the condenser washout valve in the water box is closed.
3. See that the discharge valve is closed, if one is used.
4. Admit water to the seals of the pump.
5. Prime the pump by the means provided.
6. After the pump is filled with water, start the pump turning slowly.
7. See that the oiling system is operating properly.
8. See that the proper supply of water is being maintained on the coolers.
9. Run the pump at a speed that will maintain desired pressure on the pump.
10. Open the discharge valve until water appears or suction occurs at the vent on the tail pipe, if pump has this equipment.
11. Close the tail pipe vent and open the discharge valve wide, if the pump has this equipment, and bring the pump up to desired speed.
12. Shut off priming equipment when the pump delivers water.

Circulating Pumps—Shutting Down

1. Stop the pump.
2. Close the discharge valve, if necessary.
3. Shut off the water to the seals.
4. Shut off the water from the oil cooler.

305. Hydraulic Air Pump, Independently Driven—Starting

1. Admit water to the seals of the pump.
2. Open the hurling water priming valve until the desired pressure is reached.
3. Start the air pump at slow speed.
4. See that oiling system is working properly.
5. Bring the air pump to normal speed.
6. Change over from priming to normal hurling water.
7. See that normal vacuum is produced by the pump.
8. Open the air suction valve gradually and, if necessary, adjust the suction valve so that it functions properly.

Hydraulic Air Pump, Independently Driven—Shutting Down

1. Close the air suction valve.
2. Stop the pump.
3. Shut off the water to the seals.
4. Shut off the oiling system.
5. Close the hurling water suction valve after the pump has come to rest.

306. Steam Jet Air Pump, Two Stage Inter and After Surface Condenser Type—Starting

1. See that auxiliary cooling water is passing through the pump condenser, if pump is so equipped.

2. Open air suction pipe between main condenser and pump.

[NOTE: On pumps with multiple elements, open suction valves to all elements and bring all in operation on starting.]

3. See that the drain from the pump after-condenser is open.

4. Open steam throttle and pass steam through secondary nozzle.

5. Open equalizer drain between pump inter-condenser and main condenser.

6. Adjust steam throttle to secure proper working pressure.

7. When proper back pressure has been secured in the main condenser and the turbine put into operation, pass condensate from main condenser through the pump condenser instead of raw circulating water.

8. Open primary steam nozzles and bring the back pressure in the main condenser as low as possible.

[NOTE: On pumps with multiple elements use only as many elements as are necessary to remove the air.]

Steam Jet Air Pump, Two Stage Inter and After Surface Condenser Type—Shutting Down

1. Close the suction pipe between main condenser and pump.

2. Close the equalizer drain between pump inter-condenser and main condenser when pump has separate inter-condenser.

3. Close steam throttle.

307. Corliss Engine Driven Air and Circulating Pump—Starting

1. Open all drains from the steam cylinder.

2. Open the exhaust valves and exhaust line drains.

3. Disconnect the wrist plate from the eccentric rod hook.

4. See that the oiling system is working properly before and after starting.

5. See that the cranks, cross heads and other movable parts are not obstructed by any foreign material.

6. See that the cross head pins, crank pins and valve gear pins are tight.

7. See that the crank is in such a position that it will start readily.

8. Open the air cylinder discharge valve.

9. See that cooling water is turned on to the air cylinder jacket.

10. See that water is turned on to the circulating pump seals.

11. Prime the circulating pump by the means provided.

12. Open the discharge valve on the circulating pump.

[NOTE: Because of large clearances and absence of suction valves in certain pumps, it may be necessary to keep the discharge valve closed until the pump is turning over slowly.]

13. Place the bar in the wrist plate of the engine.

14. Open the throttle valve slightly and rock the valve gear with the bar, admitting steam alternately to each end of the cylinder, warming it up and allowing the piston to move backward and forward a number of times to clear the cylinder of water. Note whether any bearings are loose when rocking.

15. Close the throttle, then engage wrist plate with eccentric rod hook and lock it in place.

16. Open the throttle.

17. Turn the engine over slowly.

18. Open the suction valve of the circulating pump slowly and see that water starts to circulate.

19. Bring engine up to normal speed.

20. See that the oil pump is removing oil from the reservoir.

21. Close the drains.

22. Shut off priming equipment.

23. Open the air suction equalizing valve on the pump, if one is provided.

24. Open the air suction valve on the air pump.

25. See that there is no excessive leakage from the circulating pump glands.

26. See that the lubricators on the air valves and steam cylinders are operating.

Corliss Engine Driven Air and Circulating Pump—Shutting Down

1. Partly close the throttle valve.

2. Close the circulating pump suction valve.

3. Close the throttle until the engine is turning slowly.

4. Disengage the eccentric rod from the wrist plate and insert the bar.

5. Stop the engine in a starting position by rocking the wrist plate with the bar.

6. Close the main throttle valve.

7. Place the wrist plate in the central position.

8. Open drains before closing exhaust valve, if non-condensing.

9. Exhaust valve should be closed and drains opened.

10. Shut off the oiling system.

11. Close the air suction valve on the air pump.

12. Shut off water to air cylinder cooling jacket.

13. Close the discharge valve on the circulating pump.

14. Shut off water to the seals.

15. Make a general inspection.

308. Wet Pump, Centrifugal Type—Starting

1. Admit water to the seals.

2. Open the suction valve.

3. Open vacuum equalizing line.

4. Start the pump, turning slowly.

5. See that the oiling system is working properly.

6. Open the discharge valve, if not already open.

7. See that the proper water level is maintained in the hotwells to which the pump which is operating is connected.

[NOTE: If the water level rises and one pump does not meet the demand, a second pump must be put into operation. Look for air leaks around the pump on putting on the second pump.]

Wet Pump, Centrifugal Type—Shutting Down

1. Stop the pump.

2. Close the discharge valve, if pump is provided with check valve.
3. Close the suction valve, if necessary.
4. Close the vacuum equalizing line.
5. Shut off the water to the seals.

309. Surface Condensers—Periodic Test for Tube Leakage

Periodic tests should be made for leakage on surface condensers. There are several methods in general use for this purpose, two of which are outlined below.

While shutting down the turbine, a test should be made for leakage on the condenser, as follows:

1. Maintain as low a back pressure as possible in the steam space of the condenser.
2. With the suction valve of the wet pump closed (also the suction equalizing line when one is installed) note the rate at which water rises in the hotwell, deducting steam and water used for sealing. The rise of water in the hotwell under these conditions indicates a leakage of circulating water into the steam space.
3. Record in the daily log sheet the rate at which the water rises and the back pressure at that time.
4. When an additional chemical test is required, (a) take a one to two gallon sample of circulating water while the hotwell is filling; (b) take a one to two gallon sample of water in the hotwell immediately at the end of the test; (c) forward the samples to the laboratory for analysis.

When salt water or water unfit for boiler feed is used for circulating water, a test should be made each time a unit is put into service, regardless of how short a time it may run. It is also desirable to test each eight hours, or oftener, while on continuous runs. Chemical or electrical tests may be employed. The most commonly used method is that of titrating for chlorine where circulating water is salty. The measure of the outstanding quality of circulating water can be used in any case to determine the leakage.

310. Surface Condensers—Periodic Test for Air Leakage

1. Just before shutting down the turbine, close the suction valve to the air pumps and note time required for vacuum on condenser to drop one inch. This will give a measure of the air leakage.

[NOTE: Back pressure should be watched continuously during operation. Appreciable change at any given load may indicate a leakage.]

311. Jet Condensers—Test for Air Leakage

Fill the condenser with water up to turbine glands, and if there are any leaks, stop them.

312. Pumps, Plunger Type—Starting

1. See that the exhaust valve is open.
2. Open drains on steam cylinder and exhaust line.
3. See that the discharge valve is open.

[NOTE: If bypass is provided, pump should discharge back to the suction through bypass, when starting.]

4. Open the suction valve.

[NOTE: Where a pump is being started in parallel with another already in operation, the danger, due to air binding of the latter, caused by the opening of the suction valve on the incoming pump, particularly where there is a suction head, can be overcome by starting the incoming pump slowly, establishing a vacuum on its suction side somewhat greater than that on the pump in operation before opening the suction valve. Then when the suction valve of the incoming pump is opened the operation of the pump already in operation will not be affected.]

5. See that the lubricator is working properly and oil all moving parts both before and after starting.
6. Open the throttle valve and start slowly.
7. Bring the pump up to speed for the desired pressure.
8. Close the drains.

Pumps, Plunger Type—Shutting Down

1. Close the throttle valve.
2. Close the exhaust valve.
3. Turn off the lubricator.
4. Close suction valve.
5. Close discharge valve.

313. Accumulator Pumps—Starting

1. See that the exhaust valve on the steam end is open and that the exhaust line is drained.
2. See that the drains on the steam cylinder are open.
3. See that the suction and discharge valves are open and that all air is out of the pump.
4. See that the lubricator is working and oil all moving parts before and after starting.
5. Open the throttle sufficiently to warm cylinders.
6. Start the pump moving slowly and bring the accumulator slowly to the normal running position without sticking or binding.
7. Close the drains.
8. Examine glands and nuts.
9. See that pump does not speed up.
10. See that alarm signals are in service.

Accumulator Pumps—Shutting Down

1. Close the throttle slowly, allowing the accumulator to come slowly to the bottom stop.
2. Cut out alarm signals before accumulator reaches stop.
3. Open the drains.
4. Close the steam valves to the lubricators.
5. Close the suction and discharge valves.
6. Clean the strainers.
7. Exhaust valve should be closed.

314. Air Compressors, Synchronous Motor Driven—Starting

1. Close the suction valve.
2. Open bleeders on air cylinders and connections.
3. Open the water valves to the cooling jackets.
4. See that the oiling system is working properly, both before and after starting and do any necessary oiling previous to starting.
5. See that the discharge valve is closed.
6. Open the free exhaust valve on the discharge line.

7. Start the synchronous motor and bring it up to speed.
8. Open the discharge valve.
9. Close the free exhaust valve on the discharge line.
10. Open the suction valve.
11. Close all bleeder valves.
12. See that all control valves are working properly.

Air Compressors, Synchronous Motor Driven—Shutting Down

1. Stop the compressor.
2. Close the discharge valve.
3. Open the free exhaust valve on the discharge line.
4. Close the suction line.
5. Shut off the water supply to the cooling jacket.
6. Shut off the oiling system.

315. Air Compressors, Steam Driven—Starting

1. Open the exhaust valve.
2. See that the steam drain valves are open.
3. Open the bleeders on air cylinders and connections.
4. See that the oiling system is working properly both before and after starting and do any necessary oiling previous to starting.
5. Open the water valves to the cooling jackets.
6. Latch the cut-out valve in the closed position.
7. Open the throttle slightly and run the machine slowly while heating up.
8. Gradually open the throttle wide, bringing the compressor to speed.
9. See that the governor operates and holds the speed constant.
10. Close the bleeder and drain valves.
11. Release the cut-out valves.
12. When working pressure is almost reached, open the air discharge valve.
13. See that the cut-out valves and the control valves are operating properly.

Air Compressors, Steam Driven—Shutting Down

1. Latch the cut-out valve closed.
2. Close the air discharge valve if check valve is not used.
3. Close the throttle valve.
4. Open the drain valves.
5. Shut off the water supply to the cooling jackets.
6. Shut off the oiling system after the machine has stopped.
7. Shut off the lubricators.
8. The exhaust valve should be closed.

B—ROUTINE, CARE AND MAINTENANCE

1—Turbines

1001. General

1. Machines should always be kept as clean as possible and wiped periodically.
2. Inspect wheel and thrust clearances periodically and make necessary adjustments.
3. Make complete internal inspection of turbines periodically and make necessary repairs.

1002. Oiling System

1. Oil should be carefully watched, maintained in good condition and changed when necessary.
2. Clean the screens of the turbines oiling system periodically as required by local conditions.
3. Blow out the cooling coils of the oil cooling system when necessary, as shown by the oil and water temperatures.
4. Clean the oiling systems and gravity filter tanks when necessary.

1003. Governors

1. Examine the worms and gears of the governors periodically and repair same, if necessary.
2. Inspect the needle valve oil supply to the governor knife edges periodically.
3. The roller transmission (Gimbal bearings) of the governor should be given a thorough internal cleaning periodically and oiled as often as local conditions require.
4. A periodic examination of the overspeed device should be made as often as possible.

[NOTE: It should be definitely known each time the machine is started up that the overspeed device is in perfect operating condition, especially if the machine has been out of commission for some time. Because of differences in design and operating conditions, it is recommended that on vertical turbines examination should be made not less than once each week and on horizontal turbines not less than once each month.]

2—Auxiliaries

2001. Small Turbines and Reciprocating Engines on Auxiliaries

1. Insofar as they are applicable, Rules 1001, 1002 and 1003 should be followed.
2. The racks and pinions of valve gears should be scraped and cleaned periodically.

2002. Condensers

1. Examine the interior of condensers periodically.
2. Clean condenser tubes when necessary.

2003. Miscellaneous

1. Examine motor operated valves periodically and make necessary adjustments and repairs.
2. All remote control valves should be operated periodically.
3. All water strainers should be kept clean.
4. Operate the main valves of the forebays periodically, being sure adjacent valves are open as each is manipulated.
5. Clean out the debris from the bottom of the screen basin well and overhaul the apparatus periodically.

BOILER AND TURBINE ROOM INSTRUMENTS

GENERAL

Within the past decade there has been a decided change in the attitude of both designing and operating engineers toward the use of station instruments. The development of such instruments has necessarily been slow; they were expensive in first cost as well as maintenance and somewhat unreliable in their results. This was particularly true of instruments for boiler and turbine operation; and, when the boilers seldom exceeded 7000 sq. ft. of heating surface, and the turbines were small, the cost of the instrument was a large proportion of the total cost of the installation. With increasing size of the boiler units, as well as the generating units, the cost of an instrument installation has become a very small percentage of the total cost of the equipment.

The intelligent use of instruments has fully justified these expenditures and in consequence we find a tendency toward the use of extremely elaborate instrument installations. The Committee, while fully indorsing the extensive use of instruments as aids in proper operation, wishes to repeat a warning published in the report of 1923 which included the following paragraph:

> "The Committee wishes to offer one warning. It is believed better to install too few instruments than to install more than can be taken care of by the operating organization. There is nothing so disastrous as to install devices for improving economy which are not kept in operating condition constantly. The failure of such a device often destroys the confidence of the operating force in all of them and it is sometimes months before this confidence is restored."

In general, the Committee finds that boiler and turbine room instruments, as now offered by various manufacturers, show marked improvement in accuracy, reliability and decreased maintenance, but feel there is still room for further progress in these directions, particularly as to flow meters and instruments for the measurement of the temperature of water, gases and steam where weighted averages are so necessary for obtaining true efficiencies. It should be remembered, however, that these instruments are necessarily of a somewhat delicate construction and consequently need intelligent care and supervision.

In general, the measurement of steam and water quantities depends upon measurements of the drop in pressure across an orifice. A mistake in the size of the orifice introduces a constant error and, when the operating force is not equipped for the calculation of such orifices, some means of checking the meter readings should be used before full reliance is placed on them. The present practice of manufacturers seems to be to calibrate their meters for a constant coefficient of discharge, whereas, if the actual curve for this constant were used, a greater accuracy could be obtained.

The installation of an elaborate set of instruments does not of itself insure economical operation. The instruments are valuable tools which, when intelligently used, will assist in maintaining a higher operating economy than would otherwise be possible. Such an intelligent use of instruments is described in the report of the Committee on Station Betterment for this year.

CO_2 INSTRUMENTS FOR COMBUSTION CONTROL BOILER WATER LEVEL INDICATORS OR RECORDERS

The Committee endeavored to learn something of the present status among member companies as to the use of CO_2 instruments and boiler water level recorders as aids in boiler operation.

Replies were received from thirty-nine members, and these replies have been summarized below.

Co2 Instruments

About one-third do not use CO_2 instruments, and approximately two-thirds do, and while the latter do not approve wholeheartedly of the equipment, the consensus of opinion seems to be that they are an aid to the firemen and useful in combustion control.

The instruments used are of the chemical, mechanical and electrical types, with the chemical in the majority due, no doubt, to the fact that they have been on the market for a longer time than the others. Where other than the Orsat type alone is used, they are practically all of the recording type and many have, in addition, an indicator.

The favored location is on the boiler instrument panel, but in some instances other locations, such as the boiler room engineers' office, have been chosen.

Generally there is one instrument per boiler, though some plants have one instrument for a group of boilers.

It is the practice to check the instruments at regular periods, the intervals being daily, weekly or monthly as experience dictates, while the standard for comparison is in all cases the Orsat.

The accuracy varies within the limits of —0.5 per cent to +3.0 per cent of the Orsat reading and is fairly well maintained provided the instruments are given reasonable care.

Records may be continuous or intermittent with intervals between readings as much as five minutes.

The maintenance cost varies from "very small" in one case and "one man hour per day per instrument," in another, to "$4.00 per instrument per week" for a third with all the gradations between.

Gas samples, as a rule, are taken from one point at the center of the flue, though in several instances two or more points across the breeching are selected, and the gas with few exceptions is drawn through porous filters.

Publication No. 289-59. Serial Report, Prime Movers Committee.

Boiler Water Level Indicators or Recorders

These instruments, which are both recording and indicating, are reported by only five members who list four makes.

The instruments are said to be dependable, to require but little attention, to be easily installed by unskilled labor and to cost about the same as a flow meter.

The instruments are checked by comparison with the boiler gage glass, the comparison being made at intervals of 6 hr., 8 hr., twice a day, and in one case "almost constantly," as it is compared with the gage glass at every reading.

The reports do not, however, indicate that any of the members are giving serious thoughts at present to a general use of such instruments as a necessary or desirable adjunct to the regular water glass on the boiler drum.

STATEMENTS BY MEMBER COMPANIES

Statement by the Union Gas & Electric Co.

Ranarex CO_2 Recorders

"As a result of the success of a trial installation at West End Station, Ranarex CO_2 Recorders were included in the initial order of instruments for Columbia Station. The recorders installed at Columbia are not of the 'strip chart pin punch' type, but have disk charts, driven by 24-hr., spring-wound clocks, and the record is made by an inking pen.

"The strip chart on the trial installation gave considerable trouble. The chart at times would not feed and it was impossible to adjust the time of the chart with any degree of accuracy. The disk chart inking pen recorders have proved satisfactory. The quantity of ink in the pen does affect the reading, but this inaccuracy can be decreased by filling the pen at frequent intervals. The disk chart is superior to the strip chart for filing and reference.

"It is possible to operate the recorders by checking them to zero, but the increase in accuracy makes a daily Orsat check advisable. The filter and water legs are installed below the boiler operating floor, above a landing, making them easily accessible for inspection and eliminating unsightly piping near the recorder. An air line is provided for blowing out the line from the filter to the boiler. This line is blown every 24 hr. In addition, it has been found necessary to blow out the remainder of the piping with an air hose every two weeks.

"The cleaning, inspecting and checking is a routine daily job. For 6 recorders in operation the total time required is 4 man-hours per day. The recorder mechanism has needed but few repairs. It has been necessary to replace the can that contains the filter material by one made of copper, to prevent corrosion.

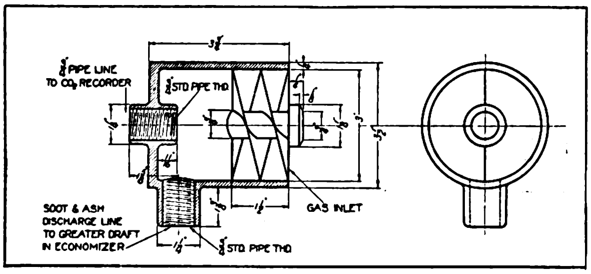
3/8" PIPE LINE TO CO_2 RECORDER
3/8" STD PIPE THD
3¾"
GAS INLET
1½"
SOOT & ASH DISCHARGE LINE TO GREATER DRAFT IN ECONOMIZER
3/8" STD PIPE THD

FIG. 1—Detail Drawing of Gas Cleaner for Ranarex CO_2 Recorder Used by the Union Gas & Electric Co.

"The recorder draws a large volume of gas and on pulverized fuel installations the sampling line becomes stopped with ash. This necessitates very frequent blowing of the line when the boilers are operated at high ratings. Fig. 1 shows a gas cleaner that has been used to good advantage in keeping the sampling lines clear. The gas sample is taken in the last pass of the boiler. The sample is taken into the cleaner through spiral vanes, which give it a circular motion. A pipe runs from the bottom of the cleaner to the economizer outlet where the draft is 1 in. of water more than in the third pass. This pipe serves both to produce high velocity through the vanes and to discharge a large per cent of the ash. The line to the recorder takes its sample from the center of the 'whirl' where there is the smallest amount of ash.

"This cleaner has given better results than porous filters installed on the end of the pipe. They were made at the plant by the welder. The vanes are made of 16-gage iron brazed to ¾-in. bolts and then brazed in position in the 3¾-in. length of 3-in. pipe.

CALIBRATION OF THERMOMETERS

In order to operate the modern power plant efficiently, it is necessary to obtain accurate temperature records of boiler feed water, condenser circulating water, boiler flue gas temperatures, etc. Various types of indicating and recording thermometers, having temperature ranges between 32 deg. fahr. and 2500 deg. fahr., are used to obtain these records.

The mercury thermometer is the commonest of the indicating instruments used for such purposes, temperatures as high as 950 deg. fahr. being measured with this type of thermometer. Recording thermometers, of the mercury, vapor tension or gas type are also extensively used.

When it is desirable to measure temperatures at inaccessible points, or to measure temperatures higher than 950 deg. fahr., thermocouples and resistance thermometers are generally most suitable.

To obtain reliable temperature readings with any type of thermometer, great care must be taken not only to install the instrument properly, but also to make sure of the accuracy of the instrument itself. Since the calibration of practically any thermometer is subject to change, it is advisable that occasional checks be made with a suitable standard. This is particularly necessary with recording instruments which are quite apt to change their calibration.

In order to obtain an accurate check, it is necessary to keep the sensitive element of both the thermometer under test and the standard at exactly the same temperature, since the accuracy of the check depends on the uniformity in temperature of the test bath.

It is thought, therefore, that the descriptions of the laboratory methods used by several member companies for this work will be of interest.

Methods of Calibration of Thermometers and Pyrometers

STATEMENT BY DETROIT EDISON CO.

Engraved Stem Glass Thermometers

Apparatus

"For temperatures up to 550 deg. fahr. an electrically heated oil bath with stirring attachment similar to that described in the A.S.M.E. Power Test Code (Instruments and Apparatus) is used.

"For temperatures between 550 deg. fahr. and 800 deg. fahr., a similar bath of sodium and potassium nitrate is used.

Calibration

"The purpose for which the thermometer is to be used governs the general calibration method.

"For instance, a general service thermometer having a range of 30 deg. fahr. to 800 deg. fahr. is checked at any desired immersion against a standard resistance thermometer at every 50 deg. fahr. on both an increasing and decreasing temperature curve.

"Thermometers for special service or for some particular range where a high degree of accuracy is required are checked at a desired immersion against a standard resistance thermometer at intervals of 10 deg. fahr. somewhat above and below the range when in use. The emergent stem temperature of such thermometers is usually determined during the calibration so that steam temperature correction can be applied to field readings to cover any difference between stem temperatures during calibration and field conditions. The corrections are determined by reference to the A.S.M.E. Power Test Codes, Instruments and Apparatus Section.

Industrial Thermometers

"The same apparatus and method is used as for engraved stem thermometers, the industrial type being screwed into tapped holes arranged inside of the tank for this purpose.

Recording Thermometers

(Metal tube extended bulb-types)

Low Range—0 deg. fahr. to 220 deg. fahr.

"The metal bulbs are removed from the thermometer well or protection tube. Several bulbs are wired together with bare copper wire and immersed in a bucket of water. One standard glass stem thermometer is tied to the group of metal bulbs using a small pad of tinfoil around the bulb of the standard thermometer; another standard thermometer is placed a few inches away from the group of bulbs under test.

"The recorders are mounted on a convenient board as near the bucket as possible with the extension tubes coiled up to a circle approximately 1 ft. in diameter. The whole assembly is allowed to stand overnight so as to assume room temperature of as close to 70 deg. fahr. as possible before making the calibration test.

"Readings are taken against the standard thermometer every 10 deg. fahr., the temperature of the water bath being raised by adding, and stirring well, hot water to the water in the bath.

High Range—above 212 deg. fahr.

"These are checked against standard engraved stem thermometer by immersion of the bulbs in first the oil and then the nitrate bath, readings against the standard being taken every 50 deg. fahr., while heating and cooling.

Thermocouples

Apparatus

"For low range thermocouples the calibration is carried out in the baths used for thermometers and checked against standard thermometers.

"For high range thermocouples use is made of:

1. An electrically heated bath of metal of known melting point. (Used only for preparing standard couples.)
2. An electrically heated bath of pure lead for checking against standard couples.

Calibration

"For low ranges (0 deg. fahr. to 500 deg. fahr.), where great accuracy is required, the couples are checked every 25 deg. fahr. against a standard thermometer; the millivoltage in all cases being measured by a low range precision potentiometer, the cold end being maintained at 32 deg. fahr. with ice in a vacuum bottle. For all other ranges and where extreme precision is not required, readings are taken against a prepared standard every 50 deg. fahr. and the millivoltage developed is measured with a semi-precision potentiometer. The cold end here also is 32 deg. fahr.

"Indicators and recorders are checked against a semi-precision potentiometer at frequent intervals; this potentiometer in turn being checked against a potentiometer of high precision."

STATEMENT BY THE CLEVELAND ELECTRIC ILLUMINATING CO.

"The apparatus employed by this company in calibrating mercury-in-glass laboratory type thermometers is that shown in Fig. 2.

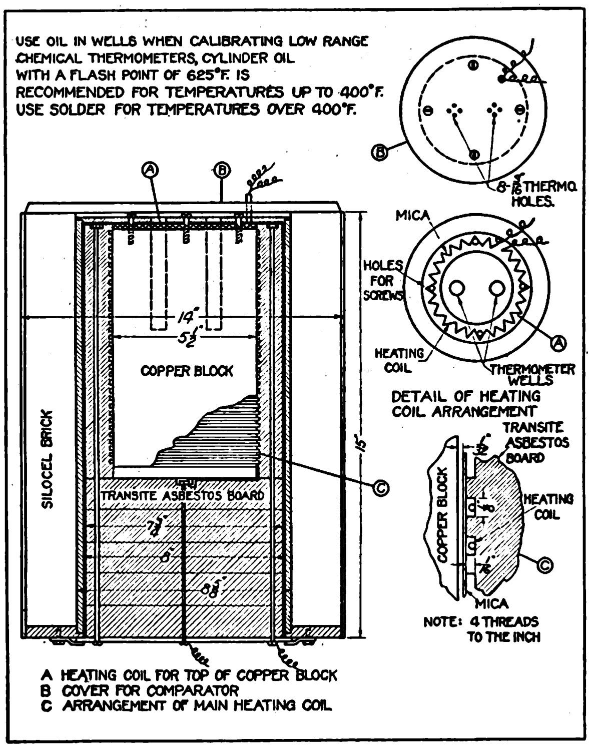
USE OIL IN WELLS WHEN CALIBRATING LOW RANGE CHEMICAL THERMOMETERS, CYLINDER OIL WITH A FLASH POINT OF 625°F. IS RECOMMENDED FOR TEMPERATURES UP TO 400°F. USE SOLDER FOR TEMPERATURES OVER 400°F.
A
B
14"
5½"
COPPER BLOCK
SILOCEL BRICK
TRANSITE ASBESTOS BOARD
7¾"
8"
8⅝"
15"
C
8-5/16 THERMO HOLES.
MICA
HOLES FOR SCREWS
HEATING COIL
THERMOMETER WELLS
DETAIL OF HEATING COIL ARRANGEMENT
TRANSITE ASBESTOS BOARD
COPPER BLOCK
HEATING COIL
MICA
NOTE: 4 THREADS TO THE INCH
A HEATING COIL FOR TOP OF COPPER BLOCK
B COVER FOR COMPARATOR
C ARRANGEMENT OF MAIN HEATING COIL

FIG. 2—DETAILS OF ELECTRIC COMPARATOR FOR THERMOMETERS, THE CLEVELAND ELECTRIC ILLUMINATING CO.

"A copper block 5½ in. in diameter x 11 in. long, mounted in a hollow transite cylinder, is maintained at any desired temperature by a heating coil of No. 17 Nichrome IV resistance wire. This heating coil is fixed in grooves cut in the inner surface of the hollow transite cylinder. The turns of the coil are held in place by porcelain cement and are kept from grounding on the copper block by sheet mica A flat auxiliary heating coil mounted over the top of the block compensates for the heat loss through the cover and maintains a uniform temperature throughout the depth of the block.

"Two wells, each 1¼ in. in diameter, serve to hold the

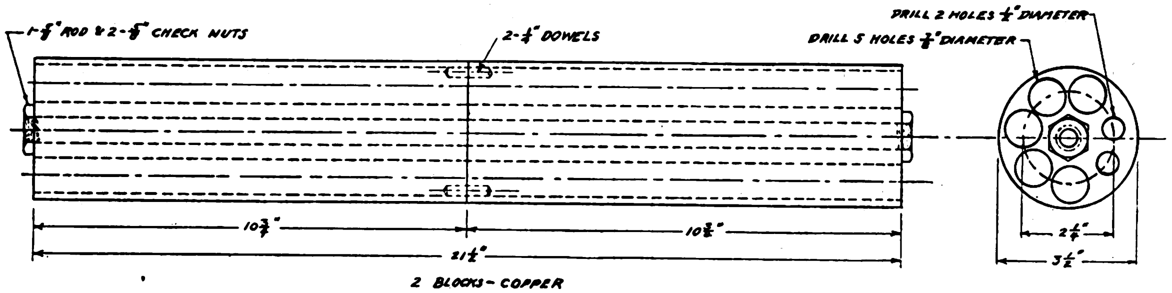
1-⅝" ROD & 2-⅝" CHECK NUTS
2-¼" DOWELS
DRILL 2 HOLES ½" DIAMETER
DRILL 5 HOLES ⅞" DIAMETER
10¾"
10¾"
21½"
2¼"
3½"
2 BLOCKS-COPPER

FIG. 3—THERMOMETER TEST EQUIPMENT, CONSTRUCTION OF COPPER BLOCK, PUBLIC SERVICE ELECTRIC & GAS CO.

oil or solder in which the thermometers are immersed. Cylinder oil is used for temperatures up to 400 deg. fahr.; common solder is used above this temperature.

"Calibration is always against primary standard thermometers certified by the Bureau of Standards. Both ascending and descending calibrations are run, but in every case the temperature is held constant for five minutes during the period of readings at each point of calibration.

"Industrial type thermometers are not able to be calibrated in this comparator on account of the heat loss from the thermometer case. Instruments of this class are calibrated only under the actual conditions of use against laboratory type thermometers immersed in wells, inserted in the pipe or line as near the point of immersion of the industrial instrument as possible.

"Flue gas temperature instruments of the gas-filled type are calibrated against thermocouples. These are in turn calibrated against laboratory thermometers in a closed box in which is circulated heated air. Care must be exercised in calibrations of this kind to adequately shield the thermocouples and thermometers against radiation from the air heating elements."

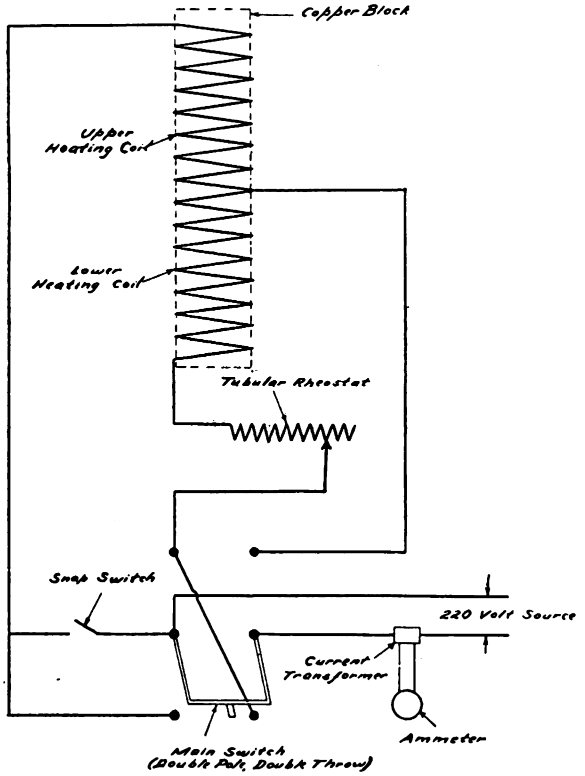

FIG. 4—WIRING DIAGRAM OF COPPER BLOCK THERMOMETER TESTER, PUBLIC SERVICE ELECTRIC & GAS CO.

Equipment and Method for Testing Thermometers

STATEMENT BY THE PUBLIC SERVICE ELECTRIC & GAS CO.

"In order to calibrate the various types of thermometers conveniently and accurately, the Testing Laboratory of the Public Service Electric & Gas Co. has designed and built one copper block thermometer tester and two test tanks suitable for use with either oil or water as a medium. All three testers are electrically heated from a 220-volt a-c. source.

"The copper block tester consists of cylindrical copper blocks 3½ in. in diameter and 1 ft. 9½ in. long. Five ⅞-in. and two ½-in. holes are drilled lengthwise through the block for inserting thermometers. The block is made in two sections, which are fastened together by means of dowel pins and a bolt through the center, as shown in Fig. 3. The block is mounted vertically on an iron frame and is surrounded with 3 in. of flaked asbestos, exposing only the holes at the top of the block.

"The wiring diagram for the copper block tester is shown in Fig. 4. Two heating coils, each consisting of 126 turns of No. 18 nichrome wire, are wound on the block, sheet mica be-

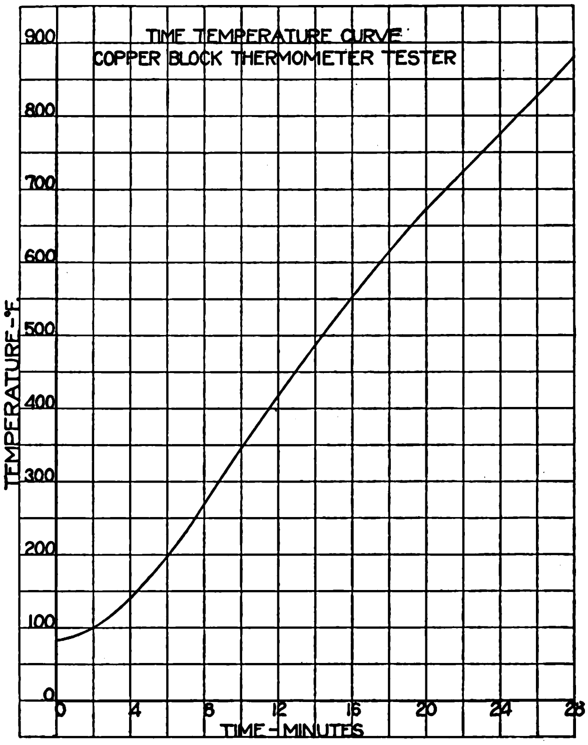

FIG. 5—TIME TEMPERATURE CURVE OF COPPER BLOCK TESTER, PUBLIC SERVICE ELECTRIC & GAS CO

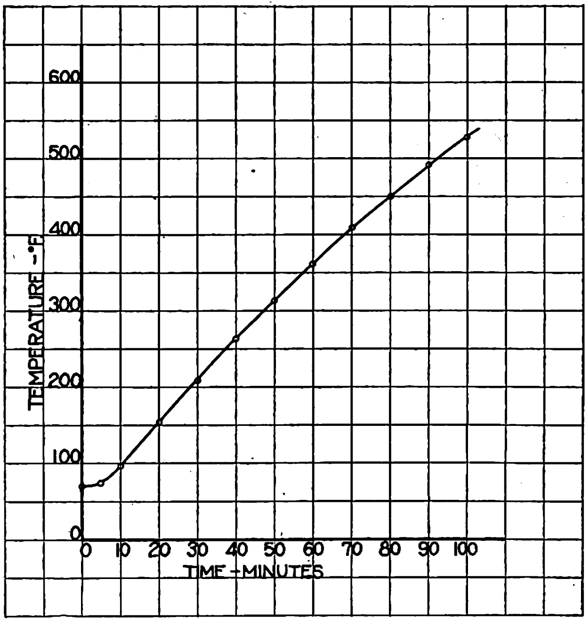

FIG. 6—Time Temperature Curve, Oil Bath Thermometer Tester, Public Service Electric & Gas Co.

ing used to insulate the coils from the block. When the double-pole, double-throw switch in the diagram is down, the two coils are connected in series; when the switch is up and the snap switch open, one coil is in service all alone; and when the main switch is up and the snap switch closed, the two coils are connected in parallel. By the above arrangement of switches and by adjusting the tubular rheostat shown in the sketch, the current may be varied from 1.3 amperes to 13 amperes, when connected to a 220-volt a-c. source. In the actual installation a special 6-point covered snap switch is used, taking the place of the double-pole, double-throw switch shown in the diagram. The time temperature curve, Fig. 5, shows that the temperature rises from 85 deg. fahr. to 650 deg. fahr. in 19 min. After the apparatus is once heated to the required degree, very little current is required to maintain the temperature. This equipment has been used for checking at temperatures as high as 1200 deg. fahr.

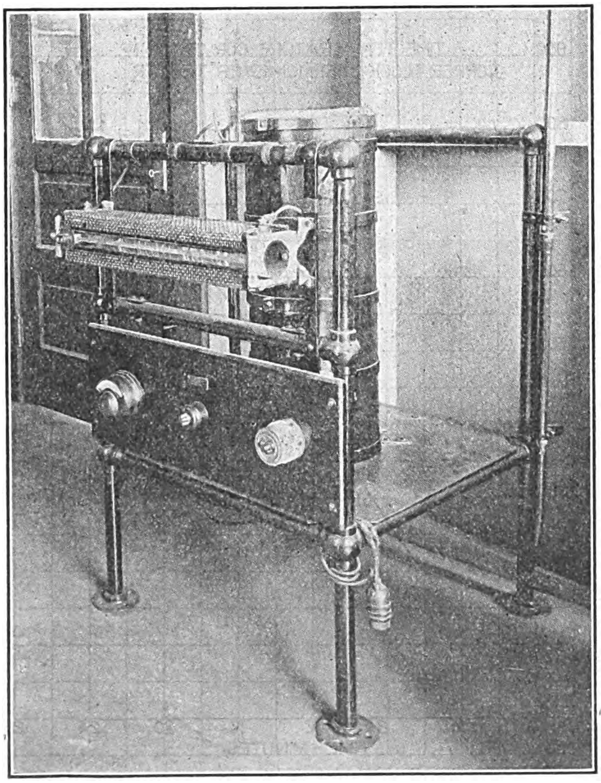

FIG. 7—Thermometer Test Equipment. Copper Block, Public Service Electric & Gas Co.

"Both the oil and the water bath testers have a brazed galvanized tank 7.75 in. in diameter x 1 ft., 6 in. in height, designed for holding oil at 600 deg. fahr. This tank is supported in a larger outer tank, and the space between the two filled with asbestos insulation. Both tanks are bolted securely to a heavy iron cover. The top of the inner tank is left open for inserting thermometers to be checked.

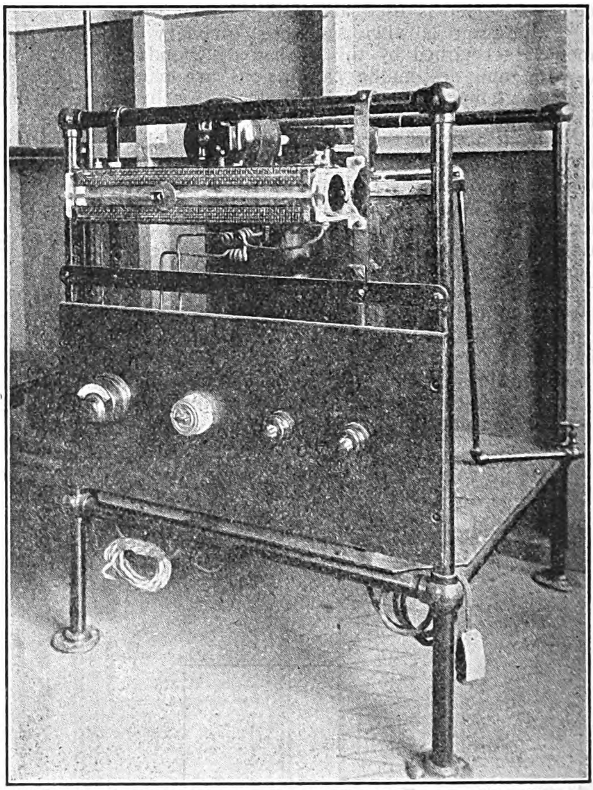

FIG. 8—Thermometer Test Equipment. Oil Bath, Public Service Electric & Gas Co.

"In order to obtain a uniform temperature throughout the bath, two impellers mounted on a vertical central shaft force the liquid down through an inner cylindrical tube and thence up along the heated surface of the tank, thus aiding the natural circulation. Holes in the upper end of the cylindrical tube allow the liquid to enter the tube above the impellers. The vertical shaft is driven through a worm gear by a ¼-hp., a-c. motor mounted on the top of the frame.

"The wiring diagram for the oil and water bath testers is the same as that for the copper block tester, shown in Fig. 4. Both heating coils, each having 69 turns of B. & S. No. 20 'Advance' wire, are wound on the outside of the inner tanks. This wire has a resistance of 287 ohms per 1000 ft. The time temperature curve, Fig. 6, shows the heating characteristics of one of these baths when filed with oil. The current consumed by each of these baths amounts to 13 amperes at 220 volts alternating current.

"Photographs of the copper block tester and of the two baths are shown in Fig. 7 and 8."

STATEMENT BY PHILADELPHIA ELECTRIC CO.

"Thermometers, according to their ranges, are tested in the laboratory by one of three comparators.

"The comparators and their ranges are:

	Range
1—Water bath	32 deg. fahr. to 212 deg. fahr.
2—Oil bath	212 deg. fahr. to 450 deg. fahr.
3—Lavite bath	450 deg. fahr. to 1100 deg. fahr.

Water Bath Comparator

"This comparator consists of a water bath tank made of copper. It is approximately 15 in. in diameter and 18 in. deep and is lagged with 1¾-in. thickness 85 per cent magnesia. The heat is supplied from a gas flame at the bottom of the tank. The water in the bath is agitated by introducing compressed air at a low pressure into the bottom of the tank by means of a ⅛-in. perforated ring which has a diameter of approximately 12 in. The thermometer indication is checked against that of a standard thermometer.

Oil Bath Comparator

"This bath consists of a vertical lagged tank 10 in. in diameter and 54 in. high. It is filled with oil commercially known as '600W,' which has a flash point of 700 deg. fahr. This oil is heated by means of heat generated in 24 electric resistors uniformly placed at the bottom of an 8-in. diameter tube. This tube extends up in the center of the tank almost to the top. Below the heating units is a motor-driven propeller, which assists in driving the heated oil up through the center tube to the top, where it flows over into the outer compartment and circulates down again to the propeller.

"The resistance units are connected in eight groups and the terminal wires from each group are so arranged externally to the heater that they may be connected in series or parallel, as desired. In this manner the current value can be controlled from 1 up to 80 amperes. The thermometers tested in this bath are also checked against standard thermometers.

Lavite Bath Comparator

"The third comparator is known as a 'lavite' bath, which consists of a steel pot approximately 8 in. in diameter by 24 in. deep, filled with lavite. The pot is heated by a gas furnace using a mixture of compressed air and gas. The pot is practically surrounded by gas flames except over the top. In this manner a more uniform temperature in the pot is assured. The thermometers checked in this bath are compared against standard thermometer or thermocouple indications.

"All standard thermometers and thermocouples have been certified by the Bureau of Standards at Washington.

"In all cases of checking, the thermometers are immersed to the proper depth and readings are taken after bath has been held at a constant temperature for a sufficient length of time to permit the thermometer to register a constant value.

"Thermometers are checked at various points as requested.

Lavite Bath Comparator

"In checking the various types of thermometers, the time required to reach a constant temperature depends upon the type being tested. The chemical type without any metal armor requires a minimum time of approximately 2 min., provided it has been previously heated to a temperature near the same value. Some of the commercial types equipped with metal armor require a much longer period of time to reach a constant value, as this time limit depends upon the amount of metal present which can radiate heat. In regard to this latter statement, some types have been checked where the amount of heat radiated by the thermometer armor was greater than could be supplied by a slow heating bath, so that the metal surrounding the thermometer bulb would never attain the temperature of the bath.

"In general, it may be stated that, if the circulation in a bath has sufficient velocity, a thermometer will reach a constant temperature in from 5 to 15 minutes, depending partly upon the amount of exposed metal armor and partly upon the difference in temperature between the room and the said armor."

Comparison of Water Flow Meters

STATEMENT BY THE UNITED ELECTRIC LIGHT & POWER CO.

"In an effort to determine the most satisfactory type of integrating and recording mechanisms for feed water service the United Electric Light & Power Co. installed several instruments connected to a common flow tube in a feed water riser supplying three boilers at Hell Gate Station.

"The instruments which were installed represented practically all of the generally used mechanisms from the standpoint of operating principle. There were three different types of recording and integrating meters.

1. Straight mechanical type using mechanical integration which is characteristic of the meters of this class.
2. Electrical type employing mechanical integration.
3. Combination of 1 and 2.

"The uniformity of flow through the feed water riser used for this test would be considered very good practice from a metering standpoint and conducive to accuracy in recording and integration as there were no pulsations in the flow or rapid and extreme changes of flow which often results in errors of metering.

"To further simplify the comparison, the peculiarities of the flow element itself were eliminated, since this is a problem of hydraulics rather than one of recording and integrating records. The problem in this instance was to determine which meter gave the most consistent record of the differential pressure in terms of water flow produced by the common Venturi tube under ordinary operating conditions. It has not been desirable to conduct a weighed water test on the installation for the reason that it was altogether too obvious that the instruments themselves were lacking in some important particular.

"The several meter manufacturers were each given a copy of the characteristics of the meter tube together with the maximum capacity required so that the instruments could be designed to record and integrate the water flow for the condition specified without any responsibility as to the accuracy of the meter tube. In other words, it was considered desirable to study the performance of the meter mechanism itself independent of the differential producing element. Past experience had indicated that the majority of the inaccuracies of metering were due to the mechanism, and that the differential producing element would at least give correct relative indications day after day, besides with water the Venturi tube or flow nozzle may be tested and

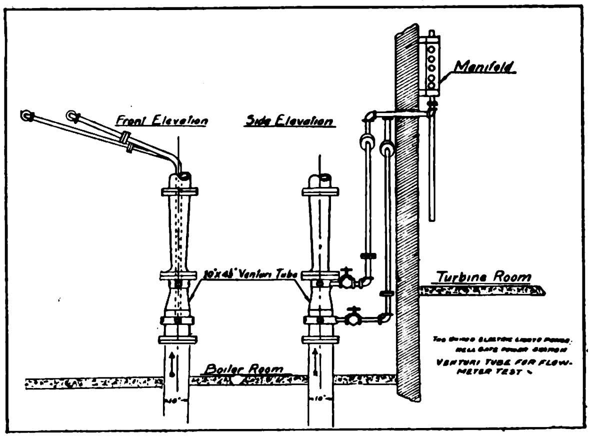

FIG. 9—VENTURI TUBE FOR FLOW-METER TEST, THE UNITED ELECTRIC LIGHT & POWER CO.

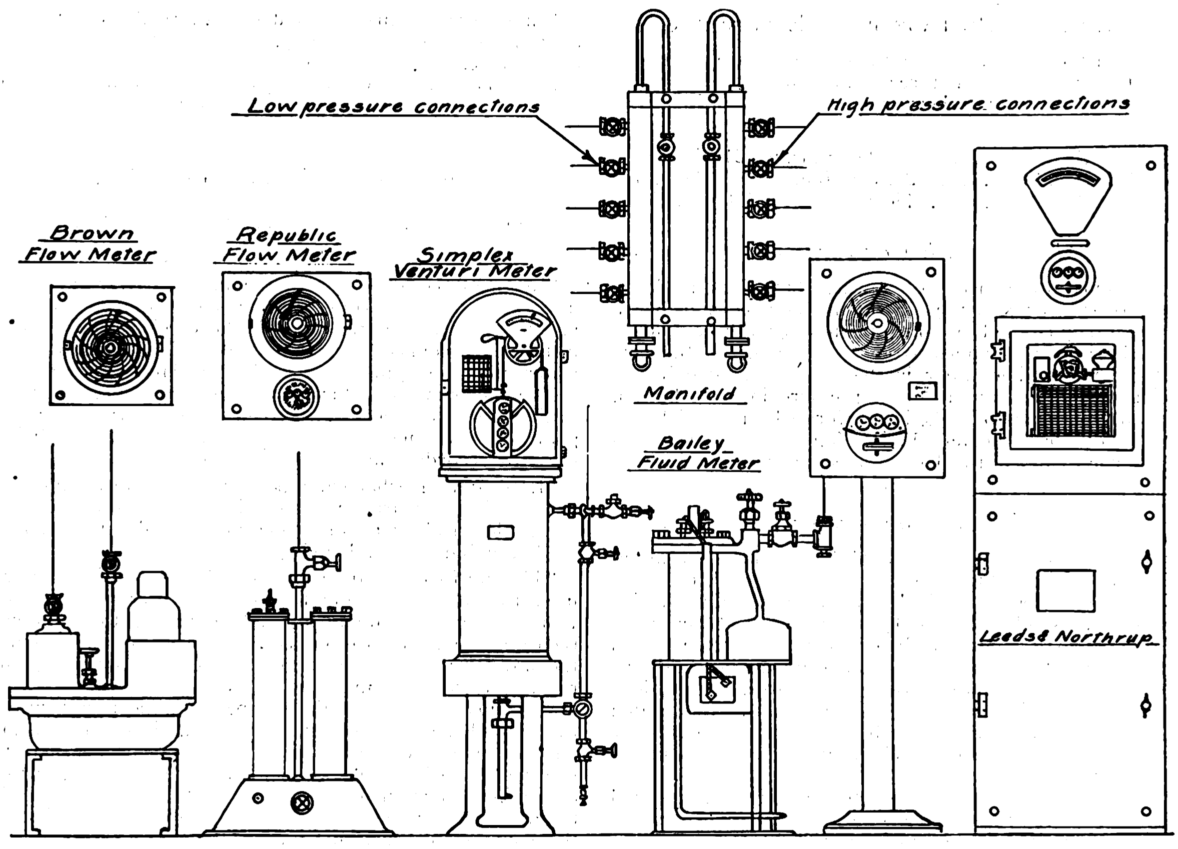

FIG. 10—ARRANGEMENT OF FLOW-METERS ON TEST, THE UNITED ELECTRIC LIGHT & POWER CO.

its characteristic determined with scientific precision. Once standardized, there is little likelihood of the nozzle or Venturi changing under ordinary conditions. The mechanism itself, however, is still subject to all of the ills indicated in this report.

"Instruments were selected for a capacity of 600,000 lb. per hr. which corresponds with a differential pressure of about 9 in. of mercury. It may be observed from the report that much of the time the instruments were operating at low capacity, which partially accounts for some excessive errors.

"The installation of the Venturi tube is shown in Fig. 9 and a group of meters, together with the manifold location, is shown in Fig. 10. The manifold was located higher than the Venturi tube, but this was not objected to by the manufacturers inasmuch as the tube was under high pressure which eliminated the possibility of air leakage into the system.

"The principal characteristics of the meters are as indicated in Table I. This table incidentally brings out in a striking manner the lack of uniformity of meter charts.

"The characteristic of the 10-in. Venturi tube with 4½-in.

TABLE I

FLOW METER TEST—HELL GATE STATION
No. 5 Feedwater Header, Meter Information

Bailey Fluid Meter	Brown Flow Meter	Leeds & Northrup Gibson Flow Meter	Republic Flow Meter	Simplex Venturi Meter
Type MPA-13	Model 203-4.		No. 421-124.	No. 10-114-1488GK.
Circular chart 12 in. dia. Equal increments across chart range. This makes it possible to integrate chart with polar planimeter.	Circular chart 12 in. dia. Unequal increments across chart range. This chart cannot be integrated. (?)	Paper chart roll. 10⅝ in. wide. Chart feed about 3⅛ in. per hr. Equal increments across chart range. This chart can be integrated with ordinary planimeter, but a great deal of time is involved on account of its excessive length for a 24-hr. period.	Circular chart 10¼ in. dia. Unequal increments across chart range. This chart cannot be integrated. Special planimeters are available.	Cylindrical chart 13½ in. by 4 in. Equal increments for chart range. This chart can be integrated with an ordinary planimeter.
Range 0-600,000 lb. per hr. Multiplying factor 10,000.	Range 0-100. Multiplying factor 5080 lb. per hr.	Range 0-600,000 lb. per hr. No multiplying factor.	Range 0-100. Multiplying factor 7500 lb. per hr.	Range 0-600,000 lb. per hr. No multiplying factor.

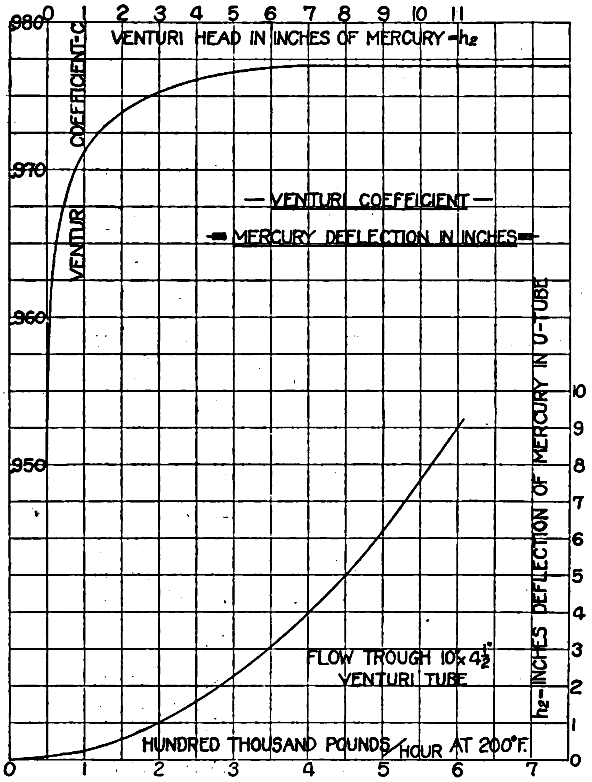

FIG. 11—Curve Showing Venturi Coefficient with Differential Head, the United Electric Light & Power Co.

throat is shown in Fig. 11. This curve also indicates the change in Venturi coefficient with differential head. While the coefficients are interesting in connection with hydraulic flow, this curve is of little significance in this particular installation, inasmuch as the United Electric Light & Power Company assumed the responsibility for the tube accuracy in order to eliminate this as a source of error or disagreement. The actual design data which was furnished the meter manufacturers is given in Table II.

Table II

Characteristics of 10 In. x 4.5 In. Venturi Tube 200 Deg. Fahr. Feedwater

Giving design information submitted for various recorders and integrators connected in parallel across the differential producing element of this tube.

Flow Lb. Per Hr.	Deflection Inches of Mercury[1]
20,000	0.011
40,000	0.0431
60,000	0.0947
80,000	0.1669
100,000	0.2580
150,000	0.577
200,000	1.017
250,000	1.583
300,000	2.28
350,000	3.097
400,000	4.045
450,000	5.098
500,000	6.294
550,000	7.616
600,000	9.064

[1] Water at room temperature above Mercury Legs.

"Varying coefficients are sometimes given as a cause of difficulty in meter installations, which is probably true in some instances, but in the light of our observations it appears that the larger part of the difficulties are caused by deficiencies in the recording and integrating mechanisms. Records of comparison between integrator and chart areas in terms of total flow are included to show the daily variations which exist. In spite of some fairly good monthly checks, some of the daily variations are excessive and would be decidedly misleading to the operating men who attempted to judge changes in operating conditions by records of this character. Although perfect agreement between chart and integrator record is not necessarily a measure of meter accuracy, it is one of the desirable characteristics of a good meter.

"In the light of our experience it appears that most meters are selected too large for the purpose intended, and that it would be better to select meters with a range which would be low enough so that for the majority of the hours of their use they would operate well out toward the upper end of their range with occasional peaks going beyond the chart range. This would necessitate a satisfactory seal to prevent loss of mercury at rates of flow beyond the range of meter, but it would seem to insure higher average accuracy.

"It might also be desirable to cut out the registration of the integrator and chart entirely when the pen drops within a few per cents of zero, depending largely upon the inherent amount of friction in the mechanism.

"During the time these instruments were under observation they received somewhat more expert and careful attention both on our part and the manufacturer's than should be expected under ordinary circumstances and a careful record was kept of the service requirements as well as the records and other observations. After the first installation some time elapsed before all of the meters could be made to operate with sufficient regularity so that their indications were worthy of comparison.

"In this report much of the preliminary difficulties are omitted, since this material would be too comprehensive to serve any useful purpose. Records of instruments which were replaced are also omitted where possible, since the information merely indicated at an early period that they were not worthy of the effort required to keep them in service.

"In the record of meter service the meter is identified by name but the comparison of the meter records is designated by letters; such as A, B and C. These meters have been in practically continuous service under operating conditions and the service requirements represent what might be expected in regular operation. The total flows as shown by the integrator by weeks and months from December, 1927, to September, 1928, inclusive is shown in Table III.

"A comparison of the total flow as shown by measuring the chart with that shown by the integrator for meters B and D shows the following differences based on the chart flow:

	Meter B Per cent	Meter D Per cent
April, 1928	—0.44	—5.80
May, 1928	+0.47	—2.30
June, 1928	+2.26	—3.41
July, 1928	—0.28	—1.58
August, 1928	+1.12	+1.77
September, 1928	+1.64	—1.95

"The importance of high accuracy and dependability of metering equipment in large scale power production can hardly be overstated. It seems reasonable to assume, however, that to secure meters with accuracy consistent with their importance, higher prices than we are now accustomed to pay may be necessary."

Recording Differential Pressure Gage, Developed from Type F12 (G. E. Co.) Bailey Flow Meter

Statement by Public Service Electric & Gas Co.

"For some time the need has existed for a differential pressure recorded suitable for obtaining a continuous record

TABLE III

FLOW AS TOTALED BY INTEGRATORS OF DIFFERENT METERS CONNECTED TO COMMON VENTURI TUBE IN NO. 5 FEEDWATER RISER AT HELL GATE STATION

	Meter A	Meter B	Meter D	Meter C	Mete E		Meter A	Meter B	Meter D	Meter C	Meter E
Dec., 1927, week's total..	33,774	36,378	37,340	36,778	37,784	May, 1928, week's total..	26,129†	41,556	37,348†	36,544†	......
	31,462	33,600	34,510	35,175	31,195		30,834†	35,554†	35,820†	36,139†	......
	31,511	24,432†	36,170	38,155	36,088		30,455†	42,216	34,820†	44,771	......
	35,770	36,786	35,850	40,451	39,106		41,960	45,468	46,310	55,271†	......
	17,030	19,410	19,480	20,448	20,455		18,955	20,328	20,950	12,508†	......
Month's total........	149,547	150,606	163,350	171,007	164,626	Month's total........	148,333	185,122	175,248	185,233	......
Jan., 1928, week's total..	33,487	14,424*	35,800	43,647	39,308	June, 1928, week's total..	42,717	46,542	39,740*	45,467	......
	23,134	......*	31,970	37,995	36,280		29,942†	33,962†	31,080†	37,309	......
	15,681	......*	31,710	38,965	37,141		25,402†	24,858†	25,730*	23,512†	......
	20,654†	15,750*	......*	34,406	29,979		21,338†	25,062	17,760*	18,537†	......
	13,229	14,130	......*	17,015	16,943		10,229	10,104	10,240	9,530	......
Month's total........	106,185	44,304	99,480	172,028	159,651	Month's total........	129,628	140,528	124,550	134,355	......
Feb., 1928, week's total..	37,062	33,390	5,280*	34,508	43,032	July, 1928, week's total..	24,395†	23,005†	22,970†	19,598†	......
	22,743*	36,216	33,560	20,662	27,278		28,892	32,036	33,760	31,260	......
	28,947	31,998	36,500	38,067	37,611		50,024	32,823†	29,120†	33,238†	......
	21,191	34,344	34,680	36,101	40,674		51,535	49,212	50,950	52,249	......
	6,330	6,654	6,620	7,020	7,555		19,969	12,588†	13,000†	12,502†	......
Month's total........	116,273	142,602	118,640	126,358	156,150	Month's total........	174,815	149,673	149,800	148,847	......
March,1928, week's total	42,817	45,594	45,310	47,663	49,290	August, 1928, week's total	30,783	36,510	38,288	36,930	......
	32,688	37,278	37,050	39,210	11,250*		43,072	46,536	49,360	47,170	......
	35,825	40,362	30,950	40,746	......*		46,382	42,954	45,412	43,240	......
	31,793	35,912	36,790	40,650	......*		24,999†	28,968†	29,536†	30,110†	......
	11,661	13,485	13,910	17,320	......*		11,863	14,916	15,189	13,730	......
Month's total........	154,784	172,631	164,010	185,586	60,540	Month's total........	157,099	169,884	177,785	171,180	......
April, 1928, week's total.	25,417	28,278	28,780	30,150†	......	Sept., 1928, week's total..	15,269†	21,390†	21,890†	21,213†	......
	15,847	11,388†	20,250	19,767†	......		25,238	32,208	32,410	32,808	......
	19,927†	19,212	20,430†	19,995	......		19,870†	26,951†	26,040†	26,399†	......
	45,963	43,272	39,370†	46,773	......		40,617	41,194†	48,710	49,985	......
	3,450†	2,982†	10,180	10,222	......		10,960	13,632	13,350	14,045	......
Month's total........	110,604	105,132	119,010	126,907	......	Month's total........	111,954	135,375	142,400	144,450	......

*Meter out of order or service.
†Checking or Calibrating Meter.

of pressure drop ranging from 0 to 50 lb., such as, for example, might exist across boiler feed water regulating valves.

"At the present time there are several types of differential pressure regulating valves which are supposed to maintain a fixed pressure drop across the feed water control valve. This constant pressure drop tends to eliminate the hunting action set up by varying feed line pressure and changes in boiler drum pressure.

"In order to obtain a continuous record of the pressure drop across one of these feed water valves, thereby showing the action of the differential valve, it was found necessary to obtain a differential pressure recorder having a maximum differential of 50 lb. The Testing Laboratory of the Public Service Electric & Gas Co. conceived the idea of adapting a recording flow meter for this purpose and found that the Bailey mechanically operated meter (G. E. Co., type F12) would serve very well.

"A cross-sectional view of the type F12 flow meter is shown in Fig. 12. The high pressure side of a mercury U-tube supports an iron float which is geared by a rack and pinion to a cross shaft which carries a U-shaped permanent magnet. The magnet poles face toward the copper cap bolted over an opening in the meter body. The external mechanism of the meter has a shaft in axial alignment with the inner shaft and carries a similar magnet. By means of the two magnets the outer shaft is turned synchronously with the inner shaft, thus moving the indicating pointer, recording pen and integrating cam. The outer case of the meter contains the record chart and driving clock, also the indicating pointer, recording pen and integrating device. The integrating device may be removed when using the meter as a differential pressure recorder.

"As the differential pressure across the meter increases, the mercury and float are deflected downward in the inner chamber. The mercury displaced from the float chamber rises in the external chamber. The total differential pressure corresponding to a given depression of the mercury in the float chamber therefore varies in the ratio of the squares of the diameters of the float chamber and the external chamber.

"To adapt this type of meter for use as a differential pressure recorder it was, therefore, only necessary to change the diameter of the external chamber to one suitable for measuring the existing differential pressure.

"Three external chambers of different diameters were made from Shelby seamless steel tubing so that the meter could be used for maximum differentials of 15 lb., 30 lb. and 50 lb. The 15-lb. differential chamber has an internal diameter of 0.750 in., the 30-lb. differential chamber 0.498 in. and the 50-lb. chamber 0.364 in. The internal diameter of the float chamber is 2.0 in. Seamless steel tubing with an external diameter as near as possible to that of standard wrought-iron pipe was selected so that standard pipe fittings could be used. The new external chamber is connected at drain hole 'Y,' Fig. 13, the hole 'Z' being plugged.

"As a safeguard against loss of mercury in case the meter becomes overdeflected, a check valve containing a

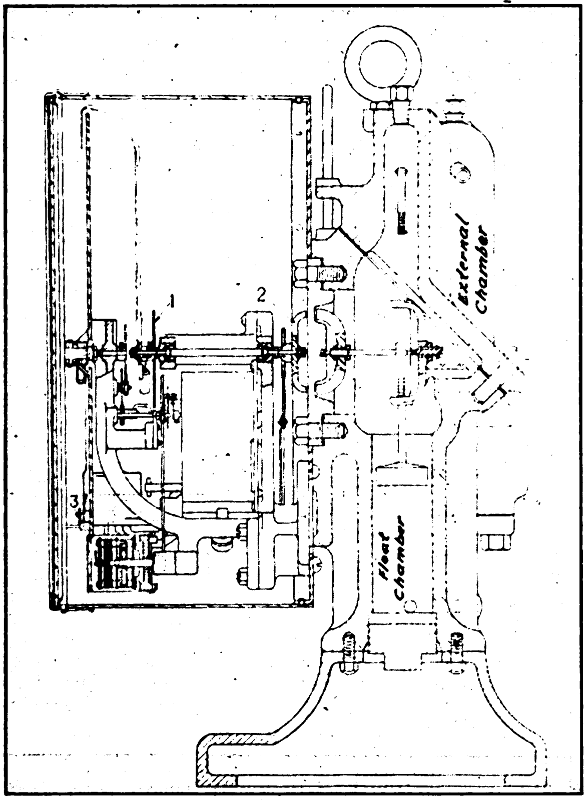
External Chamber
1
2
3
Float Chamber

FIG. 12—SECTION VIEW OF G. E. TYPE 12 FLOW-METER USED AS A DIFFERENTIAL PRESSURE RECORDER, PUBLIC SERVICE ELECTRIC & GAS CO.

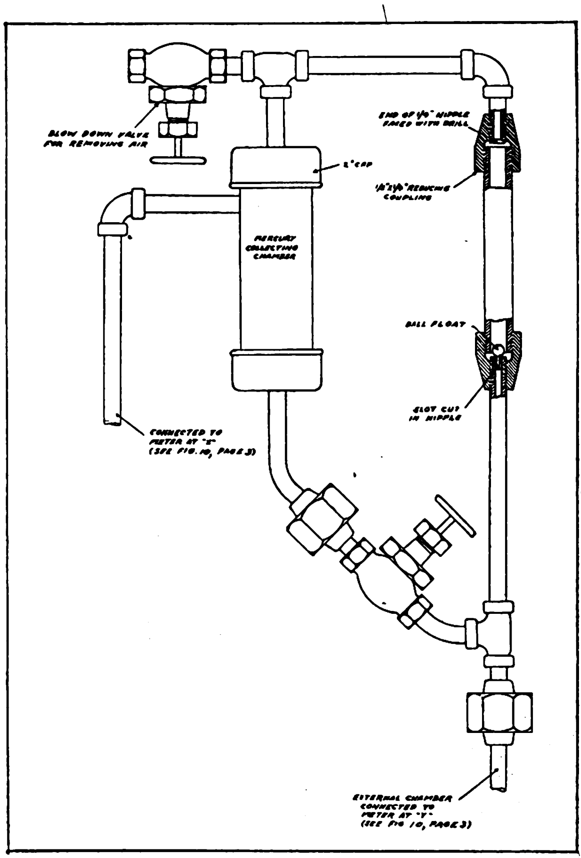
BLOW DOWN VALVE FOR REMOVING AIR
END OF 1/8" NIPPLE FACED WITH DRILL
2" CAP
1/2"x1/8" REDUCING COUPLING
MERCURY COLLECTING CHAMBER
BALL FLOAT
SLOT CUT IN NIPPLE
CONNECTED TO METER AT "X" (SEE FIG. 10, PAGE 3)
EXTERNAL CHAMBER CONNECTED TO METER AT "Y" (SEE FIG 10, PAGE 3)

FIG. 13—BALL FLOAT AND MERCURY COLLECTING CHAMBER FOR G. E. TYPE 12 FLOW-METER USED AS A DIFFERENTIAL PRESSURE RECORDER, PUBLIC SERVICE ELECTRIC & GAS CO.

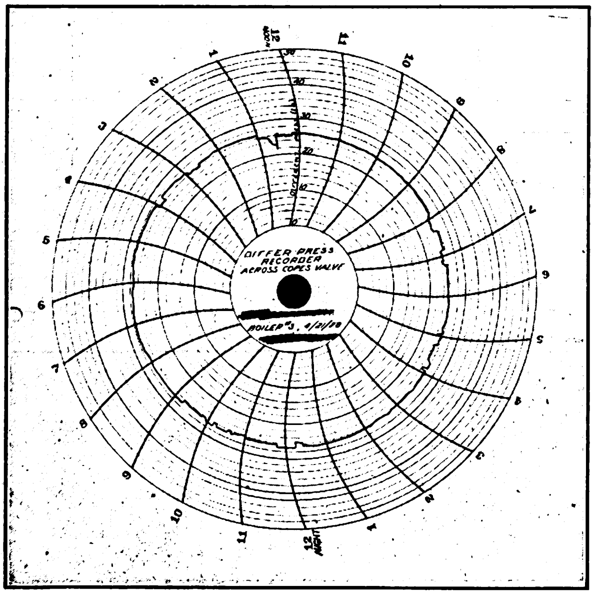

FIG. 14—DIFFERENTIAL PRESSURE RECORDER CHART, PUBLIC SERVICE ELECTRIC & GAS CO.

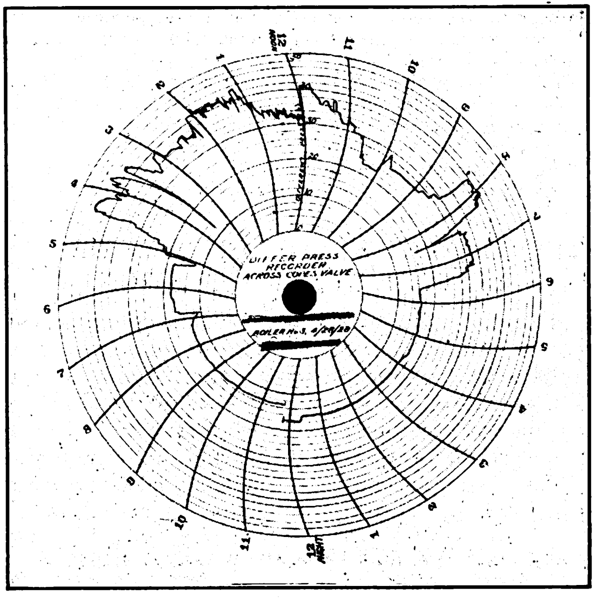

FIG. 15—DIFFERENTIAL PRESSURE RECORDER CHART, PUBLIC SERVICE ELECTRIC & GAS CO.

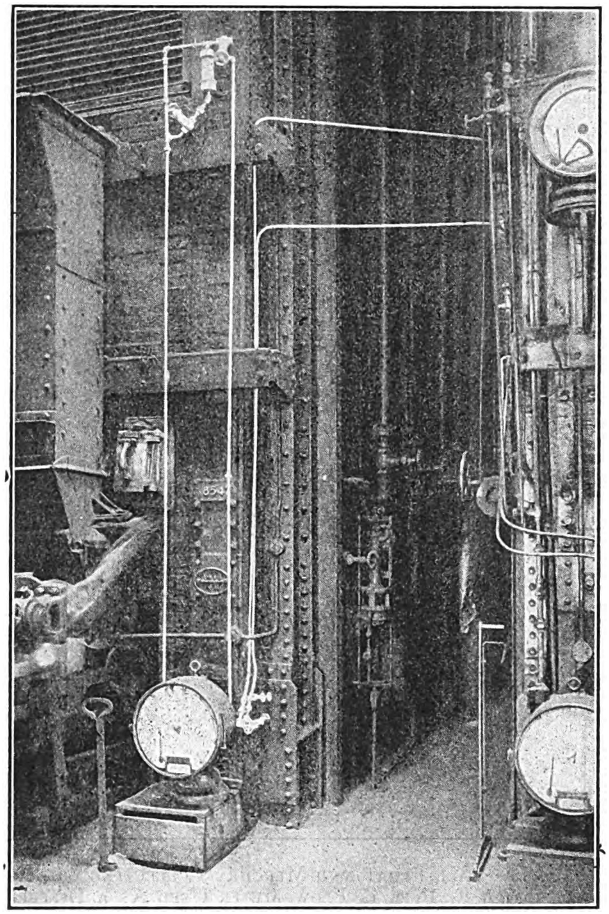

FIG. 16—INSTALLATION OF DIFFERENTIAL PRESSURE RECORDER, PUBLIC SERVICE ELECTRIC & GAS CO.

solid iron ball float is installed above the external chamber. A collecting chamber is provided for any mercury which may blow by the check valve before the latter closes. Provision is made for returning any mercury collected in this chamber to the meter when conditions again become normal. The construction of the mercury check valve and collecting chamber is shown in Fig. 13.

"The differential pressure recorder charts in Fig. 14 and 15 shows the pressure drop across a Copes feed water valve with and without an excess pressure regulator controlling the pressure drop.

"Fig. 16 shows the installation of a differential pressure recorder across the feed water regulating valve of a boiler."

THE PRESENT STATUS OF METERING IN BLEEDER TURBINE STATIONS

In the metering of Bleeder Turbine Stations there appears still to be no very close standardization. Perhaps this is due to some extent to the lack of faith expressed by several members in the ability of flow meters now on the market to give and continue to give results anywhere comparable to weighing.

The Commonwealth Edison Co. makes an interesting statement in this connection which follows:

STATEMENT BY THE COMMONWEALTH EDISON CO.

"We do not have in any of our plants any complete metering system from which performance is computed.

"In our system we use the turbo-generating unit as our meter for steam consumption as we regard it as a better meter than anything else of which we know. Such a scheme involves knowing all the characteristics of the meter, or, in other words, the calibration must be known. This calibration, or water rate test is done at least once each year or oftener if any suspicion exists that the calibration has changed due to damage, etc.

"By the use of correction factors as supplied by the manufacturer and usually checked on the original guarantee tests (particularly the vacuum factor) we reduce our actual water rates, heat rates, thermodynamic characteristics, etc., over the desired load range to a set of standard conditions, usually the manufacturer's designed conditions but not necessarily so. In the case of the extraction cycle, the characteristics as to heat drops to each extraction point at all loads must be known.

"From our standard calibration, therefore, at the average load for the month the actual conditions are computed by use of the correction factors. The average conditions are those determined from the log sheets. We therefore have all the necessary data to obtain the actual steam supplied to turbine unit, the heat rate, extraction percentages, etc., from which the boiler room efficiency can be determined. Auxiliary steam, if any, is measured by the thermal method and is, of course, charged up to the particular unit using it. We make use of two kinds of boiler room efficiency. One is based on the quantity of heat actually delivered to the turbine and auxiliaries. The other is that based on the actual evaporation of the boilers. This one, of course, is higher, as it includes steam losses of any kind avoidable or unavoidable. The efficiency based on delivered heat is the one that means the most from the viewpoint of overall station performance. The other one is a better gage of the actual performance of the boiler room separately.

"The calculation of the boiler room evaporative efficien-

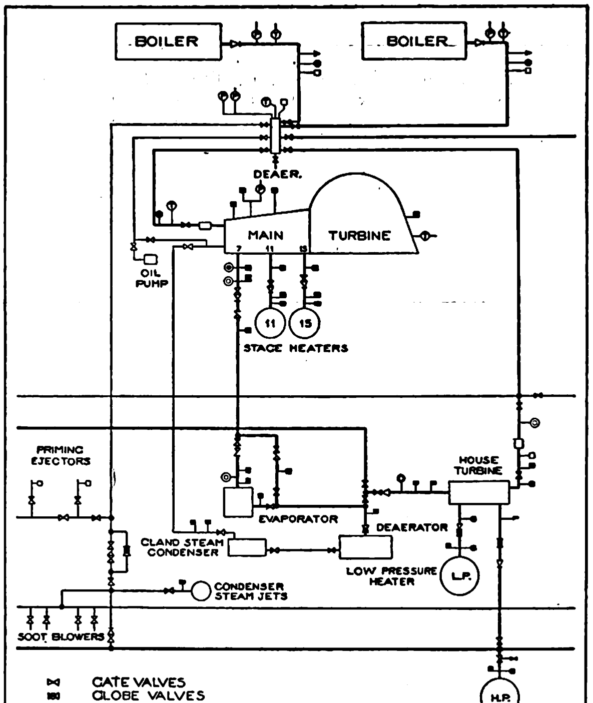
BOILER
BOILER
DEAER.
MAIN
TURBINE
OIL PUMP
11
15
STAGE HEATERS
PRIMING EJECTORS
HOUSE TURBINE
EVAPORATOR
DEAERATOR
GLAND STEAM CONDENSER
LOW PRESSURE HEATER
L.P.
CONDENSER STEAM JETS
SOOT BLOWERS
H.P.
HIGH PRESSURE HEATER
GATE VALVES
GLOBE VALVES
REGULATING OR PRESSURE RED. VALVES
CHECK VALVES
INSTRUMENT LOCATED IN MECH. CONTROL ROOM
STEAM FLOW METER
FLOW TEST ORIFICE
RESTRICTION ORIFICE
INDUSTRIAL TYPE THERMOMETER
RECORDING THERMOMETER
THERMOMETER TEST WELL
INDICATING PRESSURE GAUGE
RECORDING PRESSURE GAUGE
TAP FOR TEST GAUGE

FIG. 17—STEAM-FLOW DIAGRAM, TORONTO STATION 1927 EXTENSION, OHIO RIVER EDISON CO.

cies involves knowing make-up, blow-down, drainage and other conditions obtained by meters and check-ups.

"The general method as above outlined does involve careful calculation, as would be expected, and the use of the results relatively give us the trend of our conditions which, after all, is mainly what is wanted. We have no difficulty in finding the 'bad spots' from our final analyses. In our case we have five large stations to check. It takes the time of one man about one week out of each month to calculate these summaries. On the other hand, we have no expensive metering system.

"In such a system as we use it is readily admitted that certain small errors from an absolute viewpoint are probable, but fortunately they are relatively small in per cent and in addition concern mostly conditions that are only of small effect as well. In order to verify our method from a practical standpoint we have taken a unit at Crawford Avenue, running with reheat, three stage extraction and some auxiliary steam. The unit was operated for a period involving all usual operating conditions. From the hourly log readings and the use of the test data characteristics the water rate was calculated to be 9.574 lb. The actual weighed water was 9.650 lb., or an error of less than 0.8 per cent, part of this difference explainable by a slight heater leakage which allowed of recirculation. If in such a heat cycle there existed any appreciable heater leakage it can be readily seen that meters would be useless, whereas the effect on the calculated steam consumption would be negligible from any practical standpoint."

The Committee would point out that the above method appears to assume a straight Willans' line for the turbines and therefore must be in error if the overload valves are open from any appreciable time during the period considered.

In general, however, most members depend upon flow meters of some sort to keep a check upon turbine performance. Two members, out of the eleven replying, use steam flow meters at the turbine throttle, but in most cases the turbine steam consumption is determined by condensate measurements.

Frequently the bleeder heater drips are not measured separately, nor are they included with the condensate meter. In some cases they are merely estimated and in others they are included with the boiler feed meters or dischargd into the condenser.

In the boiler room the general practice seems to be at least to meter the flow to the individual boilers with the addition in some cases of the total boiler feed. This addition makes one group of meters check another and the idea is used by one company to work up a balance sheet for the meters.

Boiler blow-downs are about the only losses of which any attempt is made to obtain a record. Where this is done it is by the V-notch weir meter.

Weigh larries and automatic scales give record of coal to individual boilers.

Fig. 17-18-19-20 and 21 are the connection diagrams of several stations in which the locations of instruments are shown.

It is becoming a more general practice to keep a check upon station operation by comparing periodic results with some form of "bogey," as is illustrated in the Report of the Prime Movers Committee entitled "Power Station Betterment" (Pub. No. 278-101, September, 1928). Half of the replies received report use of the "bogey," while others merely make daily, weekly and monthly tabulations of operating results which are compared with each other to show the trend.

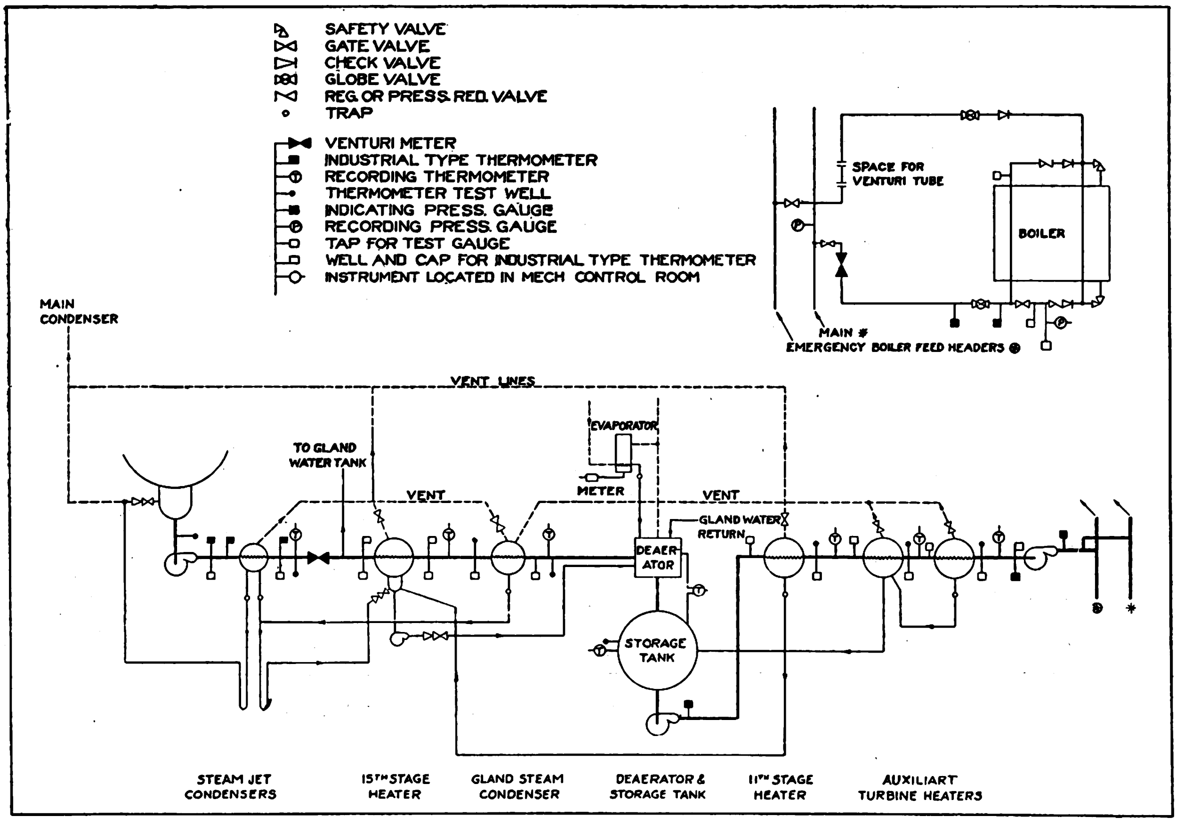
SAFETY VALVE
GATE VALVE
CHECK VALVE
GLOBE VALVE
REG. OR PRESS. RED. VALVE
TRAP
VENTURI METER
INDUSTRIAL TYPE THERMOMETER
RECORDING THERMOMETER
THERMOMETER TEST WELL
INDICATING PRESS. GAUGE
RECORDING PRESS. GAUGE
TAP FOR TEST GAUGE
WELL AND CAP FOR INDUSTRIAL TYPE THERMOMETER
INSTRUMENT LOCATED IN MECH CONTROL ROOM
SPACE FOR VENTURI TUBE
BOILER
MAIN *
EMERGENCY BOILER FEED HEADERS ●
MAIN CONDENSER
VENT LINES
TO GLAND WATER TANK
VENT
EVAPORATOR
METER
VENT
GLAND WATER RETURN
DEAERATOR
STORAGE TANK
STEAM JET CONDENSERS
15TH STAGE HEATER
GLAND STEAM CONDENSER
DEAERATOR & STORAGE TANK
11TH STAGE HEATER
AUXILIART TURBINE HEATERS

FIG. 18—BOILER FEED WATER DIAGRAM, TORONTO STATION, UNIT NO 4, OHIO RIVER EDISON CO.

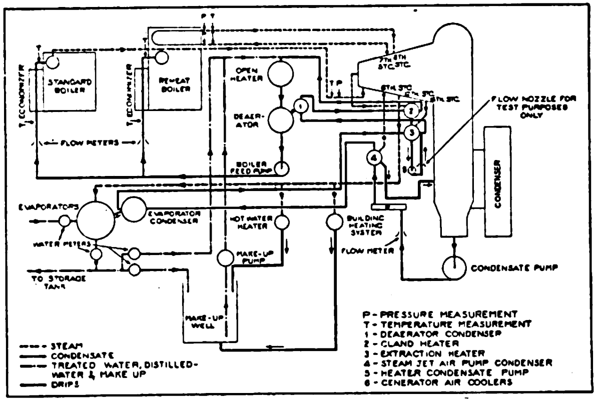
P T
T ECONOMIZER
STANDARD BOILER
T ECONOMIZER
REHEAT BOILER
FLOW METERS
OPEN HEATER
DEAERATOR
BOILER FEED PUMP
7TH STG. 8TH STG.
T P
6TH STG.
5TH STG.
3TH STG.
FLOW NOZZLE FOR TEST PURPOSES ONLY
CONDENSER
EVAPORATORS
EVAPORATOR CONDENSER
WATER METERS
TO STORAGE TANK
HOT WATER HEATER
MAKE-UP PUMP
BUILDING HEATING SYSTEM
FLOW METER
CONDENSATE PUMP
MAKE-UP WELL
STEAM
CONDENSATE
TREATED WATER, DISTILLED-WATER & MAKE UP
DRIPS
P - PRESSURE MEASUREMENT
T - TEMPERATURE MEASUREMENT
1 - DEAERATOR CONDENSER
2 - GLAND HEATER
3 - EXTRACTION HEATER
4 - STEAM JET AIR PUMP CONDENSER
5 - HEATER CONDENSATE PUMP
6 - GENERATOR AIR COOLERS

FIG. 19—METERING SYSTEM FOR CHECKING EFFICIENCY, PHILO PLANT, OHIO POWER CO.

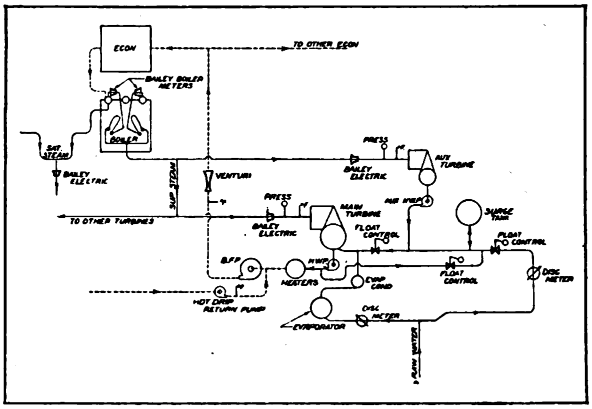
ECON
TO OTHER ECON
BAILEY BOILER METERS
BOILER
SAT. STEAM
BAILEY ELECTRIC
SUP. STEAM
VENTURI
PRESS
BAILEY ELECTRIC
AUX TURBINE
AUX HWP
PRESS
MAIN TURBINE
TO OTHER TURBINES
BAILEY ELECTRIC
SURGE TANK
FLOAT CONTROL
FLOAT CONTROL
B.F.P.
HWP
HEATERS
EVAP COND
FLOAT CONTROL
DISC METER
HOT DRIP RETURN PUMP
EVAPORATOR
DISC METER
RAW WATER

FIG. 20—METER LOCATION DIAGRAM, TRENTON CHANNEL POWER HOUSE.

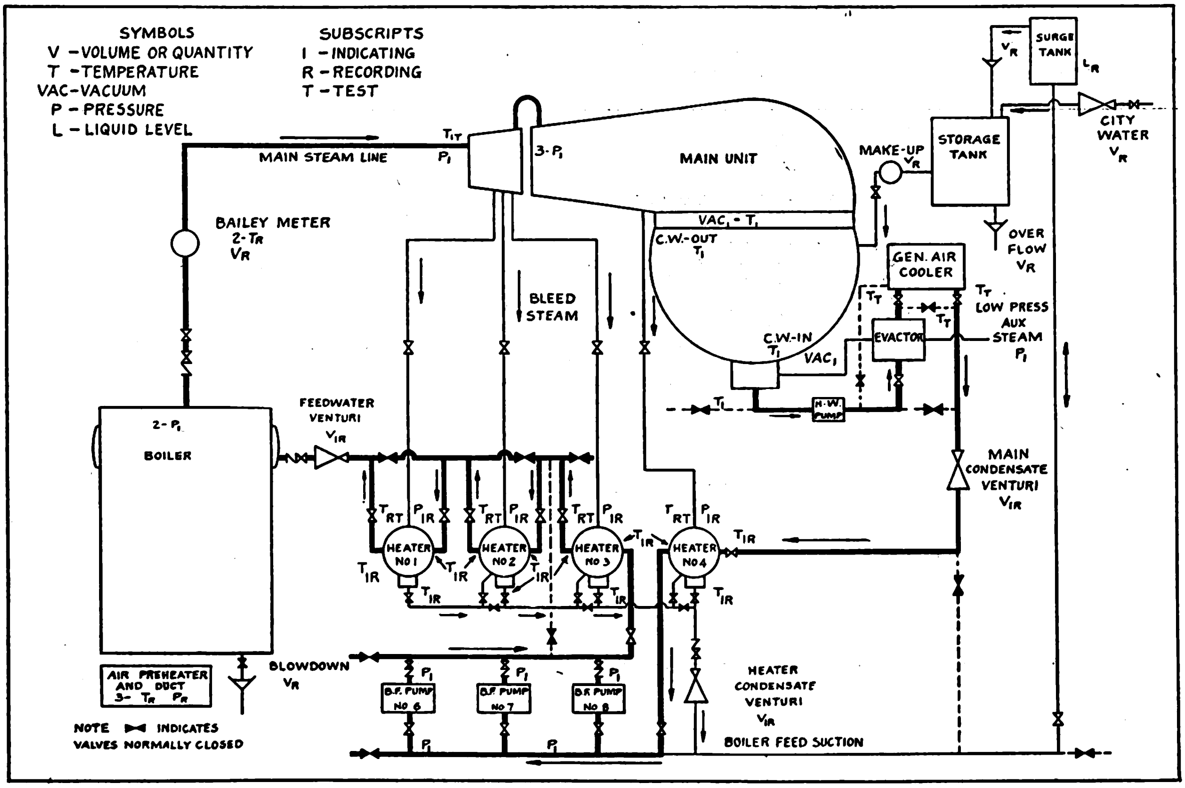
SYMBOLS
V - VOLUME OR QUANTITY
T - TEMPERATURE
VAC - VACUUM
P - PRESSURE
L - LIQUID LEVEL
SUBSCRIPTS
I - INDICATING
R - RECORDING
T - TEST
SURGE TANK
V_R
L_R
CITY WATER V_R
MAIN STEAM LINE
T_{IT}
P_I
3-P_I
MAIN UNIT
MAKE-UP V_R
STORAGE TANK
OVER FLOW V_R
BAILEY METER 2-T_R V_R
VAC$_I$ - T_I
C.W.-OUT T_I
GEN. AIR COOLER
T_T
T_T
T_T
LOW PRESS AUX STEAM P_I
BLEED STEAM
EVACTOR
C.W.-IN T_I
VAC$_I$
T_I
H.W. PUMP
FEEDWATER VENTURI V_{IR}
2-P_I
BOILER
MAIN CONDENSATE VENTURI V_{IR}
T_{RT} P_{IR}
T_{RT} P_{IR}
T_{RT} P_{IR}
T_{RT} P_{IR}
HEATER NO 1
HEATER NO 2
HEATER NO 3
HEATER NO 4
T_{IR}
T_{IR}
T_{IR}
T_{IR}
T_{IR}
T_{IR}
T_{IR}
T_{IR}
T_{IR}
AIR PREHEATER AND DUCT 3- T_R P_R
BLOWDOWN V_R
P_I
P_I
P_I
B.F. PUMP NO 6
B.F. PUMP NO 7
B.F. PUMP NO 8
HEATER CONDENSATE VENTURI V_{IR}
NOTE ▶◀ INDICATES VALVES NORMALLY CLOSED
P_I
P_I
BOILER FEED SUCTION

FIG. 21—STEAM AND WATER-FLOW DIAGRAM, UNIT NO. 4, HUDSON AVENUE STATION, BROOKLYN EDISON CO.

MANUFACTURERS' STATEMENTS

The Prime Movers Committee Does Not Accept Responsibility for Any Manufacturers' Statements

STATEMENT BY BAILEY METER COMPANY, CLEVELAND, OHIO

Remote Recorders and Indicators

"This company is now in a position to supply equipment for recording and indicating pressure, temperature, draft, liquid level and other factors at practically any distance from the source. In fact, any condition which can be measured can be recorded and indicated at the desired distant point through the use of the mechanism now made available by this company. Positive and accurate transmission of measurement is assured.

"The elements used for measuring pressure, temperature, etc., at the source, are standard equipment, having been in service in power plants for years. For the transmission of the measurements, the Selsyn motor is used. This is the device which for some time has been in service on battle cruisers, for the direction of gunfire from the bridge, and in practically every central station for the transmission of signals from the control room to the operators. A unit for indicating draft is shown in Fig. 22.

"The Selsyn system consists fundamentally of a Selsyn motor and a Selsyn generator which are in some respects like three-phase induction motors, but have shuttle-wound rotors with definite poles whose windings are connected through slip rings or flexible leads, depending upon the type of construction, to a single-phase, a-c. source of excitation. Their stators are inter-connected electrically.

"The generator is commonly called the transmitter and is rotated by the device measuring the factor to be transmitted. The motor is installed at the remote point and is connected to the indicator or recorder.

"When the supply circuit is closed an alternating voltage is impressed on the rotors and, as the motor or receiving rotor is free to turn, it takes a position corresponding to the position of the generator or sending rotor; and, if the sending rotor is turned, the receiving rotor follows at the same speed and in the same direction.

"The reason for this synchronous operation is that the single-phase current in the rotors induces voltages in the three legs of the stators. The three voltages are unequal and vary with the positions of the rotors. When the receiver rotor is in exact correspondence with the transmitter rotor, the voltages induced in the receiver stator are equal and balance the voltages induced in the transmitter stator so that current does not flow in the stators (secondary circuits).

"If the receiver is restrained from assuming the same position as the transmitter, the induced voltages are no longer equal and balanced, and current flows in the stator circuits. This current reacts upon the rotors and sets up a torque which tends to bring them into agreement. If the transmitter is held, the torque reacts against the force which restrains the receiver, thereby tending to bring it into correspondence with the transmitter.

"Selsyns are exceptionally accurate because of the shuttle-wound rotors, careful balance of electrical and mechanical parts and low friction ball bearings. The receiver responds immediately to the position of the transmitter. There is no hesitation in starting. The transmitter moves and the receiver follows instantaneously. If power fails, the receiver automatically resets in agreement with the transmitter on resumption of power. Several receivers may be operated from the same transmitter.

Up-to-Date Boiler Control Panels

"Modern power plant practice requires that the operating guides and control equipment for each boiler be centralized on a neat-appearing compact panel conveniently arranged so that the operator can grasp operating conditions instantly and, if changes are required, make them without loss of time. Bailey meter equipment lends itself very well to these requirements as illustrated in Fig. 23.

"The panel shown in this illustration contains at the top a 12-compartment, Multi-Pointer Gage indicating drafts and pressures which are necessary to correct operation, but not essential as a matter of record. The flush front recorders at either side of the panel record Flue Gas Temperature and Air Temperature at the inlet and outlet of the two air preheaters. The recorder at the left of the twin flush front mounting in the center of the panel records and indicates Steam Flow from the boiler, records Air Flow and also Superheated Steam Temperature at the outlet of No. 1 superheater. The meter at the right of the twin flush front mounting records and integrates Feed Water Flow, Steam Temperature at the outlet of No. 2 superheater and Reheat Steam Temperature at the inlet and outlet of the reheaters.

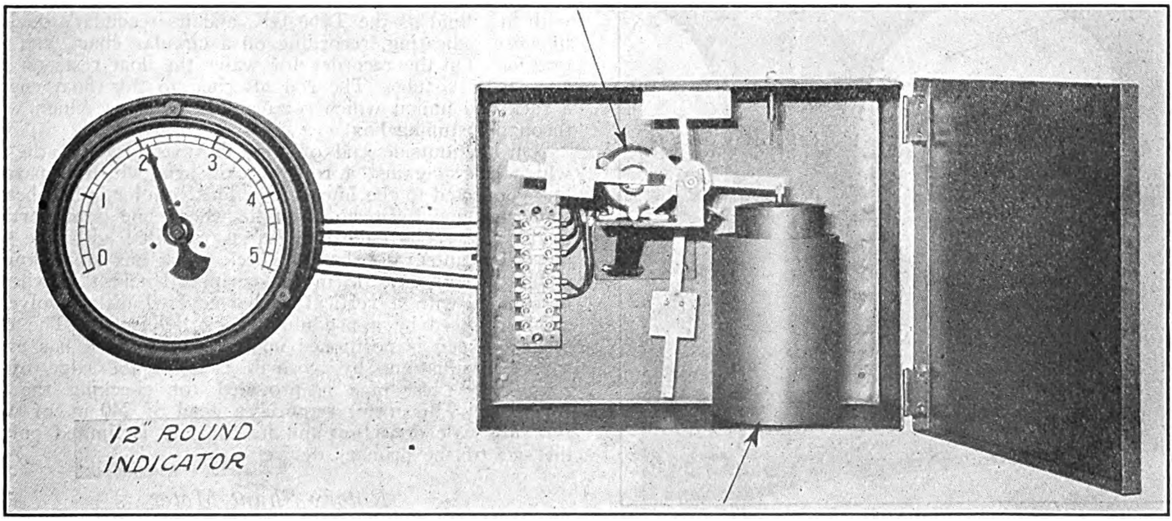

FIG. 22—LONG DISTANCE DRAFT INDICATOR, BAILEY METER CORP.

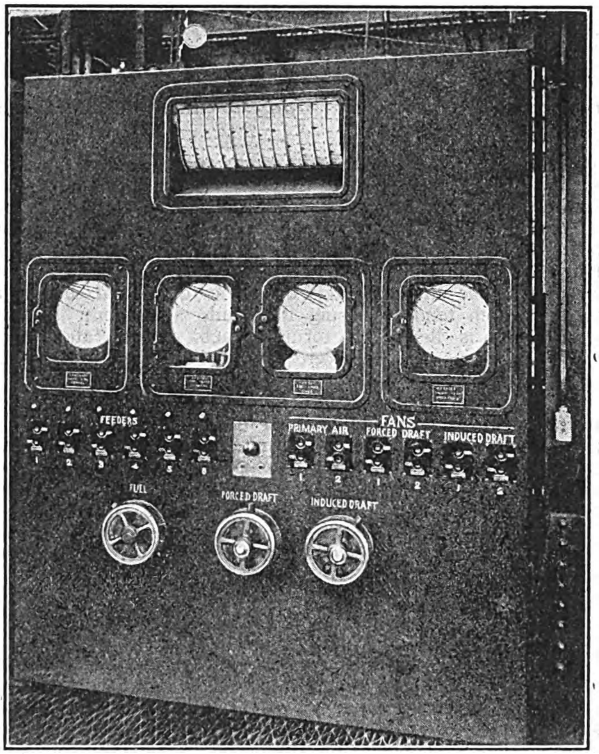

FIG. 23—BOILER PANEL—1300-LB. BOILER, LAKESIDE PLANT, MILWAUKEE ELECTRIC RAILWAY & LIGHT CO., BAILEY METER CO.

"Below the metering equipment are mounted the stop and start buttons for the feeder motors and fan motors, the automatic control system drum switch and the hand wheels for controlling the fuel, forced draft and induced draft manually, in case this procedure is necessary.

"The drum switch at the center of the panel is designed to permit push button control of induced draft, forced draft and fuel separately or together, depending on the point to which it is turned. The final switch position connects the boiler to the automatic control system.

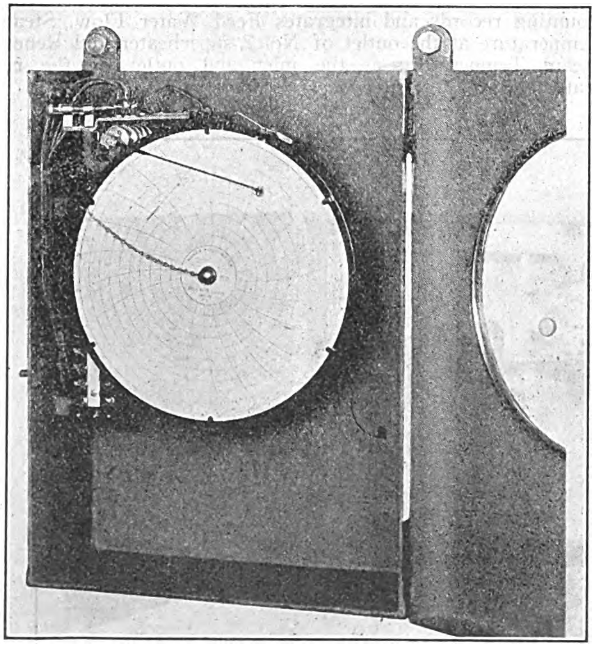

FIG. 24—SPECIAL LIQUID LEVEL RECORDER DESIGNED TO OPERATE SIGNAL LIGHTS AND PUMPS, BAILEY METER CO.

Special Liquid Level Recorders

"Fig. 24 shows an interior view of a specially constructed liquid level recorder used on a 25,000-gal. water tank. The mechanism is designed to give a record of water level on a 12-in., 24-hr., circular chart and also operates mercoid switches to sound alarms at predetermined maximum and minimum water levels. In addition, mercoids are operated to start pumps to fill the tank as the water passes the ¾-full point on a decreasing level and to stop the pumps at slightly less than full tank level.

High-Pressure Meters

"Keeping step with the tendency of modern power plant design toward the higher pressures, this company has designed and built Steam Flow Meters for operation on pressure up to 1500 lb. per sq. in. One of these meters has been in satisfactory operation over a period of about four years and several more have been in operation approximately one year."

STATEMENT BY THE BUILDERS IRON FOUNDRY, PROVIDENCE, R. I.

Diaphragm Meter, Type GK, Register-Indicator-Recorder

"This instrument employs as a primary device an orifice, nozzle or Venturi meter and its secondary device is indicating recording on a circular chart and integrating. The formed double conical diaphragm is held in position by two springs. The left-hand spring has a nut for zero adjustment on the outside of the case. A small roller rests against the diaphragm plate and is mounted on a crank arm which actuates the main shaft of the indicator hand. A small cam locates the pen on an evenly spaced chart. A guard on the pen shaft holds a pawl out of contact with the teeth of a circular rack, and this pawl is moved through a cycle at regular time intervals by a Warren electric clock. The rack actuates a direct-reading counter. The diaphragm casing contains water and this meter is used generally on steam and water. This meter is not affected by extreme overloads, requires a head of 60 in. of water for full scale deflection and its capacity is limited only by the size of the primary device.

Type "Y" Register Indicator Recorder

"This instrument has the same range of primary devices with any fluid as the Type GK, and its secondary device is likewise indicating, recording on a circular chart, and integrating. On the recorder for water the float rests on mercury in a U-tube. The rod attached to this float engages a rack and pinion which rotates a small shaft which works through a stuffing box.

"On the outside end of this shaft is attached the cam which bears against a roller on an arm which is parallel-link connected to the integrator. This counter is ball-bearing supported and twists to an angle whose sine is proportional to the rate. The indicator dial is graduated with sine spacing. The integrator has a wheel which has small knurled rollers whose axes form the periphery, and this wheel is in contact with a vertical rubber-covered disk revolved at constant speed by a pendulum clock movement. The chart recording pen is positioned upon a chart which has evenly spaced graduations by a small cam on the edge of the counter. A test pipe is provided for checking the performance. This meter requires a head of 240 in. of water for full scale deflection and its capacity is limited only by the size of the primary device.

Rotary Shunt Meter

"In this instrument the revolutions per minute of the damped turbine vary as the square root of the head, and consequently the usual orifice formula and density corrections can be used. Also, the water damping greatly reduces the turbine speed. The turbine speed then depends only upon the head and thus this is not simply a proportional meter in which the turbine speed is proportional to the velocity but a true differential type meter.

"The turbine shaft speed is gear reduced and transmitted by permanent magnets without a stuffing box, to the counter. The size of orifice and the gearing make the counter direct reading for any given conditions. This unit is used for gases and steam in 2-in., 3-in. and 4-in. sizes. Larger size mains are metered by installing the 2-in. meter in a by-pass around a standard orifice with pressure connections as usual at one diameter upstream and at the vena contracta. Pressure connections are provided at the shunts' inlet and outlet so that a simple chart rate recorder can be attached if desired. This meter requires a head of 80 in. of water for full scale deflection and can be used with steam, gas or air.

Builders' Standard Orifice Flanges

"A thin-edged orifice is used between flanges containing the pressure connections. This form is exactly reproducible and any imperfections which would effect the differential can be readily detected by visual inspection.

"A thick, amply strong plate is used; the upstream edge is square and sharp while the trailing edge is beveled so that the working edge of the orifice is relatively thin.

"The flange connections make the coefficient as nearly independent as possible of roughness and variations in pipe size. The annulus permits accurate results to be obtained in spite of rivets or other irregularities near the orifice. The independent pressure connection is used near an elbow, for example, or when it is desired to use a non-circular orifice plate to measure very large flows. Since the connections are in the flange they are of ample size to use with powerful registers and are especially good where pulsating flow occurs. Due to accurate machining, the orifice can be exactly centered. When inserting another orifice it is not necessary to disturb the pressure connections at all."

STATEMENT BY COCHRANE CORPORATION, PHILADELPHIA, PA.

"The Cochrane Flow Meter and the Cochrane V-Notch Meter have been on the market for a number of years but several improvements in the integrating mechanism made during the past year have not before been described in any publication.

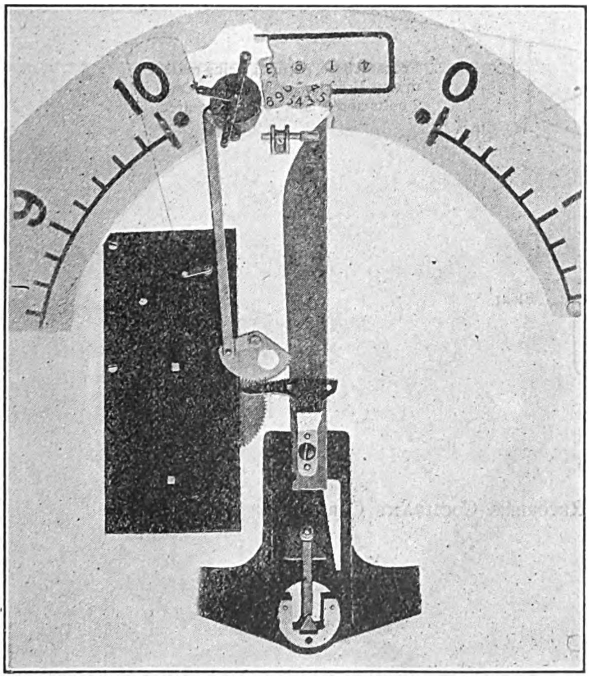

FIG. 25—INTEGRATOR OF COCHRANE FLOW-METER WITH DIAL HAVING EASILY READ FIGURES, COCHRANE CORP.

"One of these is the direct reading integrator shown in Fig. 25. The Flow Meter integrator is of the direct reading type, that is, the figures are read off directly as they appear, eliminating the possibilities of error which are inseparable from the 'gas-meter' type of counting train. With the Cochrane type of counting train only the figures which ought to be read are visible.

"The integrator itself is positive and mechanical in action and does not depend upon secondary forces, such as electrical current, magnetic attraction or sliding friction, nor is the transmission of motion affected by vibration or chattering or by other outside disturbances such as variations in voltage.

"A crank on the clock by means of a flexible link drives an oscillating lever back and forth in such a manner that the lever moves the counting train forward a distance corresponding to the instantaneous position of the U-tube balance. This is accomplished by a pawl on the oscillating lever, which engages with a disk mounted on the units spindle of the counting train. The engagement of the pawl is controlled by an integrator cam, the position of which is determined by the position of the U-tube balance, while the release of the pawl is controlled by the permanent 'knock-off point,' which is properly adjusted when the meter is calibrated in the shop. When the pin on the pawl reaches the release point of the cam, the pawl grips and moves the disk forward. On the return stroke, the pawl rides over the disk without moving it. Due to its peculiar shape, the pawl acts as a wedge in moving the disk forward and slippage does not occur, but continued high accuracy is obtained after long use. This form of integrator imposes no load upon the deflecting member and, therefore, does not affect in any way the accuracy of the latter.

"In the V-notch integrator, shown in Fig. 26, a roller carried by the float stem moves up and down in a straight line. This roller bears against a cam suspended from a pivot approaching the pivot at the higher rates of flow. The cam is so shaped that it is rotated through equal angles for equal increments in rate of flow. The pen arm is attached directly to the cam spindle and the pen inscribes upon a circular chart having equal divisions. The rotation of the cam also operates through a linkage a pointer which moves over a scale having equal divisions. A sector attached to the cam spindle moves the stop of a clock-operated integrator, consisting of a counting train which is periodically advanced in proportion to the momentary rate of flow. The cam is held against the roller on the float stem by a counter weight. All parts of the translating mechanism are slow moving and no harm results from sudden up or down movements of the float. Where the meter is used with hot water which undergoes rapid fluctuations in temperature, the float is placed in an outside float chamber communicating with the weir chamber through a narrow vertical channel, which insures the correct water level in the float chamber irrespective of differences in density between float chamber and meter chamber. The water in the float chamber remains, in general, at a temperature lower than that in the meter chamber, thus reducing the tendency to flash upon sudden reduction of pressure."

STATEMENT BY THE FOXBORO COMPANY, FOXBORO, MASS.

New Instrument

"The design of the new Foxboro Steam Flow Meter, Fig. 27 and 27a, is based on that of the Foxboro Orifice Meter, which has been extensively used for many years for the measurement of gas flow under field conditions where a rugged simple mechanism of high precision is necessary.

"The instrument is calibrated to read and record in terms of flow and is equipped with a simple and dependable integrator that reads direct without multipliers the total pounds of steam that have passed through the pipe. The chart reading is direct in lb. per hr.

"This new meter is fundamentally accurate because it is of a simple mechanical design in which friction is reduced

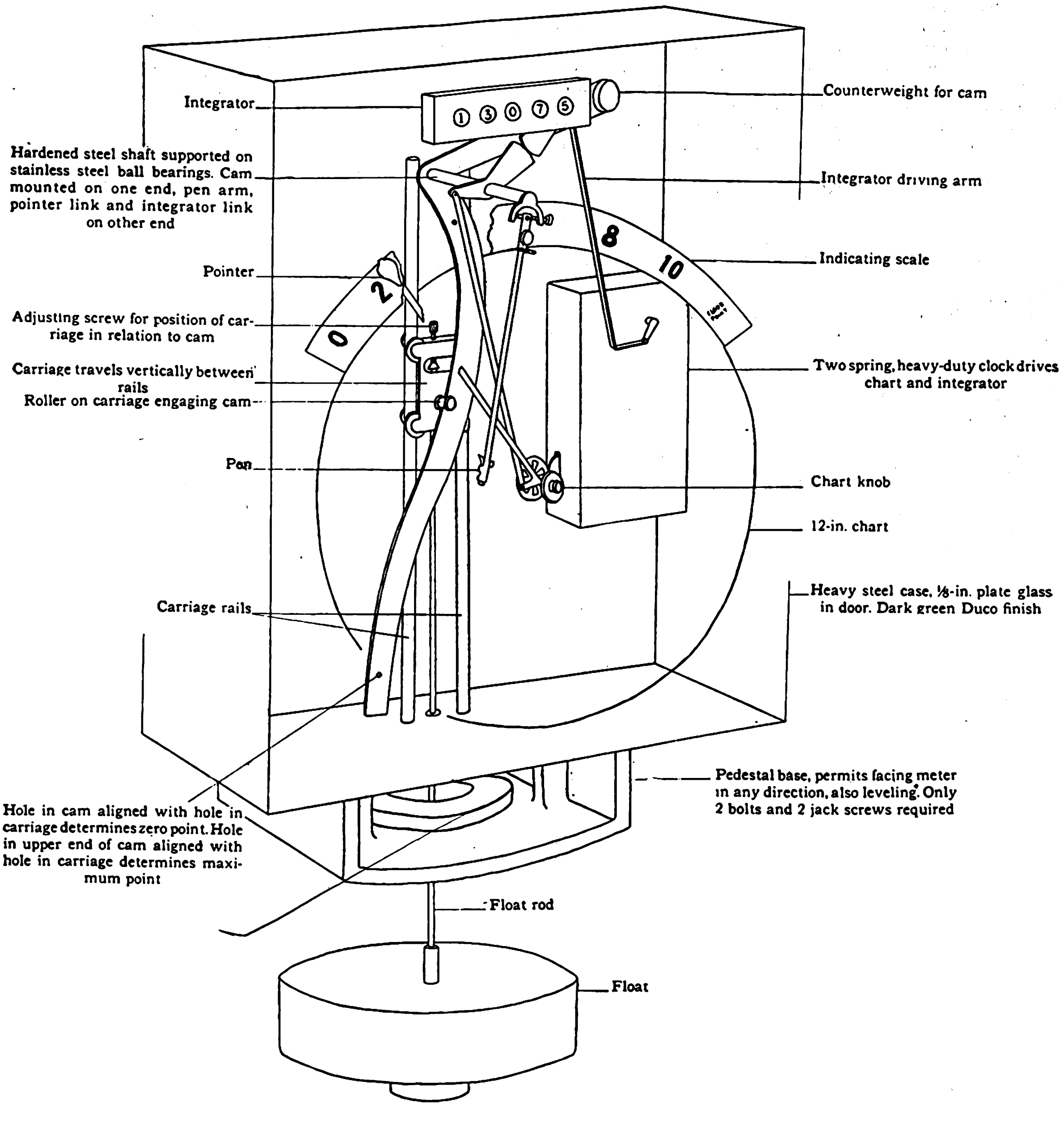
Integrator
①③⓪⑦⑤
Counterweight for cam
Hardened steel shaft supported on stainless steel ball bearings. Cam mounted on one end, pen arm, pointer link and integrator link on other end
Integrator driving arm
Pointer
Indicating scale
0
2
8
10
Adjusting screw for position of carriage in relation to cam
Carriage travels vertically between rails
Roller on carriage engaging cam
Two spring, heavy-duty clock drives chart and integrator
Pen
Chart knob
12-in. chart
Carriage rails
Heavy steel case, ⅛-in. plate glass in door. Dark green Duco finish
Pedestal base, permits facing meter in any direction, also leveling. Only 2 bolts and 2 jack screws required
Hole in cam aligned with hole in carriage determines zero point. Hole in upper end of cam aligned with hole in carriage determines maximum point
Float rod
Float

Diagram of essential working parts

FIG. 26—COCHRANE "V" NOTCH RECORDER, COCHRANE CORP.

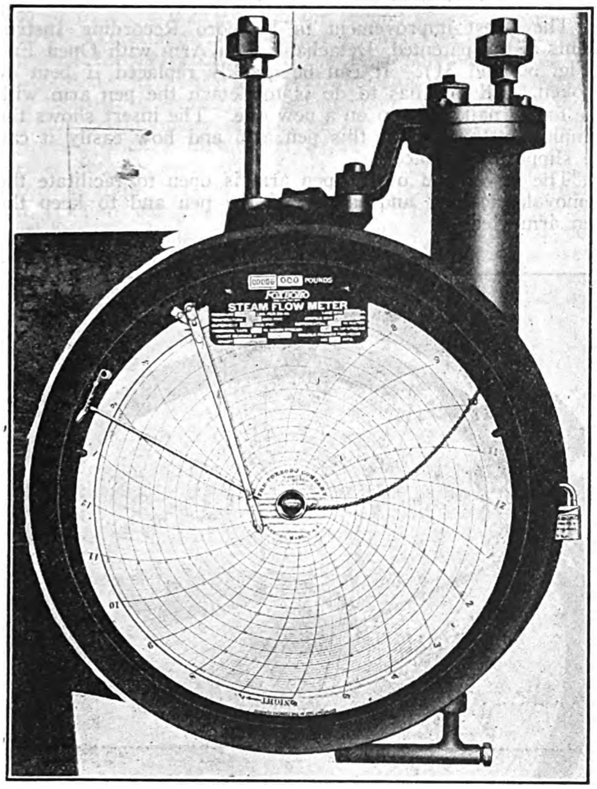
FOXBORO
STEAM FLOW METER
POUNDS

FIG. 27—FOXBORO STEAM FLOW METER, THE FOXBORO CO.

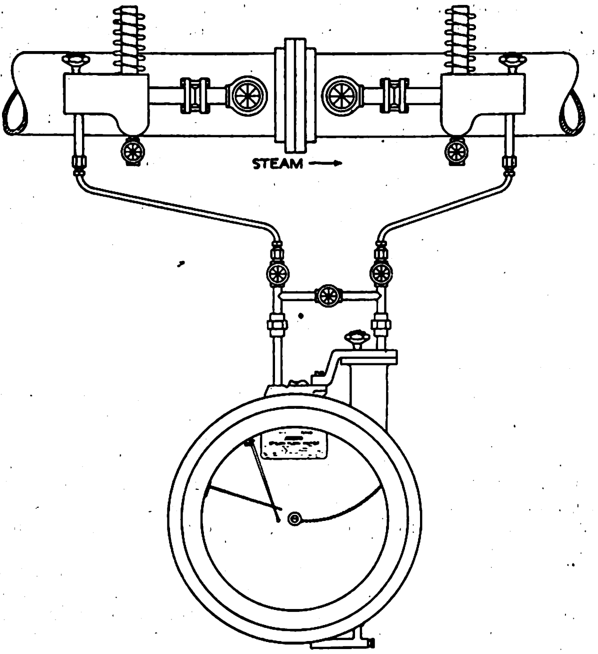

FIG. 27-a—IDEAL INSTALLATION OF THE FOXBORO STEAM-FLOW METER, FOXBORO CO.

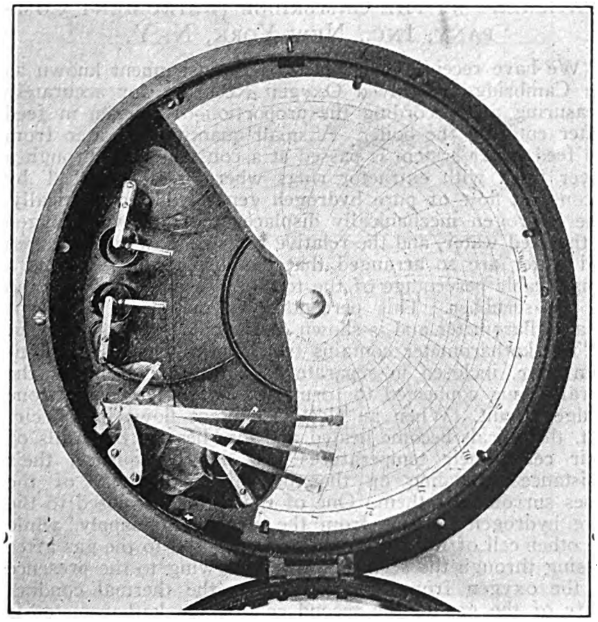

FIG. 28—PIVOTED PEN ARM MOVEMENT, FOXBORO CO.

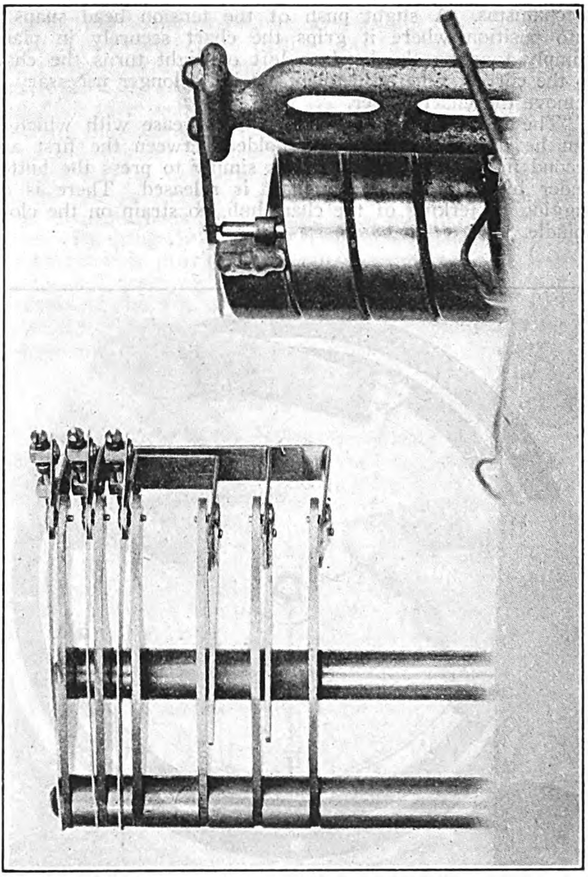

FIG. 29—PIVOTED PEN ARM MOVEMENT, FOXBORO CO.

to a minimum and a large, powerful float is employed, the motion of which is transmitted without angularity (harmonic motion) and because the coefficients were carefully determined by us after extensive research and experimentation covering a period of years.

"The hook-up of the meter with the pipe line is extremely simple. The use of separate sediment and condensate chambers has been eliminated by employing only a single chamber of unique design that serves both purposes.

"The new meter is a single unit. It has no electrical devices, special compensators, balances or stuffing boxes; and requires no maintenance except to blow the drip, change the chart and ink the pen.

Improvements

Pivoted Pen-Arm Movement

"The difficulties encountered in the construction of multiple-pen instruments have always been to make the brackets rigid enough to support the pens properly in front of the chart and to get the pens to follow accurately the predetermined arc of the chart. Our new Pen-Arm Movement, Fig. 28 and 29, absolutely overcomes these difficulties because each pen arm is pivoted at its center of motion in a firmly fixed plate above the chart disk.

"The pens move on the same fixed center of rotation and produce accurate records throughout the scale. Time differences between pens are minimized. Inking, cleaning and replacing pens are simplified. The new movement makes Multiple-Pen Instruments as practical and accurate as the Single-Pen.

New Chart Hub

"The new Foxboro Push-Button Chart Hub has all the special features associated with its predecessor. It accurately centers the chart. There are no threads or complicated mechanisms. A slight push of the tension head snaps it into position where it grips the chart securely in place. Simply twisting the head to left or right turns the chart to the correct time adjustment. It is no longer necessary to remove the chart holder.

"The latest improvement lies in the ease with which it can be detached. With the holder between the first and second fingers, the operator has simply to press the button under his thumb and the chart is released. There is no tugging or jerking of the chart hub, no strain on the clock spindle.

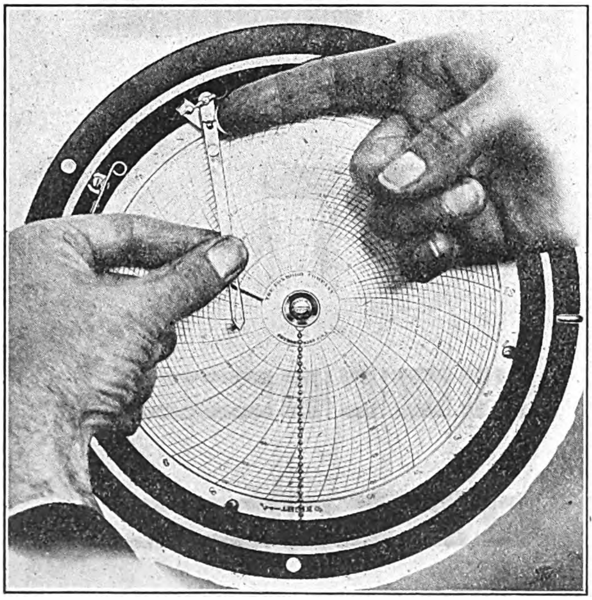

FIG. 30—DETACHING PEN ARM, FOXBORO CO.

Detachable Pen Arm with Open End

"The latest improvement in Foxboro Recording Instruments is the patented, Detachable Pen Arm with Open End (Fig. 30 and 31). It can be quickly replaced if bent or broken. All one has to do is to detach the pen arm with the finger nail and slip on a new one. The insert shows the simple construction of this pen arm and how easily it can be slipped into place.

"The lower end of the pen arm is open to facilitate the removal, cleaning and inking of the pen and to keep the pen arm clean."

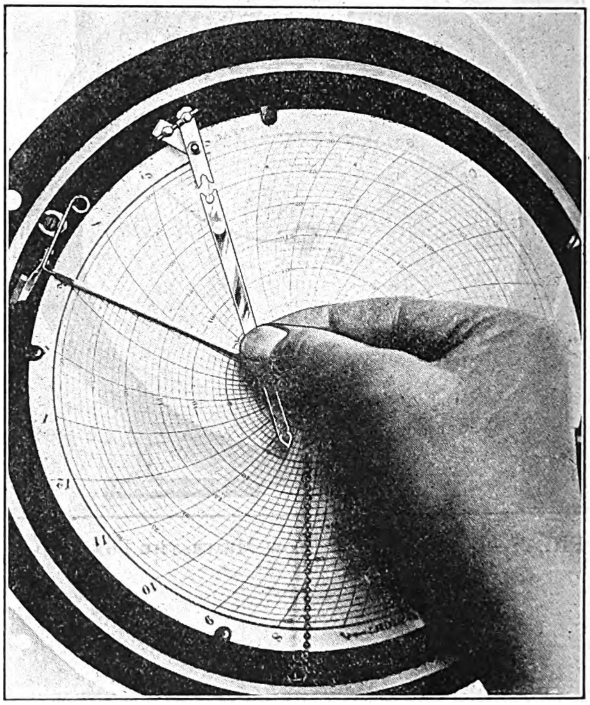

FIG. 31—REPLACING PEN ARMS, FOXBORO CO.

STATEMENT BY THE CAMBRIDGE INSTRUMENT COMPANY, INC., NEW YORK, N. Y.

"We have recently developed a new instrument known as the Cambridge Dissolved Oxygen Recorder for accurately measuring and recording the proportion of oxygen in feed water entering the boiler. A small quantity of water from the feed water system is passed at a constant rate through a tower filled with extractor rings where it is 'scrubbed' by a constant flow of pure hydrogen generated electrolytically. The hydrogen mechanically displaces the dissolved oxygen in the feed water, and the relative rates of flow of hydrogen and water are so arranged that the displaced gas forms a considerable percentage of the total gas issuing from the top of the scrubber. This percentage is measured by means of a katharometer and is shown on the chart of the recorder.

"The katharometer contains two identical spirals of platinum wire, inclosed in separate cells in a metal block, the spirals being connected to form two arms of a Wheatstone bridge circuit. When an electric current flows in the circuit, the spirals become heated and lose heat to the walls of their cells, their temperatures and, in consequence, their resistance depending on the thermal conductivity of the gases surrounding them. One of the cells is exposed to the pure hydrogen passing from the electrolytic supply, while the other cell of the katharometer is exposed to the gas after passing through the scrubber tower. Owing to the presence of the oxygen from the feed water, the thermal conductivity of the gas in the second cell of the katharometer is different from that of the first; and the Wheatstone bridge circuit is thrown out of balance, causing a deflection of the galvanometer, the extent to which is an indication of the amount of oxygen present in the second cell.

"The katharometer is connected by 4-way leads to a standard thread recorder of the type supplied by us for many years in connection with gas analysis instruments. The recorder is entirely clock-driven and consists of a moving coil galvanometer the pointer of which is automatically depressed once a minute on to an inked thread which it presses into contact with a moving chart. A continuous record is thus obtained in the form of closely spaced dots, pen friction being entirely avoided. The record for the past few hours is always visible, while the actual percentage of dissolved oxygen at any moment can be read on an engraved scale fixed over the pointer. The complete mechanism is inclosed within a robust, dust-tight, metal case which can be easily fixed to a wall or other support."

STATEMENT BY THE PERMUTIT COMPANY, NEW YORK, N. Y.

The Ranarex CO_2 Recorder

"The use of Ranarex CO_2 recorders in connection with boilers burning gaseous fuel has revealed some very interesting facts. The Ranarex principle is based on the fact that the specific weight of flue gas increases in proportion to its CO_2 content, CO_2 being about 50 per cent heavier than the other constituents of the flue gas. When insufficient air is supplied to a furnace the combustion is incomplete and with solid or liquid fuels the incompletely burned matter is mainly CO and soot. The soot is filtered out before the gas sample is analyzed; CO has the same specific gravity as nitrogen so that it does not appreciably affect the accuracy of the Ranarex recorder, which will therefore indicate the actual CO_2 percentage. In such cases the Ranarex indicates an oversupply of air by a low CO_2 reading and a deficiency in air supply can be recognized by too high a CO_2 content and, usually, by the appearance of smoke.

"When burning gaseous fuels, however, with a deficiency in air supply the unburned or incompletely burned matter consists of CO, hydrogen and hydrocarbons, the CO percentage usually being quite low. Therefore it is not possible to determine a deficiency in air supply by means of an ordinary Orsat apparatus, nor is it always possible to recognize it by observing the stack, since incomplete combustion of gas may take place without resulting in any appreciable amount of smoke. The determination by chemical methods of the hydrogen and hydrocarbons in the products of combustion requires complicated apparatus, not very suitable for use in a boiler house. However, the presence of these gases is clearly indicated by the Ranarex CO_2 recorder. Hydrogen and hydrocarbons are much lighter than air and reduce the density of the flue gases to such an extent that the Ranarex gives a low reading and may even have a tendency to indicate negative values.

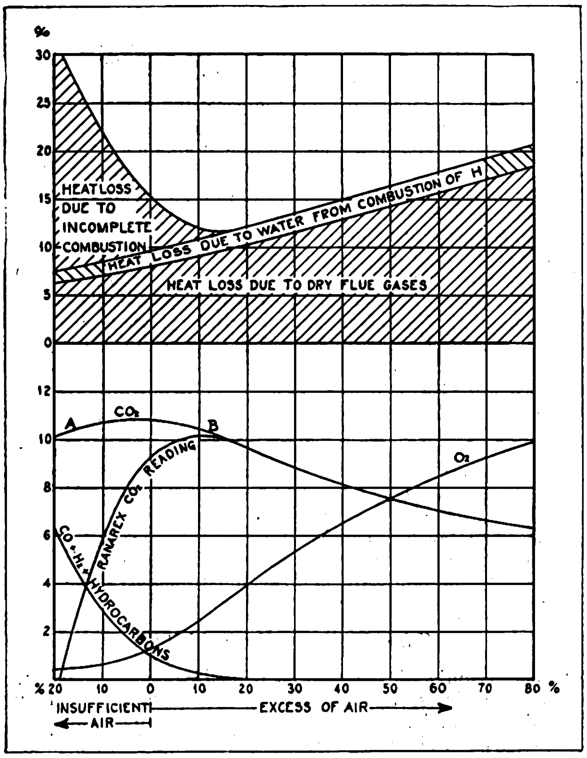

FIG. 32—THE RANAREX COMPANY, CO_2 RECORDER CURVE, THE PERMUTIT CO.

"In Fig. 32 the conditions are illustrated such as take place when natural gas, consisting chiefly of methane, is used as fuel. The lower part of this diagram shows the flue gas analysis and the reading of the Ranarex recorder. In the upper part of the diagram the stack losses have been plotted, the total stack loss consisting of the heat loss due to the heat content of the dry flue gases, the heat loss due to water formed by combustion of the hydrogen and the heat loss due to incomplete combustion.

"It can be seen from this diagram that the minimum total stack loss, corresponding to maximum boiler efficiency, just about coincides with the maximum reading of the Ranarex recorder. Whenever the Ranarex reading is low this is due to excess of air or insufficient air being supplied to the furnace. However, if the fireman cuts down the air supply in order to raise the CO_2 content and then finds that the Ranarex reading drops further, he knows immediately that he is not admitting enough air and he will therefore be able to take the proper steps to adjust the air-fuel ratio so as to result in maximum efficiency. Since there is no time required for chemical reactions and since the Ranarex draws the gas sample through the pipe line at a high rate of flow, the time lag is very short and the firemen have no difficulty in quickly adjusting the air supply to the correct value by using the Ranarex machine as a guide.

"In conclusion, where natural gas is the fuel employed and a hand operated or automatic Orsat apparatus is used to determine CO_2 and CO, the operator is easily misled by high CO_2 (see section A-B of the CO_2 curve) and low CO readings into assuming that the combustion is fairly complete and efficient; whereas in reality the amount of air supplied may be deficient, resulting in immense heat losses due to the presence of unburned hydrogen, methane and other hydrocarbons in the flue gas not detected by the Orsat. By using the Ranarex recorder instead of the Orsat, the operator is provided with an instrument which detects readily and positively the presence of these unburned constituents of the flue gas and he is, therefore, in a position to prevent the high heat losses due to incomplete combustion, as well as those due to an excess in air supply.

The Ranarex Gas Density Recorder

"A Ranarex density recorder (see Fig. 33) has been developed, which operates on the same basic principle as the Ranarex CO_2 Recorder. When gas is metered by means of an orifice meter, it is necessary to know the specific gravity of the gas in order to determine the quantity passed through the meter. In such cases the Ranarex gas density recorder will be found very useful.

"The practice of mixing different types of gases is coming more and more into use. Variations in the specific gravity of the mixed gas are undesirable since they interfere with satisfactory operation of the gas burners. Such variations can immediately by detected and, therefore, prevented in time by the use of a Ranarex density recorder."

STATEMENT BY C. J. TAGLIABUE MFG. COMPANY, BROOKLYN, N. Y.

"There have been no radical changes in our regular line, which is constantly subjected to detail improvements. The most important development is that of a fully-compensated, mercury-actuated recording thermometer, permitting the use of connecting tubes up to 150 ft. in length (previously 25

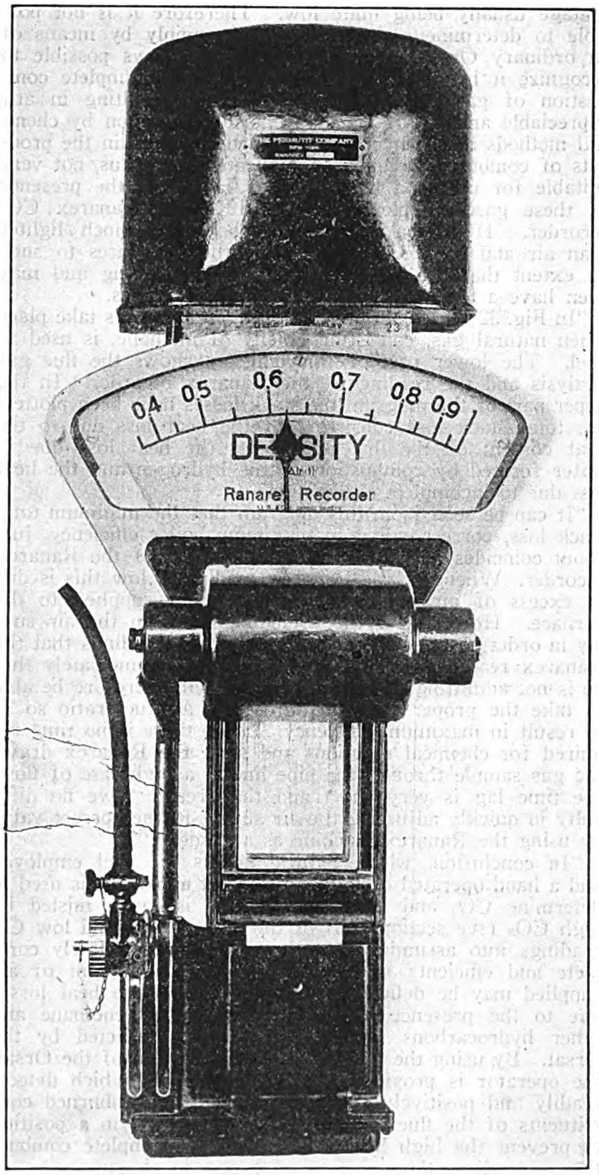

FIG. 33—THE RANAREX DENSITY RECORDER, THE PERMUTIT CO.

ft. had been the limit for this type of instrument of all makes), with no possibility of inaccurate readings even should the connecting tube be laid alongside of a boiler or of a refrigerating room."

STATEMENT BY CONSOLIDATED ASHCROFT HANCOCK COMPANY, INC., AMERICAN SCHAEFFER & BUDENBERG CORPORATION DIVISION BROOKLYN, N. Y.

"Among outstanding developments in the art of manufacturing the expansion type recording thermometer should be mentioned a new steel capillary tubing we have introduced during the year. This steel tubing has a bore of 0.008 in. to 0.011 in., as against 0.023 in. for the tubing used in the past. The result of this improvement is that we are now able to furnish mercury-actuated recording thermometers with lines 100 ft. long and guarantee them accurate within 1 per cent of the scale range. The invention, therefore, has greatly broadened the field for mercury-actuated instruments, which must be preferred to all others because of the uniform characteristics of mercury, the large amount of motive power of the mercury system and the great mechanical strength and durability of the welded steel systems, which are used in mercury-actuated thermometers."

STATEMENT BY THE BROWN INSTRUMENT COMPANY, PHILADELPHIA, PA.

Resistance Thermometers

"Resistance thermometers manufactured by the Brown Instrument Company recently have been redesigned and improved. Equipments requiring the measurement of temperature in more than one place are furnished with a bridge circuit box wherein each thermometer bulb has an individual bridge circuit, thus eliminating any switching or poor contacts in the bridge circuit proper. The switching is done in the galvanometer circuit which is high enough in resistance so that no appreciable errors will be introduced.

"Indicating instruments, recording instruments, or both, can be arranged to indicate or record the temperature of the same bulb, and as many as twelve bulb temperatures can be recorded on the same instrument. Instruments can be furnished for either controlling or signalling purposes.

"In the boiler and turbine room, resistance thermometers may be used for measuring and recording the temperatures of air ducts, bearings, steam temperature, condenser water, etc. They can be calibrated to read 'differential temperatures,' as, for example, the difference in temperature of the water entering and leaving the condenser. They are especially well adapted for measuring temperatures below 300 deg. fahr., which is too low for a pyrometer or where a mercurial, gas or liquid filled thermometer has not the required accuracy, or where it is not practical to run capillary tubing or reading a mercurial thermometer.

Control Instruments and Mechanisms

"To meet the demand for closer control of temperature, pressure, flow, etc., many new developments have been made on the control instruments and the mechanisms used to operate valves, rheostats, etc. Formerly automatic control was merely an 'ON' and 'OFF' proposition. If, for example, the temperature was low, the valve would be opened and the temperature would rise to a high value. The valve would then be closed and the temperature would drop to a low value. In this manner an average temperature was maintained, but considerable 'hunting' took place. With the new mechanisms conditions are anticipated automatically and corrections made before the 'hunting' starts. Also new mechanisms are available which vary the fuel supply in accordance with the fuel demand.

"In addition to the development of control instruments which would operate the above mechanisms, improvements have been made in the method of selecting and making control contacts. The galvanometer pointer merely selects the correct contact, according to the temperature, through a primary mechanism, and the operation of the contacts is taken care of through a secondary mechanism. The advantage of this scheme is to relieve the galvanometer pointer of strain, and at the same time the secondary mechanism has plenty of power to allow the use of wiping contacts. With this arrangement the duration of contact can be altered to meet the control conditions, as it is possible to time the duration by means of a simple adjustment.

"Control recorders can be supplied to control as many as six mechanisms from one instrument, the only limitation being that the point of control must be the same on all records.

The Brown Flow Meter

"The recently developed Brown flow meter uses well-proved principles, but combines them in a unique manner to make a simple, rugged and accurate meter.

"An orifice plate mounted in the flow line produces a differential pressure which varies with the flow, according to well established laws. This differential pressure is conducted to a manometer which is essentially a mercury filled

U-tube. The manometer is a simple pressure tight vessel of forged steel. The position of the mercury column is transmitted to the meter electrically by the inductance bridge principle. There are no electrical parts under pressure, and there are no stuffing boxes to leak or produce friction.

"A float on the surface of the mercury carries an iron armature which moves within a pressure tight non-magnetic tube. A divided inductance coil is mounted around this tube and a similar coil in the instrument. The meter coil is provided with a similar iron armature and electrical connections are made in a similar manner to the standard Wheatstone Bridge. Alternating current is used as a source of supply. As the armature in the manometer is moved up or down by the changes in mercury level, the reactance of the two halves of the manometer coil is altered. This unbalances the electrical circuit and causes the iron core in the instrument coil to move, which actuates a pointer. The result of this system is that any displacement of the iron core in the manometer coil is reproduced exactly in the other coil. This method of transmitting mechanical motion electrically is admirably adapted for transmission over long distances, and consequently the instruments can be mounted a considerable distance away from the manometer. The principal advantages of the inductance bridge principle in addition to the above are:

1. The electrical circuits are entirely independent of the pressure chamber. No stuffing boxes are necessary, as the effect of the iron core is produced on the coil through the non-magnetic tube which adequately seals the pressure chamber.
2. Electrical circuit is solid throughout, as all connections are either soldered or securely fastened under screws. No switches or other contacts are in the bridge circuit.
3. No errors are introduced due to voltage fluctuations, as the operation of the inductance bridge is independent of voltage in the same manner that a balanced Wheatstone Bridge is independent of voltage.

"The usual form of manometer is made of forged steel and is entirely suitable for a working pressure of 750 lb. per sq. in., although for special applications manometers can be supplied for higher working pressures.

"A very important feature of the design is the convenience of changing the range when necessary. It frequently occurs after installing a flow meter that the flow is greater or smaller than was estimated, or load conditions may change, thus demanding different range. To eliminate the necessity of changing the orifice plate, which usually means shutting down the line, a system of interchangeable range tubes has been devised. The range tubes can be readily changed and, by changing the chart to correspond to the new range tube, no readjustments are necessary except the setting of zero.

"A mercury blow-out check is provided to prevent the blowing-out of the mercury due to an excessive differential pressure. In case of a heavy overload on the line, resulting in an excessive differential pressure, the seal automatically closes, and after the overload is removed normal operation of the flow meter is automatically resumed.

"The high range manometer outlined above is offered in six different ranges. The lowest range gives full scale deflection on 1.60 in. of mercury and the highest range on 16.00 in. of mercury.

"In addition to this line of manometers, there is the intermediate line in several ranges from 2.17 in. of water to 13.71 in. of water and the low range line in ranges from 0.217 in. of water to 2.17 in. of water. These lines are for low pressure gas and air measurement and can be used in connection with the standard meters. The inductance bridge principle is used and, as in the high range line, there are no electrical parts under pressure and no stuffing boxes are used.

"The meters are of various forms suited to any requirements. The usual type is the 12-in. circular chart recorder, which may be furnished with or without an integrator which records the total quantity. An exclusive feature of the integrating recorder is the automatic planimeter which gives, on the edge of the chart, a continuous record of the quantity. By means of this, the quantity of flow for any period of time may be seen at a glance. This avoids the use of a planimeter and prevents inaccuracies in reading the counter. The counter, which reads in plain figures instead of by dials of the conventional type, is convenient for giving the total quantity per day.

"A 12-in. indicating meter with a bold dial and large pointer is offered for boiler room use, and a strip chart recorder is offered where that type of meter is preferred.

"The meters may be used in pairs; for example, an indicator may be installed in the boiler room and a recorder elsewhere. The electrical transmission system makes it possible to locate the instruments wherever convenient, without regard to the manometer location.

"All of the meters include the many important features characteristic of Brown pyrometers, thermometers, pressure gages, etc.

General Uses of Flow Meter

"While primarily designed for the measurements of gases, steam and liquids, the apparatus is readily adaptable for use as a liquid level indicator or recorder or both. The inductance bridge system can be used as a transmitting device to transmit light mechanical motions over long distances electrically.

Die Cast Aluminum Cases

"A recent improvement on all of the circular chart type and indicating type of flow meter, thermometers and pressure gages is the new die cast aluminum case, which results in a lighter non-corrosive case which readily takes a beautiful finish. Because the Brown Instrument Company has been ready to make large investments in dies and tools, it is possible to offer instruments of superior design, ruggedness and accuracy at no increase in cost."

STATEMENT BY THE KING-SEELEY CORPORATION, ANN ARBOR, MICH.

"The K-S Telegage is a distant reading gage for accurately registering in inches the depth of liquids in storage tanks. It is applicable to oil, water, gasoline, milk, chemicals and other liquids.

"The K-S Telegage is used on fuel oil storage tanks, in domestic, industrial and marine oil burners; also on locomotive tenders, hydroelectric plants, dry cleaning establishments, oil refineries, sprinkling systems and wherever it is desired to keep a check on the liquids stored in tanks. It is also used on the instrument boards of motor cars for recording the contents of gasoline tanks and is factory equipment on the majority of American and British cars.

"The K-S Telegage depends for its accuracy entirely upon the hydrostatic principle. It, therefore, has no moving mechanical parts that wear or require adjustment. The tank unit is a submerged air bell. The pressure of the liquid on the air in the bell varies in direct proportion to the head of liquid in the tank. This pressure is transmitted through the air line to the direct reading V-tube of the gage head.

"No matter where the storage tank is located, the Telegage can be placed at any reasonable distance up to approximately 500 ft. and at any point most convenient for reading, either above or below the tank. The reading is taken from a vertical liquid column. The dial is calibrated for inches of depth in the tank and has much the same appearance as an ordinary barometer.

"In addition to the usual gage line running from the tank unit to the back leg of the U-tube, two other lines are provided to prevent the possibility of blowing the reading liquid out of the top of the gage, or the syphoning of the tank contents under more than normal pressure. The second, or equalizer, line connects the top of the sight glass of the U-tube with the top of the tank, thus insuring that the pressure on the top of the recording fluid is always equal to that on the top of the supply tank. This is an important feature in insuring accuracy of reading and safety when long fill pipes extend at some height above

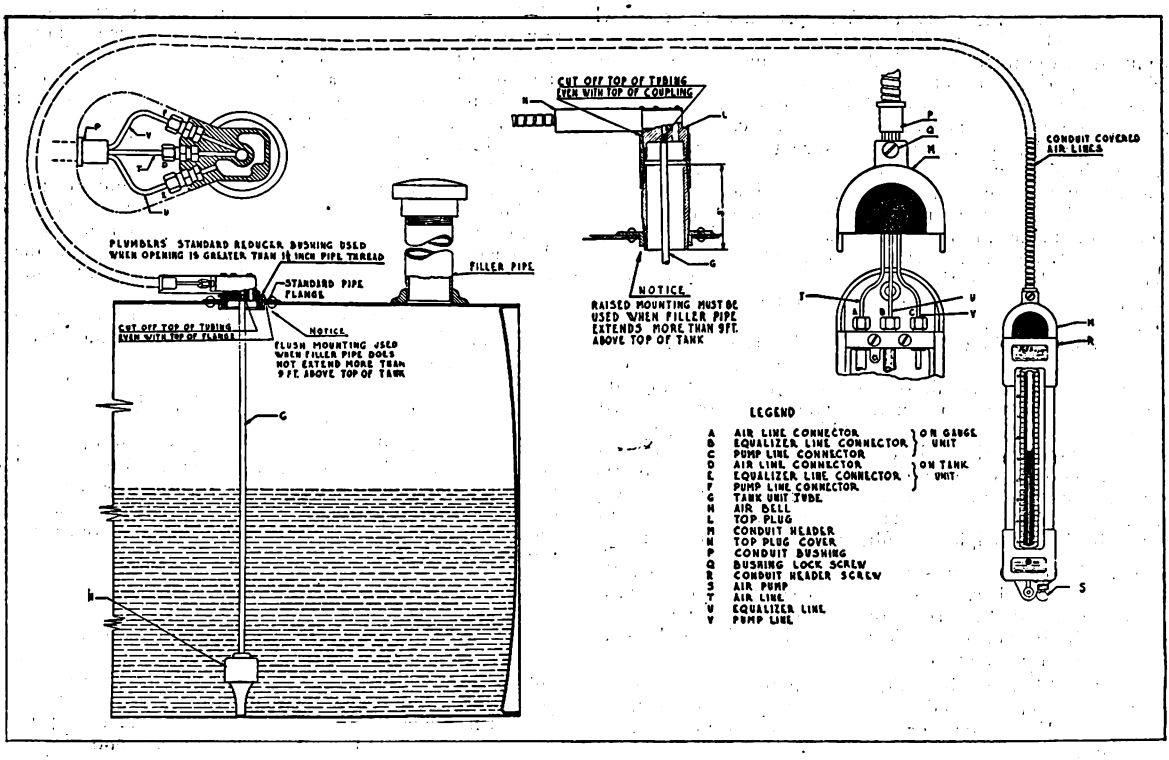
CUT OFF TOP OF TUBING
EVEN WITH TOP OF COUPLING
NOTICE
RAISED MOUNTING MUST BE USED WHEN FILLER PIPE EXTENDS MORE THAN 9FT. ABOVE TOP OF TANK
CONDUIT COVERED AIR LINES
PLUMBERS' STANDARD REDUCER BUSHING USED WHEN OPENING IS GREATER THAN 1½ INCH PIPE THREAD
STANDARD PIPE FLANGE
FILLER PIPE
CUT OFF TOP OF TUBING EVEN WITH TOP OF FLANGE
NOTICE
FLUSH MOUNTING USED WHEN FILLER PIPE DOES NOT EXTEND MORE THAN 9 FT. ABOVE TOP OF TANK
LEGEND
A AIR LINE CONNECTOR
B EQUALIZER LINE CONNECTOR
C PUMP LINE CONNECTOR
ON GAUGE UNIT
D AIR LINE CONNECTOR
E EQUALIZER LINE CONNECTOR
F PUMP LINE CONNECTOR
ON TANK UNIT
G TANK UNIT TUBE
H AIR BELL
L TOP PLUG
M CONDUIT HEADER
N TOP PLUG COVER
P CONDUIT BUSHING
Q BUSHING LOCK SCREW
R CONDUIT HEADER SCREW
S AIR PUMP
T AIR LINE
U EQUALIZER LINE
V PUMP LINE

FIG. 34—INDUSTRIAL TELEGAGE SHOWING INSTALLATION FOR DEEP TANKS, KING SEELEY CORP.

the tank, or when any abnormal pressure may come about in the tank. The third, or air supply, line runs from the gage to the tank unit, applying pressure from the pump directly at the tank. The three lines are furnished encased in flexible conduit fully protected and easy to handle, as shown in Fig. 34.

"Dials are supplied calibrated for the proper range of specific gravities of the liquids to be gaged. When liquids of varying weights are to be sorted in a tank, dials can be supplied graduated in absolute units of depth equivalent to inches of distilled water, and accompanied by charts that give the proper reading for any desired gravity."

STATEMENT BY THE HAYES CORPORATION, MICHIGAN CITY, IND.

"The Hayes Company continues with its standard line of instruments, which have been refined and improved. Recently we have added a type of draft gage new in principle and design, the instrument being free of floats, tanks, magnets or liquids.

"The gages are made in two types, Type F for one or two units, and Type V for any number of units up to twelve or more.

"In either F or V type the pointer can be made to move over the entire scale by a fraction of an inch water (a few millimeters), or the total scale range may be 6 or 8 in. water for blast pressure or 30-in. water pressure for powdered coal air lines.

"With a different mechanism higher pressures can be indicated just as accurately and as clearly.

"The operating mechanism shown in Fig. 35 and 36 consists essentially of a slack leather diaphragm and a phosphor bronze cantilever spring attached to a pointer, which is mounted on a pivot bearing. The diaphragm is a pliable, tough, gas-tight animal membrane which the Bureau of Standards found to be ideal for this kind of service. The diaphragm merely transmits the force of the draft or the pressure to the flat bronze spring, which in turn moves the counterweight pointer and produces a reading on the scale in direct proportion to the magnitude of the force.

"The spring is harnessed directly to the pointer in the simplest possible manner, using a strong non-kinkable, nickel-silver bead chain. The large area of the leather diaphragm produces such great magnification in the pressure that a surprisingly powerful force is dealt with. The spring is held rigidly at one end, and its movement is well within the elastic limit, so these gages hold their calibration indefinitely.

"The position of the strong spring determines the position of the pointer, and the spring is moved in proportion to the magnified force which is applied through the slack

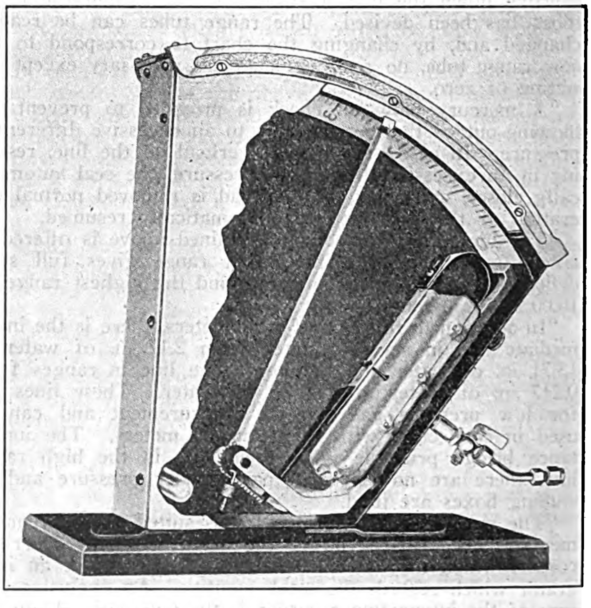

FIG. 35—OPERATING MECHANISM IN THE HAYES POINTER DRAFT GAGES, HAYES CORP.

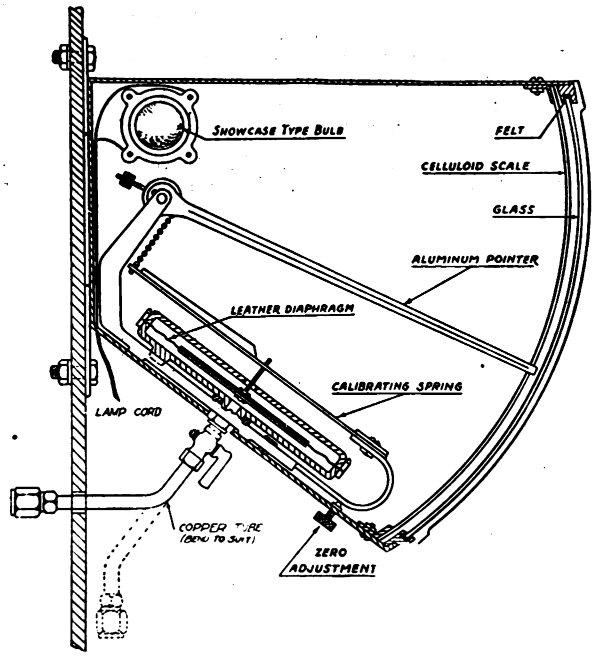

FIG. 36—OPERATING MECHANISM IN THE HAYES POINTER DRAFT GAGES, HAYES CORP.

leather diaphragm. The movement is the smoothest imaginable, and no dashpots or dampeners are necessary, as the pointers do not bob up and down. The pointers move promptly and definitely without the least sluggishness and can be depended upon to be accurate at all times. There is no surging and no changing liquid level. Vibration of walls and buildings and rolling of ships do not spoil the readings, as would be the case with swaying floats and liquids.

"The diaphragm used in the Hayes draft gages is an animal membrane, treated by a patented process.

"The leather is of a similar grade to that used to hold the rare and expensive helium gas in 'lighter-than-air' machines. Its strength and impervious nature, as well as ability to change shape according to the altitude and the amount of gas contained, make it ideal for this strenuous service."

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POWER PLANT ENGINEERING. Determination of Air Supplied to Furnace. Pp. 13-14, Jan. 1, 1928.

Apparatus and methods of measuring combustion air which is of extreme importance in maintaining efficiency.

POWER PLANT ENGINEERING. Furnace Operation Shown by Draft Measurement. Pp. 15-18, Jan. 1, 1928.

Fuel bed conditions, excess air leakage, variations in load, fallen baffles, give characteristic readings on draft gages. Various types of draft gages illustrated.

POWER PLANT ENGINEERING. Gas Measurements Indicate Efficiency. Pp. 19-23, Jan. 1, 1982.

Significance of temperatures and analyses of gas show operation of boilers and means available for securing these conditions.

POWER PLANT ENGINEERING. Means of Controlling Boiler Pressures. Pp. 35-39, Jan. 1, 1928.

Indicating and recording steam pressure gages, methods of testing and calibrating them, safety valves, capacity and tests.

POWER PLANT ENGINEERING. Temperature of Steam Is an Important Factor. Pp. 41-45, Jan. 1, 1928.

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POWER PLANT ENGINEERING. Measuring and Recording the Flow of Steam. Pp. 46-50, Jan. 1, 1928.

Description of the principles and mechanism of a number of flow meters, which consist of a primary element acted upon by screws, and a secondary element which transforms the action into an indication or record of the amount of flow.

POWER PLANT ENGINEERING. Measurements on Steam Engines and Turbines. Pp. 52-54, Jan. 1, 1928.

Determination of lb. of steam per kw-hr. for indicated h.p., use of indicator, methods of weighing condensed steam, use of dynamometers, etc.

POWER PLANT ENGINEERING. Condensed Operation. Pp. 57-60, Jan. 1, 1928.

The engineer must keep records, make frequent tests and maintain equipment in first class condition to secure best results.

POWER PLANT ENGINEERING. Air and Steam Measurements Most Difficult. Pp. 59-63, Jan. 1, 1928.

Instruments to be used in the measurements of air and steam conditions in the condenser. They must be carefully located and used to give reliable results.

POWER PLANT ENGINEERING. Speed Measurements Should Be Accurate. Pp. 194-195, Feb. 1, 1928.

Description of many types of speed indicators and recorders which simplify the speed measurement problem.

POWER PLANT ENGINEERING. Many Meters Develop Measure of Flow. Pp. 338-340, March 15, 1928.

Illustrated description of different types of meters. In general meters of same type have been developed to measure air, steam, gas or water, although details of meter construction for different fluids may vary considerably.

DISTILLATION PRODUCTS OF COAL

LOW TEMPERATURE CARBONIZATION

Present Status and Future of the Industry

During the past year the manufacturers primarily interested in the development of low temperature carbonization processes have done a great deal of work toward putting present experimental installations into commercial operation. New processes have been developed and installed. At the same time chemists have worked in associated fields in an endeavor to find the best methods of using the byproducts (in particular the tars) derived from such processes.

From the purely commercial standpoint, for conditions in this country it appears that no process has as yet proved itself in practice, particularly for use in connection with steam power plants. It is, of course, such a development that most interests the engineer entrusted with the design of power plants in his search for the process making the highest economic use of fuel.

Even the best known processes are still in an experimental stage of development, although in some of them it has been possible to correct most of the troubles that have been encountered during trial operation. Encouragement is found in the continuous successful operation of the KSG process at the Stinnes plant near Essen, Germany, since December, 1926, and the Coalite plant at Barnsley, Yorkshire, England. It is stated that the former has operated on a commercial scale since 1924, with a throughput of approximately 80 tons daily, and that the latter has been operated commercially since July, 1927, treating 200 to 250 tons of coal per day.

Power plant engineers in this country center their interest on the McEwen-Runge[1] plant installed at Milwaukee, but little information is available at the present time on the actual operation, except that from time to time difficulties have been encountered and eliminated. This plant, as well as the KSG plant recently installed at New Brunswick, N. J., is owned and operated by the holder of the patents covering the processes. The Milwaukee plant may be considered as an installation suitable for operation on a large scale; in the New Brunswick design provision has been made for commercial experimentation as well as for large scale operation. Because of the conditions underlying these installations, information concerning performance is not as easily obtainable as it would be if the ownership were in the hands of concerns primarily interested in the commercial results of the individual plants; these remarks are not intended as criticism of the owner's attitude, but to explain the circumstances that confront the power plant engineer in his study of these developments.

It should be noted that the reported commercial success of the KSG process in Germany is based on economic conditions quite different from those prevailing in this country, construction and operating costs being materially higher here; in addition, the price obtained for tar in Germany is considerably above that at present obtainable in the United States. It is, therefore, quite clear that even if this system can be economically justified for use in this country, the margin of profit will be considerably smaller than in Germany; consequently the data used in any estimate of results must be as accurate as possible.

Factors to Be Considered

While it is, of course, possible to reduce to a common monetary standard the cost of coal in Germany and the United States, such a comparison is only part of the story, and before the correct economic status of any process can be estimated, factors such as labor, materials, natural resources, markets and cost of money must be given consideration. When capital and labor costs are relatively low, it is in general easier to justify a carbonizing process than when they are high. In the United States there are large coal deposits, natural gas resources and petroleum fields, and these facts must be taken into consideration when comparison is made of justifiable capital expenditure in the United States and in Germany, England and other countries.

The essential problem for the power plant designer is, of course, an economic one rather than purely thermal. The importance of the byproducts obtained from the low temperature processes has often been pointed out. Sufficient monetary return must, however, be realized over a period of years to pay for the additional coal used, to offset the thermal losses, to cover the extra investment and operating cost, and in addition to afford a reasonable margin of profit, in order to make the installation attractive.

No general conclusions may be drawn about the economic success of any specific type of low temperature process, as everything depends on the locality where the installation is to be made and the possibility of marketing the byproducts. The coke, containing 70 to 80 per cent of the total heat of the products, will be the main source of income, but the ready marketability of the gas and tar produced will be an important factor in determining the success of the installation.

In general, it may be said that these processes should be more successful in densely populated sections of the country, where a large demand for smokeless domestic fuel as well as for gas exists. If a part or all of the coke is to be used for steam-electric generation, the power and gas producing companies should be closely affiliated or working under the same management, as close and harmonious cooperation would result in large savings.

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[1] See paper by Roland P. Soule before the Fuels Division of the A.S.M.E., Feb., 1928.

Publication No. 289-69, Serial Report, Prime Movers Committee.

In particular, so far as the electric power and light industry is concerned, a process that involves the least expense for investment and operation would be the most adaptable. As gas is generally the best and most expensive type of fuel, every effort would be made to sell it for domestic use, where the highest price could be secured. The coke not salable for domestic use would be used for steam production and could be burned with good efficiency, in whatever form produced, in one or more of the ordinary types of furnace. Attempts have been made to burn low temperature coke in pulverized form with a horizontal burner, but reports received indicate that the fire could be maintained only by using considerable bituminous coal with the coke. It is the opinion of engineers familiar with pulverized fuel equipment that low temperature coke should be burned in a vertical type of burner, in which the flame is directed downward.

A process like the KSG produces a high-grade domestic fuel that would be too valuable to be burned under steam boilers; this process is better adapted for use in connection with existing gas works, where the high heat value gas produced would be mixed with the low value gas produced in regular gas retorts. These facts make it plain, as stated by the promoters, that the KSG process is not a system especially adaptable for use with power plants. The process is described in Dr. Runge's paper, presented at the Fuel Division Meeting of the A. S. M. E., December, 1927.

The gas resulting from the usual low temperature carbonization process, having a higher B.t.u. value than the requirement of the commissions, would in general have a ready market. The gas from the KSG and McEwen-Runge processes falls in the high B.t.u. category. There are, however, processes in which the B.t.u. of the gas is lower than the commissions' standards, and in such cases the value of the gas would be about the coal equivalent.

Possibilities of Low-Temperature Tar

The byproduct from low temperature carbonization that has received the greatest attention is the tar, as the financial return from it will in many cases decide the economic success of an undertaking. Many possibilities have been pointed out. The characteristics of this low temperature tar are very different from those of the high temperature product, and the superior value of the new product for purposes other than as fuel oil has sometimes been questioned. When used as liquid fuel without refining, it would have approximately the value of petroleum. It is improbable that there will be a wide use of low temperature tar for road surfacing as it lacks the necessary binding qualities.

A simple refining process applied to low temperature tar yields 70 per cent of creosote and a residue of 28 per cent of pitch, figuring the losses as 2 per cent. The creosote obtained does not fully comply with the rigid specifications for wood preservative in this country, but its value for this purpose has been shown by numerous tests since 1921.

The consumption of creosote for wood preserving in this country has increased during the last decade or so between 10 to 15 per cent every year, and the total consumption in the United States in 1927 was over three-quarters of a million tons. Over 40 per cent (41.4 per cent during 1927) of the total has been imported from England and Germany, with prices as high as 18½ cents per gallon. It is reported that a zinc meta arsenite process for treating poles, developed by the research department of The Western Union Telegraph Company, is cheaper and more effective than creosoting. This may possibly affect the value of creosote.

It has been estimated that, with 15 cents per gallon for creosote and $4.50 per ton for pitch, the net return on the tar after deducting all refining charges would be over 8 cents per gallon. The producer of low temperature tar, particularly if it should be a gas or electric power company, would hardly intend to complicate the operating process by distilling tar. However, the development of new uses, and in particular the one mentioned above, would create a better market for the product and improve its price.

Interest in Manufacture of Resins

Since the Bakelite patents have expired, wide interest has been shown in the manufacture of resins. Although the price for this product has been considerably lowered (from a former price of $1.00 to 25 cents per lb. at the present time), it has been variously estimated that it might still be profitable to produce resins from low temperature tar. New uses have been found for this product, and chemists working in this field think that this industry is only in its infancy. But it is admitted that prices for low temperature resins would have to be kept below that of Bakelite in order to attract attention in the market.

The manufacture of resins yields by weight 11 per cent for this product with 57 per cent return in creosote and 28 per cent in pitch. After deducting all manufacturing and refining charges, it is estimated that a net return of over 10 cents per gallon of tar would result. This figure is based on prices for creosote and pitch as shown above, and 18 cents per lb. for resin. No special value is attached to the pitch resulting from the refining process, except that it could be used for fuel.

Foreign Developments

Interesting conditions are developing in Germany, where great efforts are being made to improve the economic situation of the nation as a whole by reducing imports and increasing exports. The financial powers controlling the supply of domestic fuel do not look very favorably upon the threatened augmented supply of domestic coke that would result from the expansion of the low temperature carbonization industry. It is felt that this new developmen should find other fields for its products or produce them in such form that they may compete with fuels now imported, such as fuel oil and gasoline; or that its products (e.g., synthetic ammonia) should be exported or be used in fertilizer manufacture or in the chemical industry.

Stimulated by these considerations, great progress has been made during recent years in methods of extracting hydrogen from the gases produced from high and low temperature carbonization processes. The hydrogen is used for the manufacture of synthetic ammonia, as well as for the manufacture of liquid motor fuel by the Bergius process. The hydrogen in the coke oven gas represents about one-half of its volume and one-third of its heat value. The residual gas, therefore, has a higher heat value per unit of volume than the original coke oven gas. Considering the tremendous amount of gas liberated during coal distillation, a wide field is open for these new methods where economic conditions are favorable. Processes have been developed in Germany by Linde, in France by Claude, and in Italy by Casale.

In the Ruhr Valley in Germany a new plant is being erected for a daily capacity of about 100 tons of coal, which will try out the Bergius process on a large scale using every kind of fuel available. This new plant is considered in Germany, not as a commercial proposition, but rather as an experiment.

Considerable research work has been done in England, Canada and in this country, which will be of great value to engineers who study the application of low temperature distillation to a specific installation. Assay tests have been made using the various fuels available for distillation. Detailed information may be found in the various reports published by the British Fuel Research Station, in an article by Davis and Galloway in *Industrial and Engineering Chemistry,* June, 1928, reporting on tests made by the U. S. Bureau of Mines, and in the report on tests made by the Canadian Department of Mines in *Gas Age-Record,* March 17, 1928. Although it is realized that the yield from the various coals, when carbonized in large retorts, will be different from that shown in the tests, these tests are valuable as an indication of comparative amounts of the by-products available from the various fuels.

Low Temperature Carbonization

It is worth while to learn of the attitude of some engineers prominent in the field of power generation, with respect to the relation of their industry to low temperature carbonization. One of these men, who has studied this problem both here and abroad, has concluded that the processing of coal is something to watch and keep in touch with; for the moment, however, he does not see any process that electricity supply companies should spend money on. The American Gas Association Report of 1928 covering this subject quotes the opinion of a well-known authority on fuels in this country; after discussing the results of a process that has been successful in Germany, this engineer writes as follows:

> "However, it is very doubtful in my mind whether success in one or two localities peculiarly favorable for such operation should be taken to imply any large opportunity in the United States for low temperature processing of coal in the immediate future. But even though it may seem quite pessimistic, I think we should frankly face the fact that the appropriate economic niche in our fuel and energy system has not yet been found for low temperature carbonization. When discovered for one locality, it is not necessarily known for another. And the enlargement of the niche to afford enlarged possibilities for low temperature processing will be a slow and financially painful procedure at best."

George Orrok, during the discussion of his paper on the economics of coal carbonization in the United States, presented at the Fuels Division Meeting of the A. S. M. E. in May, 1927, was accused of pessimism. However, his attitude and conclusions seem entirely justified and logical in the light of the data upon which they were predicated—at least until more definite information becomes available on the commercial aspects of the problem.

CONTRIBUTED STATEMENTS

DR. FR. MUELLER, KOHLEN SCHEIDUNGS GESELLSCHAFT, GERMANY

Dr. Mueller, who has been interested and active in the development of the KSG process in Germany, thinks that the outlook for low temperature distillation of coal is very promising in Germany and in the whole of Europe, and that undoubtedly there will be a field of operation for the various processes developed. He states that the low temperature coke produced must be a marketable product, as the largest part of the returns flows from it. Dr. Mueller sees a great future in the extraction of hydrogen from distillation gases, to be used for the manufacture of synthetic ammonia and the liquefaction of coal.

DR. C. H. LANDER, DIRECTOR OF THE FUEL RESEARCH BOARD, DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH OF THE ENGLISH GOVERNMENT

The following paragraph is a summary of statements made by Dr. Lander when interviewed by one of the leading power plant engineers in this country:

It is believed that no carbonization process available today can be economically used by electricity supply companies, unless it be some particular company like the Milwaukee Electric Railway & Light Company, where the gas and the electricity companies work in harmony and where other activities will absorb the bulk of the by-products. To make any of the processes worth while, the carbonization plant should be jointly owned and operated with the gas company, which through training and experience is in a better position to operate a process plant.

THE BABCOCK & WILCOX COMPANY

Distillation of Power Plant Coal

In the problem of reducing generating costs, every item of expense has separately been the subject of continuous effort, and among all these the fuel expense per kilowatt-hour has been reduced the most. However, the fact that fuel expense is still a large item of total cost has directed attention to the possibility of further reducing it by coal processing, such as distillation or carbonization.

Many interesting schemes for coal treatment have been proposed, and the ingenuity of some of them has tended to divert interest from the main issue, that is their value. Some of these schemes have proved to be unworkable or nonoperative, and others that were workable have failed to reach the stage of commercial success. These failures have not stopped the flow of new proposals, though they have had the effect of diverting the attention to valuation rather than technology. For the future it is to be expected that each new scheme for the distillation of power plant coal will be subjected first to the valuation test, assuming it to be workable; then, if the answer is favorable, an effort to make the scheme work would be justified.

A coal treating process may be economically judged by itself as a manufacturing operation, by comparing sales value of products with cost of producing them. On the other hand, it may be judged as an accessory to a steam power plant, by comparing the cost of steam with and without the coal process working in relation with the boilers.

It seems best that the first study be made from the second viewpoint, for many reasons, among them being the fact that there is in the steam power plant, a known market for any coal treating process that can be proved to be capable of reducing the cost of steam without impairing normal plant operation.

The first actual step must be the adoption of a suitable unit of cost, and this is "cents per million B.t.u.," rather than cost per ton of coal, per kilowatt-hour or per pound of steam. The B.t.u. is a prime factor in the rest, and the whole operation of the plant is energy conversion from one form to another, each with energy losses and money expenses. In what follows a million B.t.u. will be called a Unit.

The next step is the adoption of the principle that every energy transformation imposes three increments of cost over the original cost—"A." These are:

The inefficiency increment due to losses of energy—xA.

The investment increment representing all fixed charges —I.

The operating increment representing all disbursements due to operation—O.

The inefficiency increment of cost is the increase in cost per million B.t.u. due to losses quite independent of all other expenses. If E is the thermal efficiency or ratio of output to input energy for an energy transformation, then

$$\text{Inefficiency Increment} = \left(\frac{1-E}{E}\right) \times \text{original cost per Unit.}$$

If the cost per Unit after a transformation is B cents per Unit, and A the cost before, then

$$B = A + xA + I + O$$
$$= A + \left(\frac{1-E}{E}\right) A + I + O$$
$$= \frac{A}{E} + I + O$$

These principles were first expounded in a paper presented by Prof. Charles E. Lucke before the A. S. M. E. Metropolitan Section in April, 1924, and shortly afterward to the Schenectady and Boston Sections. It is entitled "Value of Efficiency in Transforming and Distributing Energy," and contains many numerical values, starting with the cost of fuel in cents per Unit.

Applying these principles to a steam power plant for which the costs are known, without coal processing, it is possible to determine how much the processing itself may cost without increasing the power generating costs, if two sets of data are available. The first is the yield of gas, tar and coke, with quality of each, and the second is the market price or credit value in cents per Unit for energy in each of the three forms and of the quality available. It is possible to make reasonably safe estimates for the products' values, but the figures for yields and qualities of products must be determined experimentally as characteristic of the process, of the coal and of the operating conditions—especially temperature—when the process is one of carbonization. With either actual results or reasonable assumptions for the numerical values of these two sets of data, the allowable total costs of the processing per Unit, to keep power costs the same, can be determined, or it is possible to fix an equalizing purchase price for the coal processing equipment if its efficiency and operating expenses are determined. This equalizing purchase price is what the power plant could afford to pay for a coal processing installation, with no change in its power cost, and it is, therefore, a maximum possible sales price. Any actual coal processing equipment would be valuable to the power plant in proportion as it costs less than this figure.

Working in the opposite direction, the determination of the price at which products of the coal could be sold, with no change in the cost of power, becomes possible as soon as the coal processing costs are known, and any prices obtainable above these figures represent profit applicable to reduction of power costs or to dividends.

To illustrate the procedure, an example will be worked out for application of a coal process to a power plant; the figures used are to be regarded as purely illustrative and not as representing any particular power plant or coal process. It will be assumed that the yields and qualities of the coal products are known, but that the cost of the equipment and its operation are unknown. It will also be assumed that present power costs are known, and that the problem is to determine the maximum sales price for the coal processing equipment based on an assumed efficiency and operating expense, or its highest permissible total operating expense after installation, for keeping power costs equal to what they were before.

The data for the assumed steam power plant will be taken from the above mentioned A. S. M. E. paper, as given for a plant of 25,000-kw. capacity, these data being reasonably correct for sizes up to about 75,000 kw. Other assumptions are—a coal of 12,722 B.t.u. per lb., at about $4.00 per ton of 2000 lb., costing 16 cents per million B.t.u. and having about the following analysis: Fixed carbon, 50.95; Volatile, 35.00; Moisture, 3.15; Ash, 10.90; Total, 100 per cent.

POWER COST FOR STEAM TURBINE POWER PLANT

Capacity	25,000-75,000 kw.	
Annual average load	40% of capacity	
Fixed charge rate on investment	12% per year	
Coal, 12,722 B.t.u./lb	16c. per Unit	
Efficiencies, yearly average:		
Coal to superheated steam	71%	
Superheated steam to b.h.p.-hr	20.03%	
Brake h.p.-hr. to kw-hr	92%	
Overall, coal to kw-hr	13.1%	
B.t.u. in coal per kw-hr., yearly average.		26,100
Investment:		
Real estate, etc	$2.00 per kw.	
Building, stack, etc	12.00	
Boiler room equipment	25.60	
Piping, etc.	11.30	
Turbo-generators	39.50	
Electrical switching, etc.	4.20	
Miscellaneous	4.40	
Total	$99.00	$99 per kw.
Power Costs:		
Fixed charges	0.34c. per kw-hr.	
Operating labor and material	0.40	
Fuel	0.42	
Total	1.16c. per kw-hr.	1.16c. per kw-hr.

For present purposes it is necessary to analyze the figures in greater detail for that part of the plant operation concerned with steam making from coal. This requires an apportionment of real estate, building and miscellaneous investment charges as well as labor and material for operation. The result, which follows, includes piping to give costs up to the turbine, which may be going too far.

STEAM COSTS, CENTS PER KW-HR. FOR POWER PLANT
(25,000 — 75,000 kw.)

Investment:	Per kw.	
Real estate for boiler room......	$ 1.00	
Building for boiler room........	6.00	
Equipment for boiler room......	25.60	
Piping to turbine...............	11.30	
Miscellaneous	2.29	
Total	$46.19	$46.19 per kw.
Fixed charges		0.158c./kw-hr.
Operating labor and material....		0.18
Fuel		0.42
Total steam costs.............		0.758c./kw-hr.

It is next necessary to convert these costs in cents per kilowatt-hour, their most common unit, to that adopted for present purposes, cents per million B.t.u., or cents per unit.

STEAM COSTS, CENTS PER UNIT (1,000,000 B.T.U) IN STEAM

Efficiency, coal to superheated steam, yearly average...71%
Cost of coal......................... A = 16.00c. per unit
Inefficiency increment $\left(\frac{1-E}{E}\right) \times A =$ 6.53
Investment increment .... I = 8.50
Operating increment .... O = 9.70
Total, cost per million B.t.u. in steam .... B = 40.73c. per unit

It is interesting to note that with energy in coal costing 16 cents per Unit, it has risen to 40.73 cents per Unit in the form of heat of superheated steam; so it may be stated that for steam making from fuel—

$$\text{Commercial efficiency} = \frac{16.00}{40.73} = 39.4\%$$

With such a set of figures for an existing power plant, it becomes possible to approach the problem of finding the effect of adding to it some coal process equipment, such, for example, as will produce gas and tar for sale and leave coke to be burned to make the steam. To do this requires data on yields and efficiencies somewhat like the following, the numerical values being merely illustrative but not unreasonable:

COAL PROCESSING DATA

Yields per ton coal (2000 lb.)	
Gas	3,400 cu. ft.
Tar	20 gal.
Coke	1,600 lb.
Quality-calorific power	
Gas	900 B.t.u./cu. ft.
Tar	100,000 B.t.u./gal.
Coke	12,700 B.t.u./lb.

HEAT BALANCE

Input—In calorific power of coal 12,722x2,000.	= 25,444,000 B.t.u./ton coal
(Heat 983,000).....	
In process heat (steam 1,300,000).....	2,283,000
Total........................	27,727,000 B.t.u./ton coal
Output—In calorific power of gas 900x3,400..	= 3,060,000 B.t.u.
Tar 100,000x20..................	= 2,000,000
Coke 12,700x1,600...............	= 20,320,000
Total........................	25,380,000 B.t.u.

$$\text{Thermal efficiency of coal process} = \frac{25{,}380}{27{,}727} = 92\%$$

If steam costs are to remain the same, and coke be valued at the same price as coal, i.e., 16 cents per Unit, the coal process costs can be set up.

Per million B.t.u. in coke required for steam making, there will be produced

98,000 B.t.u. in tar
150,000 B.t.u. in gas

These have credit or sales values estimated as follows. For the gas, the last report of the American Gas Association's Carbonization Committee for 1927 gives figures that may be regarded as a maximum for gas, based on its use as a blue water gas enricher in place of gas oil. This procedure fixes the value of high calorific gas such as 900 B.t.u. per cu. ft. by the cost of gas oil, and one report says that such gas would be worth 40 cents per 1000 cu. ft. for carburetting purposes. This is 40 cents per 900,000 B.t.u. or 44 cents per Unit. Other reports state that its value to a water gas works as an enricher would be between 40 cents and 60 cents per Unit, or 4 cents to 6 cents per 100,000 B.t.u., or per gal. of gas oil—its use equivalent. Gas of lower calorific power is worth less, and a scale of values could be worked out from a mean of 50 cents per Unit for 900 B.t.u. gas down to some lower figure corresponding to present costs of manufacture of blue water gas of approximately 300 B.t.u. For present purposes of illustration the value of the gas is taken at 50 cents per Unit as a water gas enriching agent.

For the tar, the minimum value will be that of a boiler fuel and so identical with the coal, which in the present example is 16 cents per Unit. At present it has a higher market value, and the maximum may be taken at some ratio to that of gas oil or fuel oil. For present purposes of illustration this will be set at one-half the value of gas oil, which would bring it to 2 or 3 cents per gallon of 100,000 B.t.u., or 20 to 30 cents per Unit, and the mean of 25 cents per Unit is used in what follows.

Expenses for the coal process begin with the coal at 16 cents per Unit, and to this must be added the cost of the heat used by the process. Such heat as is used to raise and hold the temperature required by the process and which may be derived from burning fresh coal, is to be charged at the coal rate of 16 cents per Unit, or at a lower value if boiler waste heat is used, or a higher value if, for example, steam or electricity is used. One-half of the cost of coal heat is charged in the present example. Heat of live steam, whether used as an atmosphere or a means of establishing a process temperature, is chargeable at the live steam cost of 41 cents per Unit, but if waste or partially expanded steam is used, a lower price will be proper.

The heat supply costs will then be as follows:

Heat Source	Units/Ton Coal	¢ Per Unit	Total ¢
Cal. power of coal....	27.7	16	440
Process heat	1.0	8	8
Steam	1.3	41	53
Total.............	30.0		501

$$\text{Net cost per Unit input heat} = \frac{501}{30} = 16.7¢ \text{ per Unit}$$

Considering coke as a boiler fuel to be the prime product of the coal processing, then the efficiency of the process is

$$\frac{20{,}320{,}000}{27{,}727{,}000} = 73 \text{ per cent.}$$

With this figure, the first of the three increments of cost for the coal process becomes:

$$\text{Inefficiency increment} = \frac{1-E}{E} \times A = \frac{27}{73} \times 16.7 = 6.3¢$$

The other two increments, investment and operating, are unknown, but their total can be evaluated for equal steam costs as follows:

COAL PROCESSING COSTS PER UNIT (1,000,000 B.T.U.) IN COKE

Expenses:
Efficiency, coal to coke...... 73%
Cost of input heat (coal).... (heat).... (steam).... A = 16.7¢ per Unit
Inefficiency increment, $\left(\frac{1-E}{E}\right) \times A$ = 6.3
Investment increment........ I = I
Operating increment......... O = O
Total, B = ... 23.0 + I + O cents.

Credits:
From gas 0.150 Units per Unit in coke × 50¢ = 7.5¢
From tar 0.098 Units per Unit in coke × 25¢ = 2.5¢

Total, B′ = 10.0¢

Net cost per million B.t.u. in coke, $B - B' = 13.0 + I + O$¢

This coke as a boiler fuel is valued at 16 cents per Unit, the purchase price of coal, and taking this as the cost, it follows that:

$$16.0 = 13.0 + I + O$$

and $I + O = 16.0 - 13.0 = 3$¢/million B.t.u. in coke

If, therefore, the coal process can be operated at less than 3 cents per million B.t.u. in coke delivered as a boiler fuel, all fixed charges and disbursements included, the process will be profitable; otherwise it will not when it is operated as an auxiliary to a steam power plant—subject to the accuracy of all the numerical values used.

Referring back to the boiler plant before installation of the coal process, it is to be noted that the sum of these two increments of investment and operation is:

STEAM BOILER PLANT

		Per Unit In Steam		Per Unit In Fuel
Investment increment	=	8.5¢	=	6.0¢
Operating increment	=	9.7¢	=	6.9¢
Total	=	18.2¢	=	12.9¢

It would, therefore, follow that a coal process will pay when the sum of its investment and operating increments of cost is equal to or less than $\frac{3.0}{12.9} = 22$ per cent of that for the boiler plant in cents per Unit or *dollars per year*, when the numerical values are as assumed. If the ratio of operating expense, exclusive of fuel and heat, to fixed charges were the same for the coal process as for the boiler room without it so that its installation did not change the ratio, then the investment in coal processing equipment can be estimated. In this case the investment allowable would be 22 per cent of that of the whole boiler plant, $46.19 per kw., which is $10 per kw. This means that a coal processing equipment would pay, if it cost less than $10 per kw. installed with all charges, and any less cost would be a measure of profit—all on the assumption of accuracy of the figures used.

For an actual case, other figures would apply, and for them there would be another answer; exactly the same method would, however, be applicable. This method is submitted for consideration as a tentative standard to be used in future work on coal processing evaluation for steam power plants, and for approval and adoption if, after study, it is found acceptable with such modifications as may be found desirable.

FOREIGN DEVELOPMENTS

England

The British Government is very anxious to create the facilities for an independent supply of motor fuels for the British Isles, and therefore does everything possible to stimulate the erection of low temperature carbonization plants. The government has levied an import duty of 4d per gal on fuel oil and petrol. This duty applies also to motor spirit manufactured in England from imported oil. This should stimulate the manufacture of these products from domestic coals and coal distillates. A great number of companies have been formed in order to exploit processes, but few of these processes have as yet been developed.

Of importance is the cooperative project of the British Government with the Gas, Light & Coke Company at London. The "Fuel Research Station" process will be used, and the plant will have a capacity of 100 tons per day. The British Government has guaranteed $500,000 for the erection of the plant, and the Gas, Light & Coke Company has guaranteed to operate the plant for three years as continuously as possible. The plant is not expected to start operation until late in the summer of 1928.

The Coal Oil Extraction, Ltd., of London is completing negotiations for the erection of a 500-ton plant.

A "Fusion Process" plant of 20 tons capacity has been in operation for several months at the Welbeck Collieries, Nottinghamshire.

Experiments have been made on a small scale with the "Hird Process."

In the Laing and Nielsen Process, operated by the "L & N" Coal Distillation, Ltd., of London, internal heating is applied in slightly inclined, fire-brick lined, rotating cylinders.

The Parker Process is used by L. T. Carbonization, Ltd., London; a 50-ton capacity plant was tested by the Fuel Research Board in 1924. A plant of improved type has been operating since July, 1927. at Barugh. This installation consists of 5 batteries each having 32 retorts, each retort containing 12 vertical cast iron tubes; 1500 tons of coal carbonized per week yield over 1000 tons of Coalite at 14,492 B.t.u. per lb., 28,200 gal. of oil, 3750 gal. of benzol and 7,000,000 cu. ft. of gas carrying 700 B.t.u. per cu. ft. The process consumes 2,500,000 B.t.u. per ton of coal carbonized.

The "McLaurin Process," operated by the Dalmarnock Gas Works, Glasgow, uses internally heated vertical retorts, carbonizing 50 to 70 tons per day.

The Midland Coal Products Process is in operation at an experimental plant at Netherfield, Nottingham. A plant of 500 tons capacity per day is in process of erection at the Askern Collieries, and another of 300 to 400 tons capacity, is to be erected at the Shipley Colliery.

Germany

The Plassmann Process has been developed by the Chemisch-Technische Gesellschaft at Duisburg, and a plant of 400 tons daily capacity is being installed at the Prosper mines at Essen. External heating is used in this process.

France

A plant of 200 tons daily capacity of the KSG type is being installed in the "Mines de Marles," near Paris.

Two units of the Salermo Process, with a capacity of 25 tons per day, have been working for over a year at the Sarre mines.

Spain

During July, 1927, a contract was signed by the "Cooperativa de Fluido Electrica," of the City of Barcelona, Spain, for the erection of a 500-ton plant of the KSG type.

WORLD POWER CONFERENCE, LONDON, 1928

Low Temperature Carbonization Plant at Newcastle-on-Tyne

R. P. Sloan reports on the results and future prospects of this 100-ton experimental installation. His conclusion is that under present conditions it is not likely that any large direct economies will result from low temperature carbonization, but that conditions may change; consequently, the careful study and extensive experiments that are being made in this direction may be of the greatest use in the future. At this coal distillation plant, which is at the Dunston power station of the Newcastle-on-Tyne Electric Supply Co., no important commercial economies have so far been obtained. Detail figures in the report show the returns obtained from the sale of by-products, the semi-coke and gas being burned under the boilers and therefore credited with their straight fuel value. The thermal balance shows 76 per cent of the original heat in the coke and gas, 12 per cent in the oils and 12 per cent consumed in process.

Frequent experiments and alterations have been necessary in order to adapt the system to the power plant and to make it operative.

The plant consists of four retorts and four boilers. One boiler is arranged for pulverized fuel firing to carry the peak loads. Two coke fired boilers are built together, having a combined evaporative capacity of 18,000 lb. of steam per hour, and are working in conjunction with two retorts of 20 tons capacity each. One coke fired boiler with 30,000 lb. evaporative capacity works with two retorts with a combined capacity of 60 tons per day. The complete distillation plant, therefore, is able to handle 100 tons of coal per day.

The paper gives a complete description of plant and performance. The raw coal is preheated before entering the retort by the waste flue gases, and the hot coke is discharged directly to the stoker hoppers in order to save the sensible heat.

The total cost of operation and maintenance, based on actual operation for the last three years, is given as 4s. 8d. ($1.13) per ton of coal distilled.

INTERNATIONAL CONFERENCE ON BITUMINOUS COAL, PITTSBURGH, 1928

Low Temperature Carbonization Processes

Low Temperature Carbonization of Coal by the Carbocite Process (W. H. Allen).

After giving a summary of the preliminary work since 1925 with a small experimental retort, the author describes the semi-commercial test unit in operation at Philo, Ohio, since July, 1927.

The process essentially consists of the continuous treatment of coal in horizontal or slightly inclined rotary furnaces. Crushed coal is dried and preheated to 450 deg. fahr. in the first rotary drum called the "Thermodizer." In the secondary or "Carbonizer" drum the temperature is raised to 900 or 950 deg. fahr. as the distillation and coking take place. It is found that with West Virginia coal, when the process is extended sufficiently to reduce the volatile matter to about 12 or 14 per cent, the resultant coke is tough and still dense. The pieces vary from ¼ in. diameter to 4 in., and even larger. The resultant gas, after removal of liquids, has a heat value of about 800 B.t.u. per cu. ft.

The drums consist of an inner and an outer shell, leaving a 2-in. space for the heating gases. Since August, 1927, there has been distilled nearly 4000 tons of coals, mainly from West Virginia and Ohio, with a maximum of 43 tons per day. The test plant has been shut down in order to increase the length of the Carbonizer drum from 30 to 60 ft.

The chief difficulties encountered have been of a mechanical nature, as moving parts have to be operated continuously at temperatures approaching a dull red. The worst obstacles are said to have been overcome, so that it is now possible to operate on a more or less continuous basis.

This is claimed to be an experimental installation only, but if it is found possible sufficiently to increase the throughput per unit of investment cost, it is intended to proceed with the installation of large operating plants.

The coke produced is a good grade of domestic fuel which is favorably received in the market. Under the present methods of operation about 20 per cent of the char goes through ½-in. mesh. Studies are under way to reduce the percentage of fines.

The KSG Low Temperature Carbonization Plant at New Brunswick, N. J. (Dr. R. P. Soule).

The KSG plant, which the International Coal Carbonization Co., a subsidiary of the International Combustion Engineering Corp., is building at New Brunswick, N. J., was described at length. Dr. Soule states that this plant is patterned after the successful KSG plant in Essen, Germany, where, since 1926, 50,000 tons of coal have been carbonized.

The New Brunswick plant will have a capacity of approximately 650 tons per day from eight retorts. A contract has been made with the Public Service Electric & Gas Company of New Jersey for the high calorific gas obtained from the process. This gas will be blended with blue water gas, the final mixture to have a heat value of approximately 550 B.t.u. The tar from the process is to be sold to the L. J. Lewis Company and the coke will largely be sold for domestic fuel.

It is announced by Dr. Soule that the Lukens Steel Co. of Coatesville, Pa., has contracted for a KSG plant of approximately 560 tons daily capacity. In this plant, which will be the first in this country in connection with a steel works, the gas will be used for the heat treatment of steel, instead of the raw producer gas now used.

These two KSG plants which, when completed, will be by far the largest in the world, indicate the extremely important advances made in the low temperature distillation field. They will be owned and operated by the International Coal Carbonization Co.

Dr. Soule states that approximately $20,000,000 has been spent in fruitless attempts to establish commercially successful plants, and he points out the need of very careful analysis of conditions before entering into large scale operations.

It should be noted that no claims are being made for the KSG system for the preparation of fuel to be used under boilers in power stations.

Low Temperature Carbonization of Coal by the Hayes Process.

A plant of the Hayes design has been installed by the Ben Franklin Coal Co. at their coal mines at Moundsville, W. Va. The first unit of 70 tons capacity was installed in 1927 by the Coal Carbonization Co. of Pittsburgh to produce a domestic fuel from slack coal, which amounts to 40 per cent of the coal mined. The slack is of very low price (approximately 75 cents per ton), and therefore a wide margin is available between the original fuel and the processed product. Another plant of 50 tons per day capacity was added in 1928.

The process is described in last year's report in a statement submitted by J. D. Davis of the Bureau of Mines.

The average yield of products from a ton (2000 lb.) of this coal is as follows, the process requiring 2,000,000 to 2,400,000 B.t.u. per ton:

Char (13,110 B.t.u.)	1430 lb.
Tar oil	29 gal.
Light oil	2.1 gal.
Gas (800 B.t.u.)	3750 cu. ft.

The char contains little moisture and is of a light friable character; it is readily crushed in preparation for briquetting or for pulverized fuel firing.

A still has been installed for the fractionating of the crude tar into light, medium and heavy oil, which is marketed as such. The remaining pitch is used as a binder for briquetting the char.

The cost of one 50-ton retort is approximately $50,000, with $150,000 for the auxiliary equipment. The retorts are made of a special steel that stands temperatures up to 2400 deg. fahr., although the furnace temperature is actually 1500 to 1600 deg. fahr. For a 300-ton plant, for instance, it has been estimated that the labor cost would be 50 cents per ton of raw coal.

Trumble Low Temperature Carbonization Process.

Distillation is effected in a series of retorts, using superheated steam as the heating medium. The raw material passes from storage bins into thermostatically controlled preheating chambers, where the raw material is preheated and de-hydrated by using the exhaust gases from the boilers and superheater. This preliminary de-hydration is stopped before gases are liberated.

From the preheaters the material is fed, by batch or intermittent delivery, into the distilling apparatus. This consists of a bank of retorts set in batteries of two. and each bank may consist of as many batteries as the practical application of the process through pilot plant operation has determined as being the most efficient combination for handling the material involved.

The superheated steam passes from the superheater through the first battery of retorts, and from there through the oil separator into the second interstage superheater. The temperature of the steam, vapors and fixed gases is again raised to the maximum temperature requirement. This mixture is now passed through the next battery of retorts, again giving up its heat to the raw material. The steam is reheated between each pair of retorts, the temperature being a little lower in each battery.

This cycle of heating is changed periodically and is so arranged that each successive battery of retorts receives its final cleaning from fresh superheated steam under pressure.

A pilot plant of semi-commercial capacity, 3.5 tons, has been built at Green River, Wyo., and is used for making practical demonstrations for the handling of the various oil shales found in the United States Another pilot plant has been constructed in Yokohama, Japan, for treating the coals, lignites and oil shales of Japan, Manchuria and Korea. These pilot plants have 12 retorts. The whole process of distillation takes 120 minutes; a retort is charged every ten minutes and the change in steam connections takes place in the same time interval, with a steam temperature range from 435 to 1050 deg. fahr.

It is estimated that on a 1000-ton basis the installation would cost $400 per ton daily capacity, or $600 including the refining equipment. For a 50-ton retort the cost is $600 per ton, or $750 including everything.

The "L and N" Process

The "L and N" Process and retort have been covered in detail in previous reports. This company has carried on extensive research work during the last few years in connection with their low temperature carbonization plant. The results of these investigations are given for the first time in Dr. Nielsen's paper. Data are given resulting from trials with a small test retort.

The "Plassmann" Low Temperature Carbonization Process—CTG Process.

The process has been developed specifically to use low grade, slightly coking coal, and to give as end product a lumpy coke. Distillation is continuous in a vertical retort, the coal being subjected to a pressure which may be varied to give the coke the desired compactness. Coke as produced by the Plassmann process can easily be shipped, and is claimed to be an ideal fuel, replacing anthracite, with the additional advantage that it ignites easily. Its ash content is high due to the nature of the raw product. Due to the subdivision of the flow of the heating gas, practically the same coking temperature prevails in all parts of the 18 coking chambers; the coke produced is therefore very uniform in structure and hardness. It can be crushed to any marketable size desired with only small losses in fines and dust (2 to

3 per cent). The coke contains 8 to 10 per cent of volatile matter.

Based on the favorable results obtained with a 1-ton experimental oven, a 50-ton retort was erected at the Prosper II mine, belonging to the Rheinische Stahlwerke in the Rhenish-Westphalian district, Germany, which has been in successful operation since the end of 1927. This oven has 19 heating chambers with a diameter of 13 ft., and 18 coking chambers. The height of each of the latter is 4 in., reducing the coking period to approximately 5 hours. The overall dimensions of the oven are 15 ft. diameter and 20 ft. high. The 18 coking chambers have a volume of 425 cu. ft. Aspirated fines up to 1 mm. (0.04 in.) size are carbonized.

A large plant of the Plassmann design is being erected near London. Three retorts of 65 tons capacity each are already in course of construction, and the plant is to be enlarged gradually. The coking properties of the English coals had been determined in a 2.5-ton experimental oven erected for this purpose in England.

The cost of a 50-ton retort is estimated at $80,000.

The Turner Carbonizing Retort.

This process differs from the previous ones described mainly in that it uses highly superheated exhaust steam to heat the raw coal.

The plant consists of a superheater for delivering the necessary steam to the bottom of a vertical retort. The latter is equipped with valves, to allow continuous charging and discharging. The gas outlet is fitted with a valve which opens at a particular pressure and remains open until the pressure has dropped to a fixed lower pressure. A tubular condenser is used to condense the vapors passing through the valve from the retort.

In the experimental retort at Poynton 32 different materials, including peats, lignites, oil shales, cannel coals and bituminous coals have been treated; only the last named has offered any difficulties. Some of the worst coals had to be treated for 12 hours in the retort, while the best of non-melting coals required only 2 hours with steam temperatures up to 600 deg. cent. (1110 deg. fahr.).

The solid residue or char, which is 70 per cent of the original weight, is thrown into cold water. The portion that floats, consisting of over 50 per cent of the original weight, is sold. The residue is used in the gas producers or under the steam boilers.

Yields of oil that have been obtained are: Peats, up to 20 gal. per ton of coal; lignites, up to 60; oil shales, up to 80, and with bituminous coals, up to 45.

For treating one ton of bituminous coal, one ton of steam at 650 deg. cent. (1200 deg. fahr.) is required.

Low temperature distillation of Briquets by Superheated Steam, Weiss System.

A plant of this type has been in operation since 1926 at the mines of the Compagnie des Mines de Vicoigne, Noeux et Drocourt, France. The first consideration in erecting and operating this plant was to produce a substitute for anthracite.

Coal dust is agglomerated into ovoid balls with pitch or asphalt as a binder. These balls are put into a series of stationary chambers of a capacity of 20 tons each, and heated progressively with steam superheated to approximately 1200 deg. fahr. The steam is then condensed in order to permit the recovery of the primary oils and tars, the gas and the major portion of the binder. Exhaust steam from the main turbine-generators is used, re-superheated in specially designed superheaters before entering the distillation chambers. The method of heating somewhat varies, depending on the raw coal.

The product of this process is sold for domestic use under the trade name of Anthracine.

The installation at Noeux consists of eight sheet-iron cylindrical chambers arranged around a central distributor. The chambers have a diameter of 11.5 ft. and a height of 18 ft., divided into compartments by specially shaped rings. The rings are arranged in such a way that the pressure on the briquets does not exceed permissible limits anywhere in the retort, thereby preventing deformation of the balls during the softening period.

The present capacity of the plant is 200 tons per day with a normal production of 150 tons. New steam generators are being erected at present to increase the total capacity to 400 tons.

It is stated that the cost of a plant of the Weiss type is somewhat less than that of a high-temperature coke-oven plant of the same capacity, and that the total cost of distillation will be between $3 and $3.50 per ton of marketable briquets. This figure applies to a plant of 300 to 400 tons capacity per day, using coal containing less than 18 per cent volatile matter and including all the costs for labor, maintenance, repairs, motive power and amortization; it likewise takes into account the recovery of the by-products.

The Transformation of Fine Bituminous Coal into Substitutes for Anthracite, Trent Process (A. Leaute).

The fine coal is formed into briquets before distillation, the binder used for agglomeration being chosen with consideration of the role it is to play during the distillation. The author goes into considerable detail as to the desired characteristics in the finished product in order to compete with natural anthracite.

The process is being used at present on an industrial scale at Lapugnoy; the present capacity is 50 tons of artificial anthracite a day. The installation consists of a Trent cleaning plant, a mixing and agglomeration plant and a distillation plant.

The distillation furnace consists of several chambers heated on the interior by steam superheated to 600 deg. cent. The crude artificial fuel is in buckets which are moved by hydraulic means from chamber to chamber, to subject them to the proper heating. The rate of heating can be regulated with great precision. The thermal efficiency is raised by closed circuit operation.

The International Bitumenoil Corporation Process.

The retort used in this process is of the inclined rotating tubular type. Novel features claimed are accurate zoning of the heat in separate furnace compartments along the tubular retort, methods of withdrawing vapors, introducing gases, feeding and discharging material, condensing volatile products and air sealing.

It is claimed that the methods and apparatus are conveniently flexible and adapted to widely varied treatments and results in processing a great variety of materials. The charge in the two preheating zones is heated to from 500 to 700 deg. fahr., and to from 900 to 1000 deg. fahr. in the fourth or carbonizing zone, with intermediate temperatures in the third or intermediate zone.

Of the 6000 to 8000 cu. ft. of high B.t.u. gas ordinarily recovered in the process, less than 2000 are used for distillation purposes. High oil recovery is claimed, with a maximum of 62.5 gal. per ton of Tennessee cannel coal.

A contract has been closed in England for a plant of 2000 tons ultimate daily capacity, the initial installation being for 600 tons. American interests are starting a smaller installation in Tennessee.

Two economic set-ups are submitted, one showing the application of the "International Bitumenoil Process" to cannel coal and one its application to bituminous coal. Both show a large net return resulting from small capital charges and very low cost of the raw product. A 400-ton plant is estimated to cost $300,000.

A New System of Coal Carbonization (Julien Pieters).

The Pieters carbonization process is a progressive and continuous one, starting at about 212 deg. fahr. and finishing at 1470 to 1740 deg. fahr., according to the quality of coke required. The coal passes through the zones of low temperature, intermediate and high temperature carbonization in succession.

Laboratory tests showed that such a process could only be conducted in a vertical continuous retort. A trial oven of 10 tons capacity was built in 1919, and an improved type of the same capacity in 1925 in Belgium.

The raw coal before entering the retort is ground into a fine powder, briquetted, and during the coking process is kept under pressure. In general, slow and progressive distillation improves the quality of the coke, as rapid distillation tends to break it up. Dry coal is agglutinated by adding oxidized pitch.

The oven is said to differ from other coke or gas ovens in the following respects:

1. Continuous recuperation with very low temperature of the leaving flue gases.
2. System of progressive operation.
3. Special flue construction, which allows quick firing and rapid decrease of temperature from bottom to top.
4. Special discharging system.
5. Special treatment of all combustibles, producing, after recovery of all byproducts, a new fuel having all the characteristics of metallurgical coke or anthracite, even from fuel of a non-coking nature. The coke is produced in a definite form and size and no breeze is obtained.

The following table shows a comparison between the Pieters process, a high temperature and a low temperature process. (In reference to the latter it should be noted that the author assumes that all the gas generated is used up in the process, although most low temperature processes yield surplus gas that may be sold.)

COMPARATIVE RESULTS OF THE CARBONIZATION OF A BITUMINOUS COAL WITH 35 PER CENT VOLATILE, BASED ON 2240 LB.

	L. T. Process	H. T. Process	Pieters Process
Benzol and motor spirit, gal.....	5.64	2.82	5.64
Medium heavy oil, gal..........	13.53	4.51	13.53
Naphthalene and anthracene, lb..	4.51	9.02	None
Total tar products, gal..........	20.30	12.63	19.85
Pitch, lb.	18.00	49.61	18.00
Gas produced, cu. ft............	3,594	11,500*	10,782*
Net after firing, cu. ft..........	None	5,750	8,086
Ammonia sulphate, lb...........	None	22.55	27.06
Coke, lb.	14.50	13.30	13.30
Quality of coke.................	Powder	†	‡

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* Cubic feet of 546 B.t.u.
† Very much swollen, much breeze.
‡ Dense, very hard, regular size, no breeze.

Low Temperature Distillation of High Moisture Coals (F. Seidenschnur).

Professor Seidenschnur reports on the results that he has obtained in the low temperature distillation of high moisture combustibles, especially of earthy fine-grained German lignite and lignitic lump browncoal. These results led to the perfection of the Freiberg Process. Particular attention must be paid to the drying process of high moisture coals.

Low Temperature Distillation, The British Coal Industry and Oil Supplies (R. H. Crozier).

The importance of low temperature distillation to Great Britain is shown. The author discusses the modern trend toward reorganization of the coal industry along rational lines. It is predicted that raw coal will decrease in importance while the importance of low temperature distillation products will increase. Statistics quoted show the production and consumption of coal in Great Britain, and the amount of products potentially recoverable through low temperature distillation of coal and also gives the oil resources of the British Empire. It is suggested that the treatment of a million tons of coal and the oil shales yearly, involving development of an industry of unprecedented magnitude, must be undertaken promptly for Great Britain to be in position to face an inevitable oil shortage.

Low Temperature Carbonization (C. H. Lander).

The paper shows that considerable progress has been made both by the Fuel Research Station and by industry in the solution of the low temperature carbonization problem as it affects Great Britain. A warning is sounded against both groundless optimism and unnecessary pessimism concerning the prospects of low temperature carbonization. Information on the subject is rapidly being made available by the Fuel Research Board and by many firms and individuals engaged on the problem, and it is pointed out that special local conditions exist in various parts of the world in which one or another of the plants developed can be expected to be commercially profitable. The author suggests that only experience can tell to what degree the process may develop as a really large industry and an important factor in the economy of the world's fuel.

Some Fundamentals of the Carbonization of Coking Coals: The Formation of Cenospheres (F. S. Sinnatt).

The paper is a study of the fundamental structure of coke and deals particularly with the carbonization of coal in the form of small particles. When particles of coal of a critical magnitude are subjected to heat treatment, hollow spheres, called cenospheres, are produced. The spheres are characterized by a lattice structure with the spaces covered with thin bubble-like films (called windows), black by reflected light and colorless to dark brown by transmitted light, and minute specks of material best seen in the transparent portion. The formation of cenospheres has been used to prove that different parts of the same coal seam may possess widely different swelling properties. Some particles do not swell, and others form cenospheres having 40 times the volume of the original particles of coal from which they were produced. Cenospheres have been found in quantities in the dust from various types of industrial plants (locomotives, cement works, etc.), and their low specific gravity accounts for the fact that dust from industrial furnaces may be found at considerable distances.

The Influence of Inorganic Materials in Lignite Carbonization (A. W. Gauger).

The pioneer work of Dr. R. Lessing on the influence of mineral matter in the carbonization of organic materials has been extended in a study of North Dakota lignites. Not only is the amount of char and tar affected by the presence of inorganic material, such as iron, aluminum chlorides and aluminum sulphates, but also the very nature of the char as well. Lignites ordinarily slack in the fire, and on carbonizing produce a loose, non-adherent semi-coke or char. If such carbonization is carried out in the presence of aluminum chloride or sulphate, a hard adherent pseudo-coke is formed instead of the usual loose char. In some cases this pseudo-coke possesses a silvery metallic luster resembling that of coke and gives a metallic ring when struck.

By-Products

A number of papers were delivered at the Pittsburgh conference relating to byproducts obtained from the carbonization process, among them the following: "The Tar Industry in France," Jean Bing; "Some Phases of the Organic Sulphur Problem in the Manufacture and Utilization of Gas," Wilbert J. Huff; "Gas Purification in Relation to Coal Sulphur," F. W. Sperr, Jr.; "Continuous Distillation of Coal Tars and Crude Oils by Superheated Steam by the Ab-Der-Halden Process," J. V. Henri Winkler; "The Cracking of Low Temperature Coal Tars," Dr. A. E. Dunstan; "Cracking of Tar Acids from Coal," Jacque C. Morrell and Gustav Egloff; "Extraction and Recovery of Phenols from Ammonia Liquors," Robert M. Crawford; "New Catalytic Processes for the Utilization of Coal Tar Crudes," Dr. Alphons O. Jaeger; "Formation of Benzol and Other Hydrocarbons by the Action of Heat on Methane," Franz Fischer, and "A Study of Comparative Costs of Gas Production in the Retort House," E. W. Smith.

A paper was given by Dr. Pott, relating to the recent extensive development in Germany of a pipe line system for carrying coke oven gas over a considerable territory for interconnecting producing and consuming centers. This development is of general interest, and the paper is abstracted below.

Transmission of Coke Oven Gas in Pipe Lines in Germany, Dr. Ing. e.h. Alfred Pott.

The Ruhrgas Corporation of Essen, founded in 1926, has as one of its main purposes, the distribution of gas from the Rhenish-Westphalian industrial district to neighboring and distant cities and communities. Ten billion cubic meters of coke oven gas are produced yearly in the Ruhr district. Until recently this has been largely consumed in heating coke ovens and firing steam boilers. Owing to recent progress in fuel engineering, cheaper fuels, such as low grades of coal and coke can now be used for the heating of boilers and coke ovens, etc., reserving the valuable coke oven gas for more profitable purposes.

The pressures at which the coke oven gas must be conveyed in the pipe lines depend on the quantity of gas and the distance. Large quantities of gas should be pumped at a pressure of 3 to 6 atmospheres for small distances; for longer distances it should be compressed up to 12 to 20 atmospheres in intermediate compressor stations. The diameters of pipe lines are proportioned to the gas volume and distance, ranging from 400 to 700 mm.

The author reports in detail the present status of line construction, the crossing of streets, rivers and railroads, methods of pipe welding, the application of couplings and connections. Modern technical methods and developments of the last year and a half that have proved especially valuable are mentioned. The protection of the lines against corrosion and electric currents, as well as the methods of supervision, measurements and recording along the lines, is mentioned.

By the end of 1929 a pipe line network aggregating 950 km. will be available, which will supply with gas an area of 11,000 sq. km. having a population of 10,000,000 people. The gas consumption in this area will, by the end of next year, amount to two billion cubic meters. Improvements at the coke plants in the Ruhr district make it possible (because of the large quantities of gas—totaling 400 to 500 million cubic meters per year) to clean, compress and measure gases at the individual mines. This reacts favorably upon the economical results of the overland gas distributing system.

The compression of the gas is effected by steam-driven piston compressors. It is cleaned of sulphur by the dry cleaning process using iron ore or similar material. For overland transportation the naphthalene is completely removed from the gas by a new process, in which pressure and temperature conditions during the compression of the gas are fully utilized.

The gas coming from the large coke oven plants has a uniformity in heat value and density that has never before been attained; by employing a new method, the gas can be turned out at a specific heating value and density if this should be desired. For this purpose a part of the coke oven gas is mixed with water, steam, air or carbonic acid, and this mixture is then added to the original gas in the necessary quantities.

With all these improvements the overland supply of coke oven gas can be accomplished successfully, economically and with the greatest safety, and the maximum energy economy of the coke oven gas can be realized.

Hydrogenation

A number of papers on hydrogenation and related subjects, including a complete classification of fuel, were delivered at the conference, among them the following: "New Aspects of Coal Economy," Dr. J. G. Aarts; "Hydrogenation at High Pressure and High Temperature With or Without Catalyzing Agents," Dr. Andre Kling; "Some Aspects of Hydrogenation," J. Ivon Graham; "The Hydrogenation of Coal Tars," Prof. G. Hugel; "A New Method for Direct Determination of the Best Temperatures of Hydrogenation for Bituminous Coals," J. P. Arend; "Catalysis Applied to the Conversion of Hydrocarbons," Dr. Carl Krauch, and "Transformation of Cellulose and Lignite into Coal," Dr. Friedrich Bergius.

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HIGHER STEAM PRESSURES AND TEMPERATURES

SUMMARY

The past few years have demonstrated the practicability of operation and the thermal economy of the 1200-lb. cycle.

This report contains statements on stations that have operated at the above pressure for some time, and on a number of new installations.

It is interesting to note that only a few years ago the Higher Steam Pressures and Temperatures Subcommittee's report included data on 300-lb. and 400-lb. installations; whereas, this issue contains nothing below 600 lb., and the majority of data are on installations of 1200 lb. or over.

This increased use of higher pressure is due, to a large extent, to the untiring effort of the A. S. M. E. Committee on Steam Research.

Steam temperatures have not kept pace with steam pressures. Temperatures of 650 to 700 deg. fahr. have been common with 300 and 400 lb. units; whereas, 750 to 775 deg. fahr. seems about the present practical limit for 1200-lb. installations in this country. The possible reason for this is found in a statement on The Behavior of Metals at Elevated Temperatures, submitted by Prof. A. E. White.

The rapid acceptance of the 1200-lb. cycle as economical and practical has opened the way to still higher pressures, and a study of their thermal possibilities is not only of interest but quite timely.

What the future holds in the design of higher pressure and temperature equipment is well brought out in a statement on Higher Pressures and Temperatures which C. F. Hirshfeld has contributed.

The probable relation of caustic embrittlement to higher pressures and temperatures and the desirable carbonate-sulphate ratios are covered by a statement on The Relation of Embrittlement to Higher Steam Pressures and Temperatures, by Prof. F. G. Straub.

A section of this report contains data on the relative construction costs of 400 and 1200-lb. equipment.

Manufacturers' statements also are included. The rapid increase in the use of welded vessels for high pressure service is made evident by some of these statements.

RECENT INSTALLATIONS

While two of the larger central stations in this country have operated at 1200-lb. pressure for several years, the year 1928 has shown the first stage in the more general adoption of high-pressure equipment, as evidenced by the following new or proposed installations. These stations are the 1250-lb. Holland Station, the 1200-lb. Deepwater Station and the 1200-lb. South Amboy Station (representing the first large stations originally designed for high pressure), the 1400-lb. addition to Northeast Station, Edgar Station, Lakeside Station and the 1800-lb. installation for the Philip Carey Co.

In addition to the above, several new 600-lb. and 700-lb. installations have gone into service or are under construction, namely, State Line Power Station, the addition to Powerton Station, the Grand Avenue Station (Kansas City), and the 650-lb. installation of the Waldorf Paper Products Co.

OPERATING COMPANIES' STATEMENTS

STATEMENT BY W. S. BARSTOW & COMPANY, READING, PA.

Holland Station, Holland, N. J.

The new 1250-lb. pressure Holland Station of the Pennsylvania-New Jersey Power System is being constructed at Holland, N. J., on the Delaware River by W. S. Barstow & Co. It will be the main Eastern generating station of the system.

The throttle steam conditions will be 1250-lb. gage, 750 deg. fahr. total temperature. Before adopting 1250 lb. as the operating pressure, studies of 400, 600 and 1250-lb. plants were made, and based on coal between $4 and $5 per ton and 50 per cent load factor. The 1250-lb. plant was selected as the most economical, considering combined operating and investment costs.

The first unit of the station will consist of a 55,000-kw., General Electric Company cross compound turbine generator unit consisting of an 11,800-kw., 85 per cent power factor, 13,800-volt, high-pressure element, operating at 3600 r.p.m., and a 43,200-kw., 85 per cent power factor, 13,800-volt, low-pressure element, operating at 1800 r.p.m., with direct-connected exciter of sufficient capacity to excite both generators.

At the time the Holland Station was considered, all 1200-lb. pressure installations in operation or considered at that time were arranged as an increment to an existing plant, allowing the high-pressure unit to be operated upon base load conditions. In the Holland Station is was necessary to design the plant for variable load operation, and it was realized that to build a 1250-lb. station for higher efficiency and variable load operation, the high-pressure element of the turbine must be of the multi-valve type to provide a greater range of expansion at fractional loads, and that means for maintaining a constant reheat temperature would have to be obtained. After discussing this matter with the turbine manufacturers, it was arranged to design the high-pressure unit having five steam admission valves.

Two steam-generating units will be provided, each having a capacity of 250,000 lb. of steam per hour at 1400 lb., 750 deg. fahr. and reheat at approximately 400 lb. and 750 deg. fahr. These units will consist of:

7928 sq. ft. B & W boilers.
5520 sq. ft. superheaters.
11,450 sq. ft. B & W gas reheaters.
1508 sq. ft. B & W steam reheaters.
11,880 sq. ft. Foster Wheeler economizers.
32,450 sq. ft. Foster Wheeler air preheaters.
2194 sq. ft. water walls and screens, boiler No. 1, bottom screen—plain tubes; front, rear and side—fin tubes.
1866 sq. ft. water walls and screens, boiler No. 2, front, rear and bottom—plain tubes; side—fin tubes.

Reheaters are integral with the boiler unit and the reheat temperature held constant throughout the entire range of operation by means of a first stage steam reheater.

Steam from the boiler flows to the convection superheater and thence to the high-pressure section of the turbine which exhausts to the steam reheater operated in series with a flue gas reheater, and is returned to the low-pressure section of the turbine. Saturated steam from the boiler is used in the steam reheater for supplying the heat, and constant re-

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Publication No. 289-73, Serial Report, Prime Movers Committee.

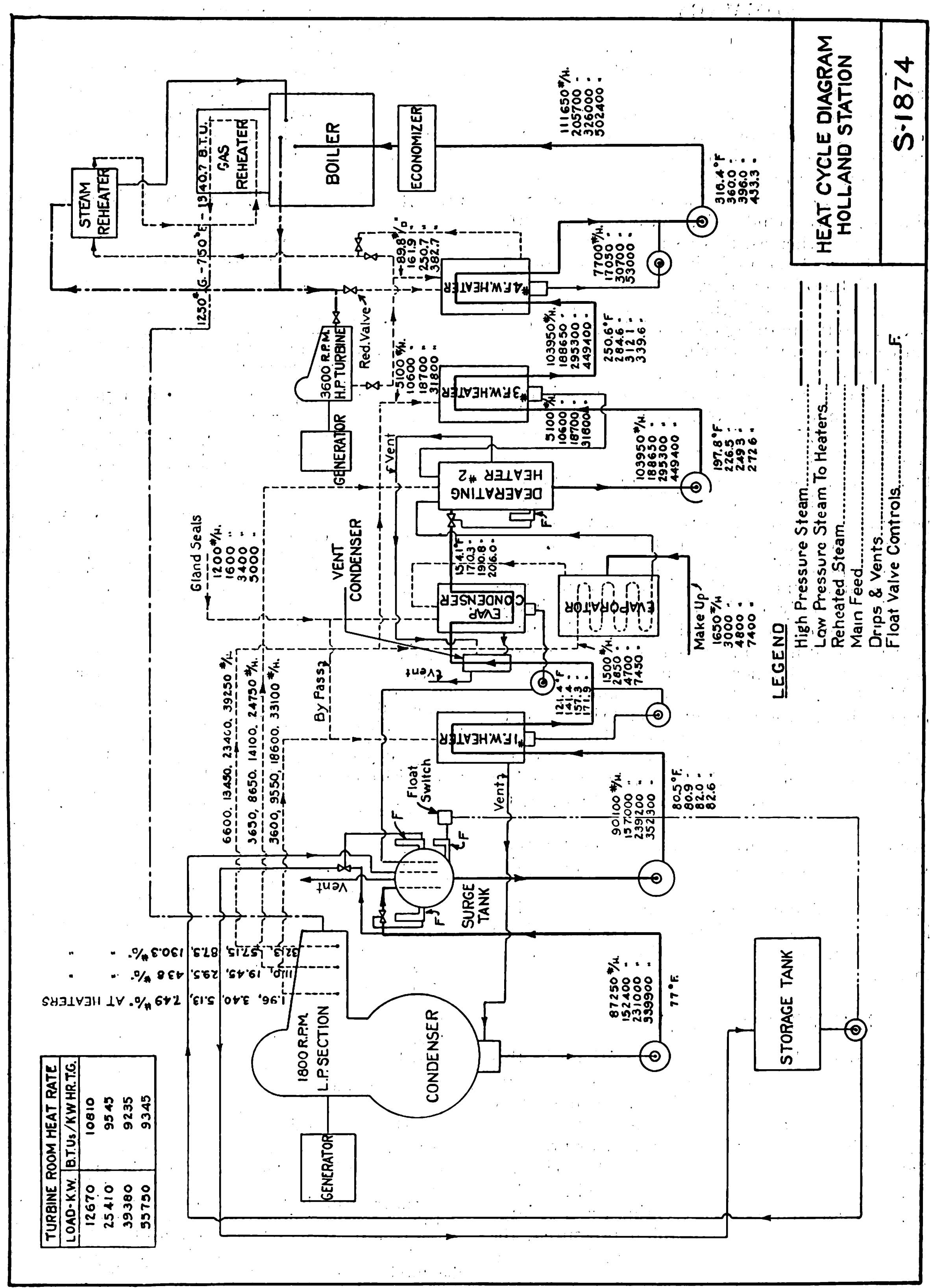

HEAT CYCLE DIAGRAM
HOLLAND STATION
S-1874
BOILER
ECONOMIZER
GAS REHEATER
STEAM REHEATER
1940.7 B.T.U.
1250# G.-750°F.
3600 R.P.M. H.P. TURBINE
GENERATOR
Red. Valve
#4 F.W. HEATER
#3 F.W. HEATER
DEAERATING HEATER #2
EVAP. CONDENSER
EVAPORATOR
VENT CONDENSER
#1 F.W. HEATER
SURGE TANK
Float Switch
By Pass
Vent
Gland Seals
1200#/H. 1600 3400 5000
Make Up
1650#/H 3000 4800 7400
1800 R.P.M. L.P. SECTION
CONDENSER
GENERATOR
STORAGE TANK
111650#/H. 205700 326000 502400
316.4°F 360.0 396.0 433.3
7700#/H. 17050 30700 53000
89.8#/D 161.9 250.7 382.7
103950#/H. 188650 295300 449400
250.6°F 284.6 312.1 339.6
5100#/H. 10600 18700 31800
197.8°F 226.5 249.3 272.6
15.41°F 170.3 190.8 206.0
1500#/H. 2850 4700 7450
121.4°F 141.4 157.3 171.9
90100#/H. 157000 239200 352300
80.5°F 80.9 82.0 82.6
87250#/H. 152400 231000 339900
77°F
6600. 13450. 23400. 39250 #/H.
3650. 8650. 14100. 24750 #/H.
3600. 9550. 18600. 33100 #/H.
1.96, 3.40, 5.13, 7.49 #/□" AT HEATERS
11.0, 19.45, 29.5, 43.8 #/□"
32.3, 57.15, 87.3, 130.3 #/□"
TURBINE ROOM HEAT RATE
LOAD-K.W. | B.T.Us/KW HR. T.G.
12670 | 10810
25410 | 9545
39380 | 9235
55750 | 9345
LEGEND
High Pressure Steam
Low Pressure Steam To Heaters
Reheated Steam
Main Feed
Drips & Vents
Float Valve Controls
F

FIG. 1—Heat Cycle Diagram, Holland Station.

heat temperature is obtained by thermostatic regulation of the steam to the steam reheater, the proportions of the two reheaters being so arranged that at full loads the steam reheater is nearly cut out, the flue gas reheater furnishing all the heat required.

The bin system of pulverized fuel will be used. Mill drying will be applied, the vents from the mills being used for secondary air supply to the burners; this eliminates the objectionable dust features of this design. The furnace is designed for a heat liberation of 20,000 B.t.u. per cu. ft. at 250,000 lb. of steam per hr. Opposed firing will be used, with three burners on each of two opposite sides of the furnace. The side walls are of the fin tube type, but the two walls carrying burners are protected by bare tubes set in the brickwork above the burners. The furnace is equipped with a special water screen above a dry ash pit of new design. The ash pit arrangement is so laid out that it can be changed to a slag tap bottom if desired at a later date without major or costly changes. The plant is designed so that all fuel can be pulverized during the off-peak period.

The heat cycle and arrangement of the auxiliary equipment was decided upon after carefully balancing the economies and first cost of various equipment. This arrangement is indicated in the heat cycle diagram, Fig. 1.

The condensate, after leaving the condenser, is first pumped to a surge tank with a float valve control, which may divert it to an evaporated water storage tank. From this point the condensate or feed water is delivered to the boiler through three separate pumps acting in series. The first pump delivers it to the deaerating heater after it has passed successively through the first stage heater supplied with steam from the 15th stage of the low-pressure turbine, a small vent condenser and the evaporator condenser. The second pump forces the water through a third and fourth stage heater, taking steam respectively from the 6th stage of the low-pressure turbine and the exhaust of the high-pressure turbine, while the third pump, working against a maximum head of 1600 lb., takes the water which has now reached a temperature of 430 deg. fahr. at full load and discharges it to the boiler through the economizer. This fourth stage heater is so arranged that it can be used as a desuperheater should it be desired to operate the low-pressure turbine only.

With four stages of steam extraction employed, the condenser is considerably reduced in size, there being only a little over 0.7 sq. ft. of condensing surface per kw. capacity of the low-pressure section of the turbine. It will be of the single-pass type with horizontally divided water boxes, and will be arranged for reversing the circulating water flow. The tubes will be expanded into both the inlet and the outlet tube sheets and expansion and contraction cared for by expansion joints adjacent to the tube sheets.

Inasmuch as the Holland Station is connected by means of four high-tension and two low-tension circuits, all of the auxiliaries will be motor driven with the exception of one feed pump. The control of the station will be centralized at one point which will materially reduce the operating personnel required. The wall which usually separates the turbine room from the boiler room will be omitted in order to allow the control operators a greater range of vision.

Fig. 2 shows a plan and Fig. 3 a cross section of the first section of the Holland Station.

Construction work on the station is progressing rapidly. The intake and discharge tunnels and all foundations and part of the building have been completed.

It is expected that the station will go into operation about October, 1929.

STATEMENT BY THE UNITED GAS IMPROVEMENT CO., PHILADELPHIA, PA.

Deepwater Plant

As noted in the 1927-28 Report of the Subcommittee on Higher Steam Pressure and Temperatures (N. E. L. A. Publication No. 278-53) there is being built jointly for the United Gas Improvement Company and the American Gas & Electric Company at Deepwater, N. J., on the Delaware River, a plant to operate at approximately 1200-lb. pressure. This plant is now under construction and is expected to be ready for operation in November, 1929.

The principal items of equipment to be installed in this plant are:

Two 53,000-kw. General Electric cross compound turbo-generator units, each set consisting of one 12,500-kw., 80 per cent power factor, 3600 r.p.m., high-pressure element, and one 41,700-kw., 85 per cent power factor low-pressure element, each generator having its own direct connected exciter. The low-pressure element of each unit is served by a 42,500 sq. ft. Foster Wheeler single-pass surface condenser.

One 12,500-kw. General Electric high-pressure unit, similar to the high-pressure element described above, for furnishing steam to the adjacent plant of the Dupont Company.

Four Standard steam-generating units, each capable of producing 331,000 lb. of steam per hour at a total temperature of 725 deg. fahr. and a nominal gage pressure of 1200 lb., and consisting of:

One 9000 sq. ft. Babcock & Wilcox boiler; one 18,326 sq. ft. Babcock & Wilcox economizer; one 46,600 sq. ft. Foster Wheeler air preheater.

Two reheat units each capable of generating at maximum capacity 290,000 lb. of steam per hour and consisting of:

One 9000 sq. ft. Babcock & Wilcox boiler; one 25,155 sq. ft. Babcock & Wilcox reheater; one 4765 sq. ft. Babcock & Wilcox economizer; one 52,800 sq. ft. Foster Wheeler air preheater.

The boilers are fired with pulverized fuel, three by the unit system and three by the bin system. Slagging type furnace bottoms will be used.

The three unit system fired boilers will each have 1781 sq. ft., projected area, of bare tube water walls, and 721 sq. ft. of Bailey blocks, while the three bin system fired boilers will each have 1797 sq. ft., projected area, of bare tube water walls, and 342 sq. ft. of Bailey blocks.

The turbines are bled at four points for feed water heating, and the best point turbine room heat rate is estimated to be 9350 B.t.u. per kw-hr., as indicated on the heat balance diagram, Fig. 4.

Fig. 5 and 6 show views of the Deepwater boilers

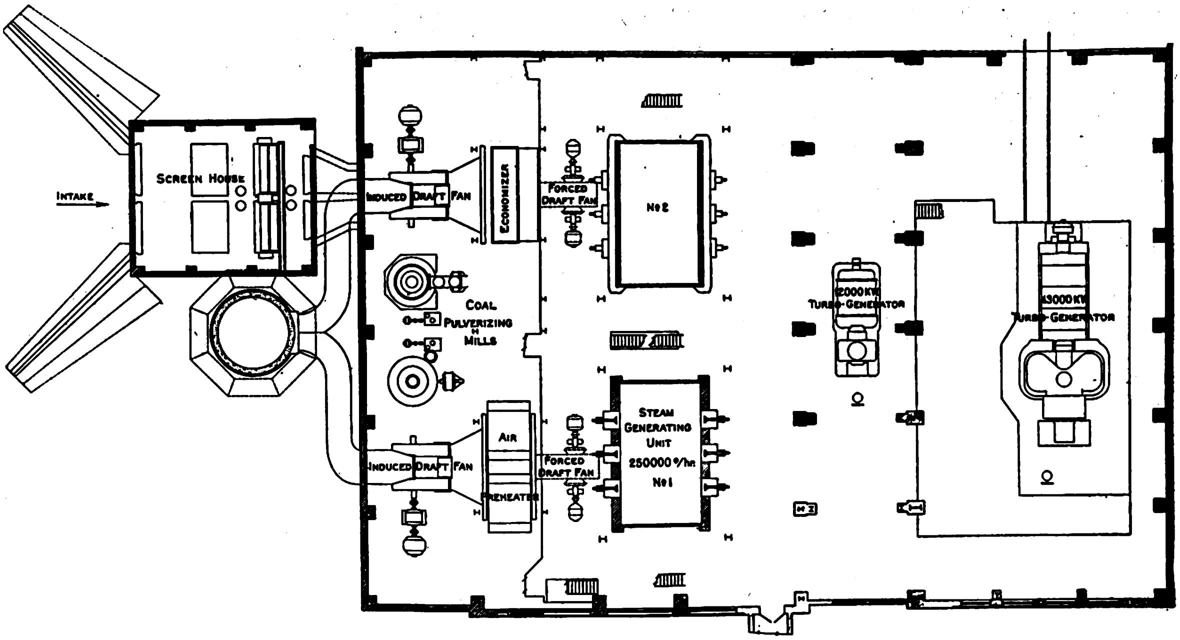

SCREEN HOUSE
INTAKE
INDUCED DRAFT FAN
ECONOMIZER
FORCED DRAFT FAN
No 2
COAL PULVERIZING MILLS
12000 KW TURBO-GENERATOR
43000 KW TURBO-GENERATOR
AIR PREHEATER
INDUCED DRAFT FAN
FORCED DRAFT FAN
STEAM GENERATING UNIT 250000 #/hr No 1

FIG. 2—PLAN VIEW, FIRST SECTION OF HOLLAND STATION.

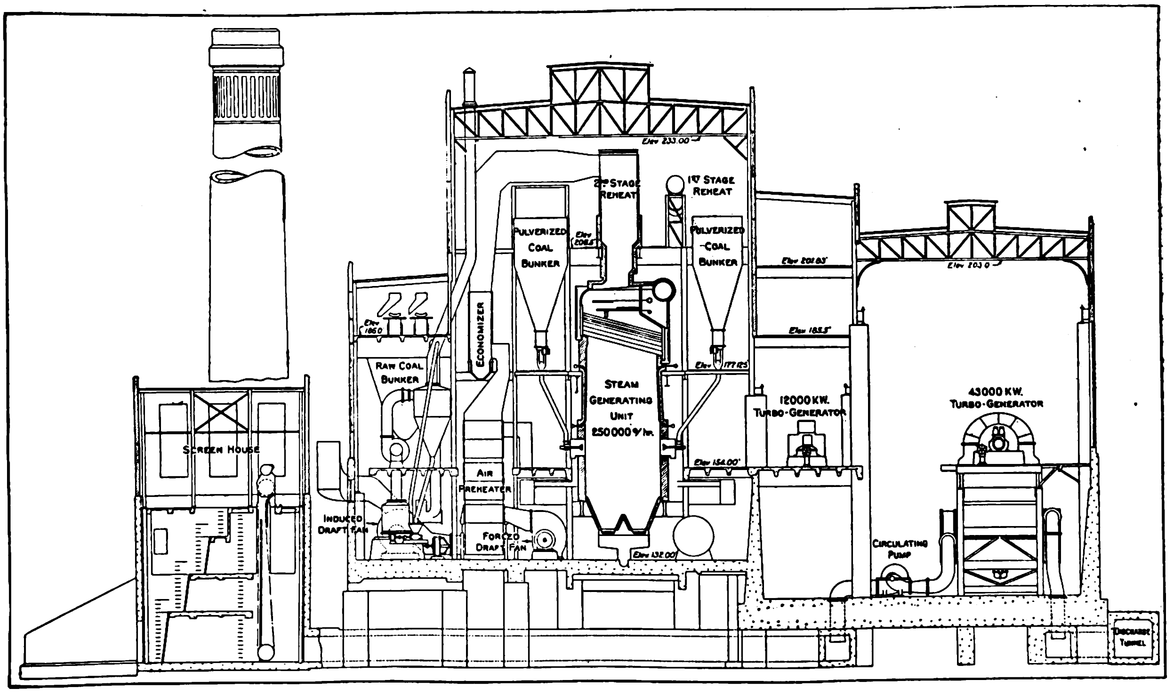
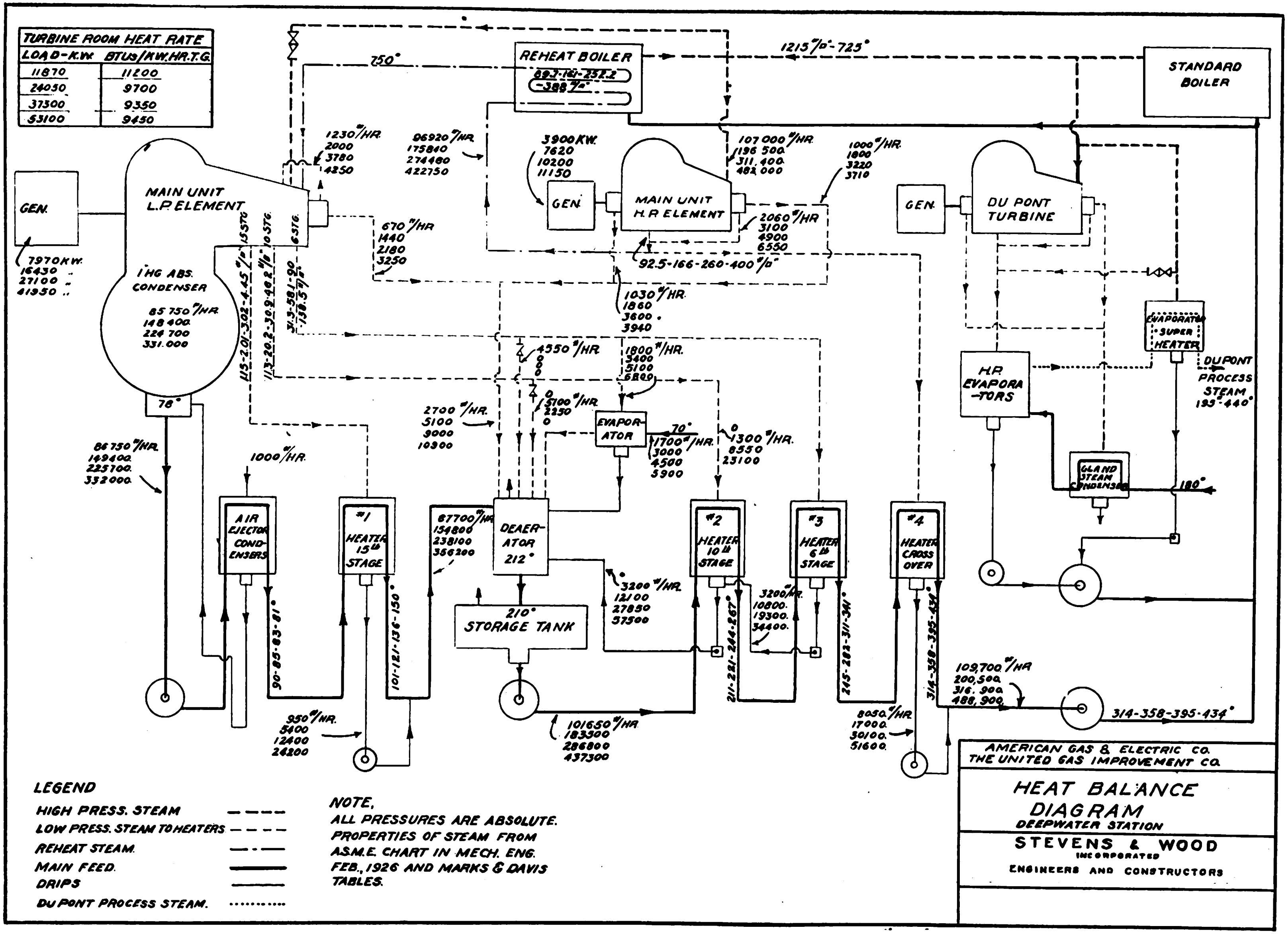

Elev 233.00
2nd STAGE REHEAT
1st STAGE REHEAT
PULVERIZED COAL BUNKER
Elev 208.5
PULVERIZED COAL BUNKER
Elev 201.83
Elev 203.0
Elev 186.0
RAW COAL BUNKER
ECONOMIZER
Elev 185.5
Elev 177.125
STEAM GENERATING UNIT 250000 #/hr.
12000 KW. TURBO-GENERATOR
43000 KW. TURBO-GENERATOR
SCREEN HOUSE
Elev 154.00
AIR PREHEATER
INDUCED DRAFT FAN
FORCED DRAFT FAN
Elev 132.00
CIRCULATING PUMP
DISCHARGE TUNNEL

FIG. 3—CROSS SECTION VIEW, FIRST SECTION OF HOLLAND STATION.



TURBINE ROOM HEAT RATE	
LOAD-K.W.	BTUS/KW.HR.T.G.
11870	11200
24050	9700
37300	9350
53100	9450

GEN.
7970 KW.
16430 "
27100 "
41950 "
MAIN UNIT
L.P. ELEMENT
1"HG ABS.
CONDENSER
85 750 #/HR
148 400
224 700
331.000
78°
86 750 #/HR.
149400
225700
332000
15 STG.
10 STG.
6 STG.
115-201-302-445 #/□
113-20.2-30.9-40.2 #/□
31.3-58.1-90-138.5 #/□
1230 #/HR.
2000
3780
4250
750°
670 #/HR
1440
2180
3250
REHEAT BOILER
893-161-252.2-388 #/□°
96920 #/HR.
175840
274480
422750
3900 KW.
7620
10200
11150
GEN.
MAIN UNIT
H.P. ELEMENT
107 000 #/HR.
196 500
311,400
482,000
2060 #/HR
3100
4900
6550
92.5-166-260-400 #/□
1000 #/HR.
1800
3220
3710
1030 #/HR.
1860
3600
3940
1215 #/□-725°
STANDARD
BOILER
GEN.
DU PONT
TURBINE
EVAPORATOR
SUPER
HEATER
DU PONT
PROCESS
STEAM
193-440°
H.P.
EVAPORA-
-TORS
GLAND
STEAM
CONDENSER
180°
4550 #/HR
0
0
0
1800 #/HR.
3400
5100
6800
0
5100 #/HR.
2250
0
2700 #/HR.
5100
9000
10900
EVAPOR-
ATOR
70°
1700 #/HR.
3000
4500
5900
0
1300 #/HR.
8550
23100
1000 #/HR.
AIR
EJECTOR
COND-
ENSERS
90-85-83-81°
950 #/HR.
5400
12400
24200
#1
HEATER
15th
STAGE
101-121-136-150°
87700 #/HR
154800
238100
356200
DEAER-
ATOR
212°
210°
STORAGE TANK
3200 #/HR.
12100
27850
57500
101650 #/HR.
183300
286800
437300
#2
HEATER
10th
STAGE
211-221-244-267°
3200 #/HR.
10800.
19300.
34400.
#3
HEATER
6th
STAGE
245-282-311-341°
#4
HEATER
CROSS
OVER
314-358-395-434°
8050 #/HR.
17000.
30100.
51600.
109,700 #/HR
200,500
316,900
488,900
314-358-395-434°
LEGEND
HIGH PRESS. STEAM — — —
LOW PRESS. STEAM TO HEATERS - - - -
REHEAT STEAM —·—
MAIN FEED ━━━
DRIPS ———
DU PONT PROCESS STEAM ....
NOTE,
ALL PRESSURES ARE ABSOLUTE.
PROPERTIES OF STEAM FROM
A.S.M.E. CHART IN MECH. ENG.
FEB., 1926 AND MARKS & DAVIS
TABLES.
AMERICAN GAS & ELECTRIC CO.
THE UNITED GAS IMPROVEMENT CO.
HEAT BALANCE
DIAGRAM
DEEPWATER STATION
STEVENS & WOOD
INCORPORATED
ENGINEERS AND CONSTRUCTORS

FIG. 4—HEAT BALANCE DIAGRAM, DEEPWATER STATION.

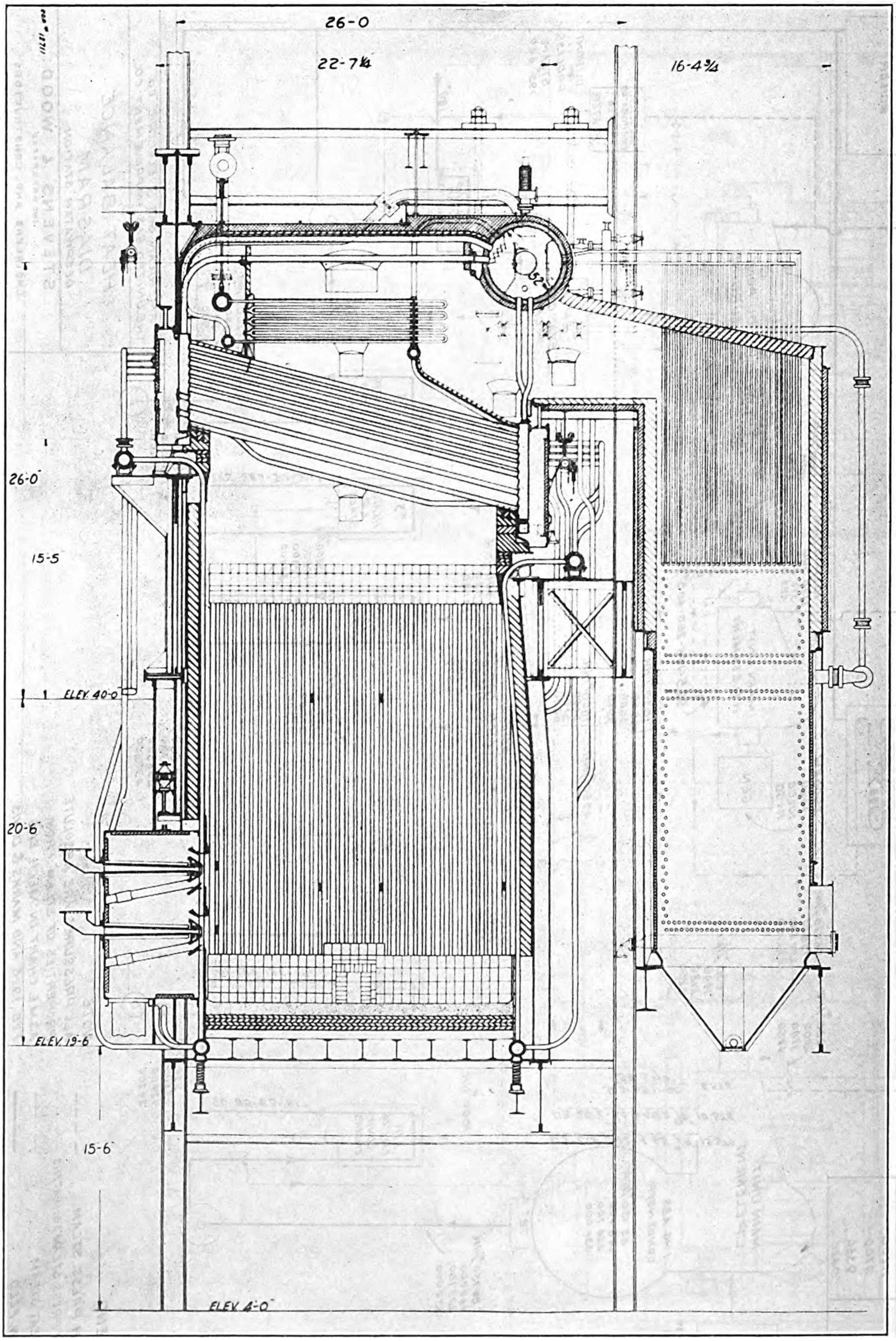

26-0
22-7¼
16-4¾
26-0'
15-5
ELEV 40-0
20-6
ELEV 19-6
15-6
ELEV 4-0

FIG. 5—SECTION VIEW, B & W 1400-LB. STANDARD BOILER, DEEPWATER STATION.

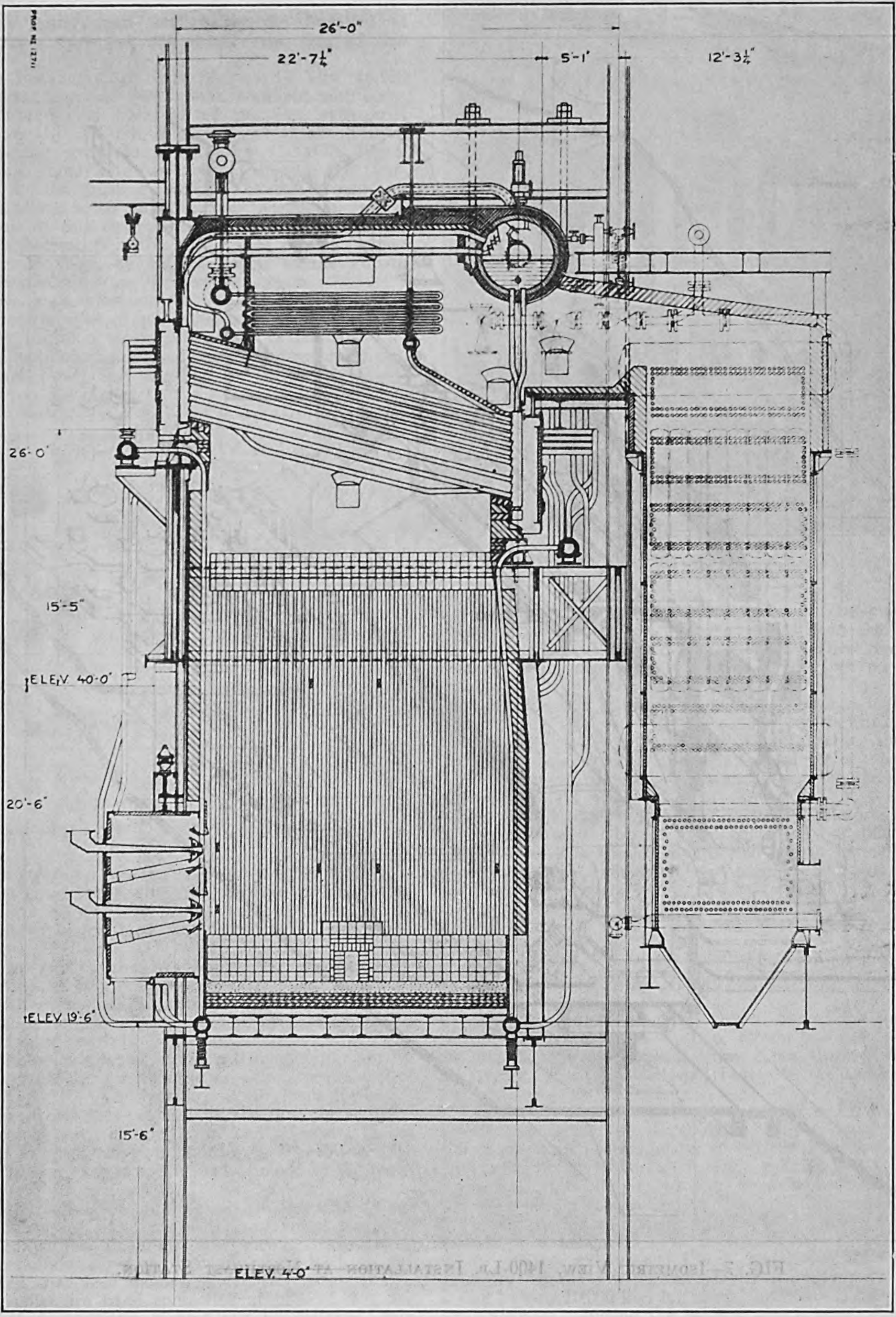

26'-0"
22'-7¼"
5'-1"
12'-3¼"
26'-0"
15'-5"
ELEV 40'-0"
20'-6"
ELEV 19'-6"
15'-6"
ELEV 4'-0"

FIG. 6—SECTION VIEW, B & W 1400-LB. REHEAT BOILER, DEEPWATER STATION.

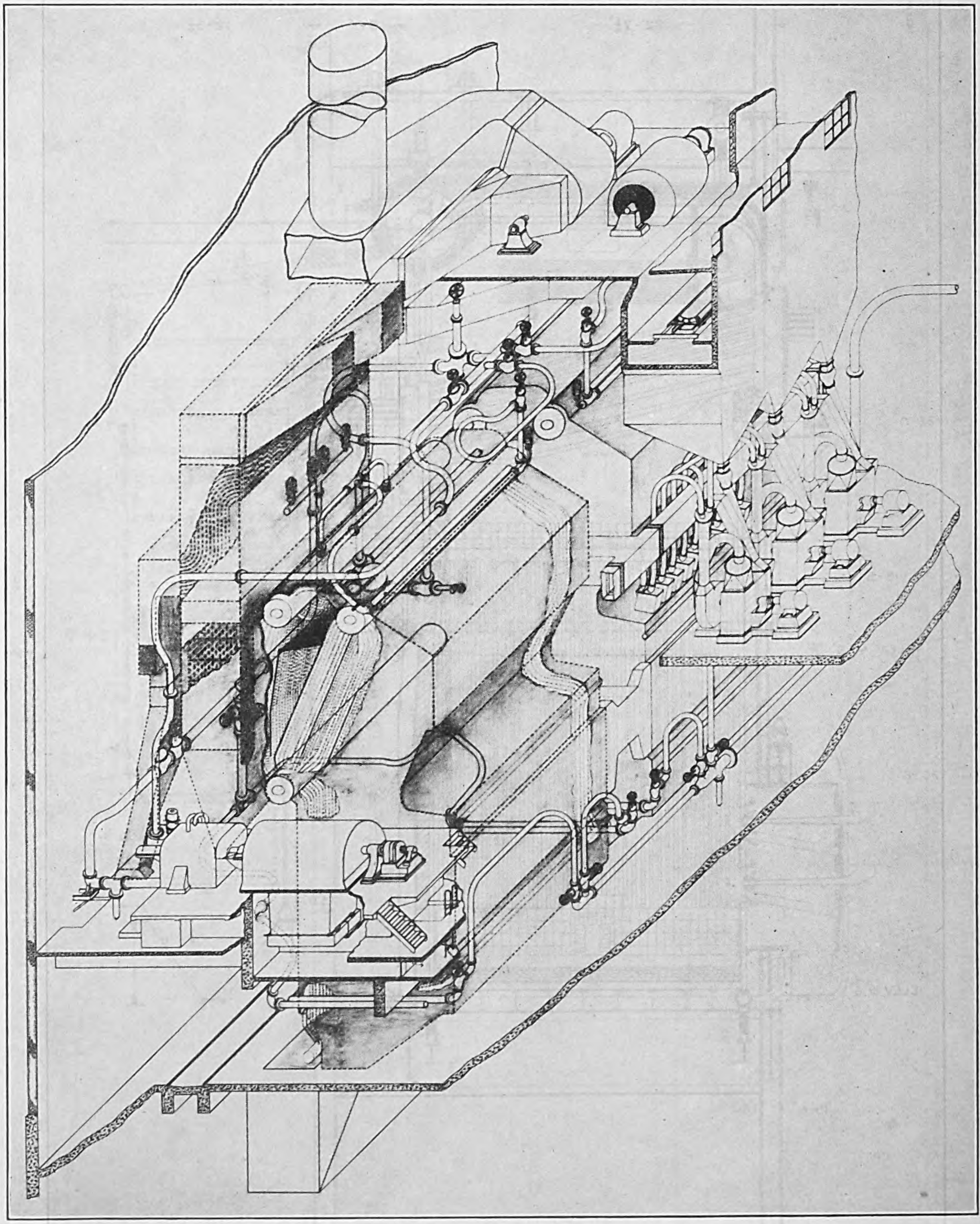


FIG. 7—ISOMETRIC VIEW, 1400-LB. INSTALLATION AT NORTHEAST STATION.

STATEMENT BY THE KANSAS CITY POWER & LIGHT COMPANY

Northeast Station

The 1400-lb. boilers and turbine recently installed at Northeast Station were put into service the first of this year.

Briefly, the installation consists of two 1400-lb., 16,950 sq. ft., three-drum Sterling type boilers, equipped with economizers, air heaters and water-cooled furnaces, each fired directly by three No. 90 unit Imp mills, of 45,000 lb. total capacity, supplying steam to a 10,000-kw., 1200-lb. Westinghouse turbine, comprising two rows of impulse and fourteen rows of reaction blading, which exhausts through reheaters in the above boiler side walls to the 300-lb. station header. Details of this equipment will be found under the manufacturer's statements in this report, and also in a paper presented Feb. 15, 1929, by Edwin Jowett at the Fourth Midwestern Engineering and Power Exposition.

Fig. 31 shows a cross section through the boiler unit, and Fig. 7 an isometric view of the boiler and turbine installation, indicating the close proximity of the boilers and turbine, which simplified piping and reduced pressure drops.

A condensate flow diagram, Fig. 8, shows the high-pressure boilers receive feed water from a surge tank supplied with condensate only, the system make-up going into the surge tank supplying the 300-lb. boilers. This should help to minimize boiler feed water trouble in the high-pressure boilers.

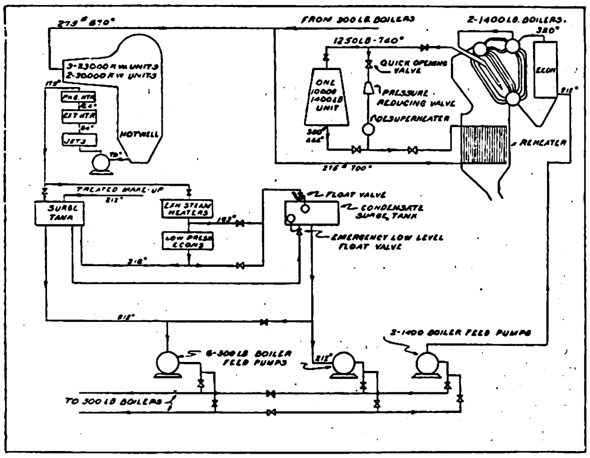


FIG. 8—CONDENSATE FLOW DIAGRAM, NORTHEAST STATION.

Fig. 9 shows one of the two boiler control boards on which are mounted the controls for the pulverized coal mills, the coal feed motors, fans and damper controls; also the boiler header, reheater, quick opening by-pass and pressure reducing valve controls.

Normally the quick opening valve will open automatically if the high-pressure turbine throttle or generator unbalance protective relays trip. This permits steam from the high-pressure boilers to by-pass the turbine and flow through the pressure reducing valve desuperheater and reheaters to the 300-lb. header, thereby supplying steam to the 300-lb. turbines, enabling them to pick up the load dropped by the high-pressure unit.

The control boards also contain electrical temperature recorders, indicating the gas, feed water and steam temperatures, together with a steam-air flow meter, draft gages, pressure gages and ammeters, indicating the load on the mills, fans and coal feed motors.

The boiler units are hand controlled at present, but are so arranged that automatic control can be installed at a later date if deemed advisable.

The completion of this installation has been retarded due to numerous delays in the manufacturing and delivering of equipment, and at the time of making this report they have only had several preliminary runs. The chief difficulty encountered during these runs has been the blowing out of a number of soft fiber gaskets. These have been replaced with metal gaskets which have given no further trouble.

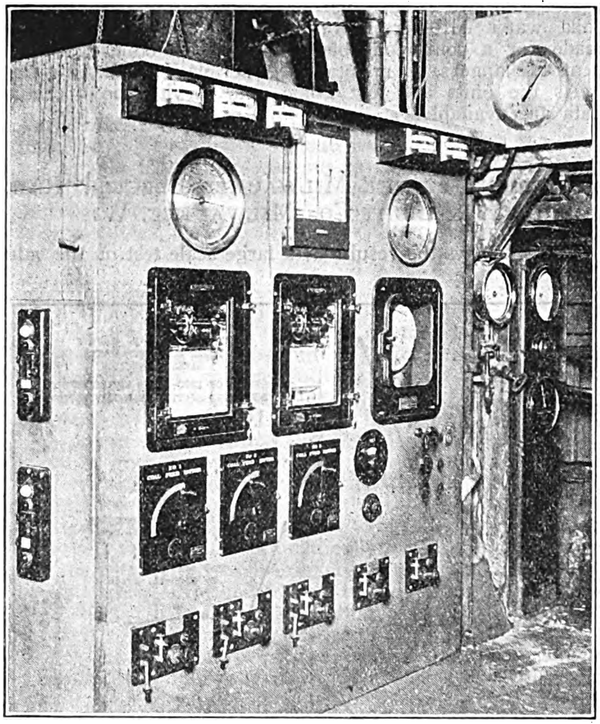


FIG. 9—BOILER CONTROL BOARD, NORTHEAST STATION.

Some tube roll leakage has been experienced in the bottom drums. This was attributed chiefly to the difference in temperature created by the feed water entering the lower drum and being fed up through the last four tube banks. The method of feed will be changed to enter the top rear drum.

The installation of the feed water regulators has not been completed as yet, but hand control is not difficult, and while the units are more complicated than a standard boiler unit, no serious difficulties have been encountered in their operation to date.

Only preliminary performance data have been taken at this time, which is not complete or reliable enough for publication.

Grand Avenue Station

At the time of writing this report, one of the three new 700-lb. boilers at Grand Avenue Station has just completed its first preliminary run, delivering steam through the pressure reducing valve and desuperheater to the 185-lb. station header.

Briefly this installation consists of three 700-lb., 15,160-sq. ft. Sterling type, three-drum boilers, equipped with economizers, air heaters, water-cooled furnaces, Green forced draft chain grate stoker, 24 ft. wide x 22 ft. long, delivering normally 150,000 lb. of 740 deg. steam to a 10,000-kw., 80-per cent power factor General Electric Co. turbine.

Details of this equipment will be found under the manufacturer's statements.

This turbine exhausts at 185 lb. and about 125 deg. fahr. superheat to the low-pressure boiler header which supplies steam to two 10,000-kw. horizontal and two 15,000-kw. vertical turbines. During the heating season part of this 185-lb. steam will be used in carrying the commercial steam heating load, none of this condensate being returned to the system.

Because of the large amount of make-up during the heating season, two 28,000-g.p.h. Cochrane hot process lime and soda water softeners have been installed, and provisions made for a continuous blowdown of the boilers, through heat exchangers, to maintain the permissible concentration.

As the units are just going into service, no operating data are available.

STATEMENT BY THE MILWAUKEE ELECTRIC RAILWAY & LIGHT CO., MILWAUKEE, WIS.

Fig. 10 shows the results of a large scale test on the value of high-pressure equipment installed in a 300-lb. pressure station. Overall station heat consumption is reported for successive months under following conditions:

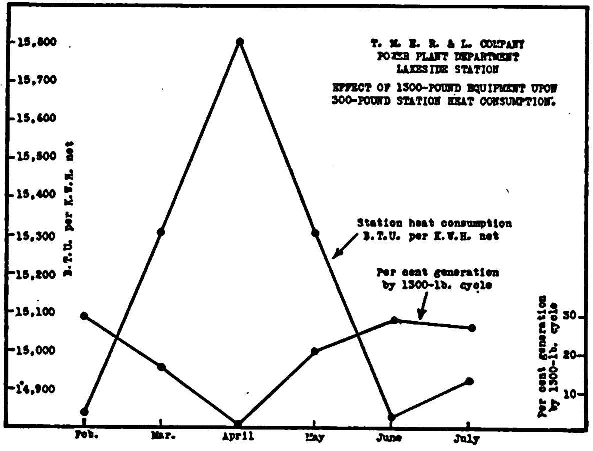


FIG. 10—EFFECT OF 1300-LB. EQUIPMENT UPON HEAT CONSUMPTION, LAKESIDE STATION.

Month No. 1—1300-lb. equipment in continuous operation with 300-lb. equipment.
Month No. 2—1300-lb. equipment in operation with 300-lb. equipment half of month.
Month No. 3—Only 300-lb. equipment operating.
Month No. 4—1300-lb. equipment in operation with 300-lb. equipment half of month.
Month No. 5—1300-lb. equipment in continuous operation with 300-lb. equipment.

Results are shown by the curve, Fig. 10, and other significant data are given in Table I.

The actual station economy data would indicate approximately 20 per cent better efficiency with the 1300-lb. equipment than the 300-lb. equipment. With outage of the high-pressure turbine, the 300-lb. equipment is handicapped slightly by operation of the high-pressure boiler throttling its steam to 300 lb. Other calculations show the difference in efficiency to be 16 per cent.

TABLE I

EFFECT OF HIGH-PRESSURE EQUIPMENT ON LAKESIDE STATION EFFICIENCY

1 Month, 1928	Feb.	March	April	May	June	July
2 Days operation of h.p. turbine	29	16	0	19	28	29
3 Per cent station output gen. by h.p. turbine	6.72	3.74	0	4.66	6.45	6.13
4 Per cent station output gen. by h.p. cycle	29	16	0	20	28	27
5 Overall station heat consumption, B.t.u. per kw-hr.	14,844	15,310	15,812	15,306	14,831	14,932
6 Per cent lower heat consumption than April	6.1	3.2	......	3.2	6.2	5.6
7 Apparent higher efficiency 6o h.p. cycle (No. 4 No. /f100)	21	20	....	16	22	20

The two months' turbine outage was occasioned by a warped shaft resulting from the use of highly efficient but unreliable interstage packings. Since installing standard seals operating continuity has been as shown in the first column. Yearly data are given in the second column:

Period	May to Dec., Incl., 1928	Year 1928
Elapsed hours	5,880	8,761
Boiler hours	5,035	6,945
Boiler use factor	86	79.4
Turbine hours	4,785.2	5,993.6
Turbine output, million kw-hr.	30.97	39.23
Turbine use factor	81	68
Turbine load factor	75	64.5

During the eight months' period from May to December, the boiler was opened once, in September, for an inspection.

The year's run verifies the reliability and economy of 1300-lb. equipment.

Details of Operating Experiences

The method of feed water control has been proved adequate to allow indefinite operation of the boiler unit without internal cleaning. Raw water make-up has averaged 0.2 per cent over the entire operating period since new, and occasionally condenser leakage of 0.5 per cent has been encountered over a week's operation. On one occasion, 2 per cent condenser leakage was treated successfully for a short period. Chemical treatment is based upon the amount of raw water passing into the boiler, and final results are the same, provided treatment and blowdown are proportional to the raw water make-up.

The 1200-lb. pressure turbine has not been affected in capacity nor efficiency since the original elimination of deposits on the blading. It is carrying its full rated capacity of 7000 kw.

The high-pressure boiler feed pumps have not proved entirely satisfactory. They increased boiler feed water pressure from 300 to 1400 lb. The water temperature is 330 deg. fahr. Thrust troubles have so affected interstage clearances that leakage has gradually increased and requires periodic maintenance of the interstage labyrinths. New type thrust bearings are being furnished by the manufacturer. Erosion of the bronze impellers has prompted installation of steel ones.

High-pressure extraction heater tubes have gradually become eroded at the entrance ends where the water temperature is 300 deg. fahr. or above. There have been failures of several individual tubes due to lack of uniformity in grain structure. It appears that use of tubes made from special metals, in cases where pressures above 300 lb. and temperatures of 300 deg. fahr. occur, is warranted.

The high-pressure equipment has necessarily carried its full quotation of station load over the recent winters, and from all standpoints has proved its commercial value. A second boiler unit has been purchased, and plans for the quite near future contemplate installation of two more boilers and attendant high-pressure turbines.

STATEMENT BY THE EDISON ELECTRIC ILLUMINATING CO. OF BOSTON

The information contained in this statement applies only to the new higher-pressure equipment contained in the recent addition to the Edgar Station, except where specifically noted. The new equipment consists of two 1400-lb. boilers with integral reheaters, one 10,000-kw. 1200-lb. turbine, two 500-lb. and three 1600-lb. boiler feed pumps.

Operating Experiences

Boilers

The load factor on these boilers has been approximately 40 per cent since installation; the limiting factors which are gradually being eliminated are excessive burning and breakage of stoker parts and the bursting of superheater and water wall tubes due to poor circulation. The performance of the firing equipment has generally been unsatisfactory. The boilers have never been taken off the line because of feed water conditions or treatment. Aside from some gasket trouble experienced at the start due to poor workmanship, the economizers have given practically no trouble. Until our stokers are free of trouble we are using our automatic boiler control only for pressure regulation. To date (Feb. 9, 1929), the longest continuous run including banked hours of one boiler is 170 hr. and the other 459 hr.

Boiler maintenance has required the following tube replacements in the two units during the first year of service:

Boilers—4—(bagged)
Superheaters—8—(7 due to poor steam distribution)
Economizers—None
Reheaters—None
Water walls—55—(two burst, 53 in poor condition)

The replacement of tubes is no more difficult in high-pressure boilers and takes practically no more time than in lower-pressure boilers. The metals used in the tubes are apparently satisfactory as regards both durability and suitability. The only failures have been caused by poor circulation and steam distribution. The manufacturers have taken steps to prevent the recurrence of these troubles.

The safety valves on the high-pressure boilers have shown the same degree of tightness as those on the lower-pressure boilers.

It has not been noted in operation that higher-pressure causes any ineffectiveness in heat saving devices.

The designed pressure drops and steam velocities are given in Table II.

TABLE II

DESIGNED PRESSURE DROPS AND VELOCITIES FOR EDGAR STATION 1400-LB. UNITS

Steam flow, lb. per hr........	125,000	150,000	175,000	200,000	225,000
Superheater drop, lb. per sq. in.	13	18	25	32	40
Reheater drop, lb. per sq. in...	1.0	1.4	1.9	2.4	3.0
Steam velocity in superheater tubes, ft. per sec..........	13.5	16.2	18.9	21.6	24.3
Steam velocity in reheater tubes, ft. per sec...........	12.6	15.1	17.6	20.1	22.6

Feed Pumps

The boiler feed pressure cycle for normal operation is broken at 500 lb., motor driven primary pumping units in duplicate raising the pressure to this point where water is either fed to the older boilers or to the secondary pumping units (also in duplicate) which discharge at 1600 lb. The primary units take their suction from the deaerator at approximately 260 deg. fahr. A steam driven emergency 1600-lb. pump is installed which is designed to take water at low heads and at temperatures up to 260 deg. fahr.

Various types of packing have been tried with inconsistent results, the same type of packing giving both long and short life under identical operating conditions. High water temperatures have caused packing failure after satisfactory operation at a lower temperature. The pumps have been packed about every two weeks when repaired for other reasons. The casings have shown but one leak which was repaired by peening.

The hydraulic balancing disks have given considerable trouble due to rapid wear. The original ball thrust bearings have been replaced with Kingsbury thrust bearings. The pumps are now balanced by hydraulic balancing drums in place of the balancing disks.

The proposed design of the completed station is such that a loss of one of the two pumps now installed, which would then be supplying eight higher-pressure boilers, will be permitted without a reduction of boiler capacity, if the emergency steam pump is used.

The driving motors and turbine have given practically no trouble. The 3600 r.p.m. motor in the initial installation threw oil and recently had to be repaired because of a ground in the slip ring leads.

Because of the frequent opening of the 1600-lb. pumps, no regular routine internal inspections have been made. Parts have been renewed frequently in these pumps. The impellers have shown no undue wear.

The new higher pressure pumps have not yet been tested. The original high-pressure pump was low on discharge pressure and efficiency, but the newer pumps have apparently maintained their original discharge pressures and capacities.

Turbines

Since the start of commercial operation, the 10,000 kw. high-pressure turbine has run in perfect balance, giving no vibration trouble, and has suffered no loss of capacity. The original high-pressure turbine has increased its water rate 20 per cent and reduced its capacity accordingly. The new high-pressure machine has been satisfactory from the standpoint of governor performance, thrust bearing service, and performance of both interstage and external packings. Although the steam by-pass with the new turbine is designed for manual and steam pressure controlled operation, it is arranged to function automatically when the turbine trips out until the third high-pressure turbine and other boilers are installed. Normally the reheat is manually controlled by a damper in the reheater setting that varies the gas flow through the reheater. A desuperheater is also provided to reduce the temperature of the steam entering the reheater when the turbine by-pass is in use or the turbine is carrying low loads. Because of pump troubles the high-pressure turbine exhaust extraction heater has been used very little; hence, no report can be made on its performance.

The longest continuous run of the new high-pressure turbine to date (Feb. 9, 1929), is 172 hr. Although the turbine could have been run almost indefinitely, a longer run was not made because of low steam load on the station.

The 10,000 kw. turbine has not been opened for internal inspection since the start of commercial operation. After a few hours of preliminary operation, one bucket was missing from the 16th wheel and another cracked. The 13th, 14th, 15th and 16th wheels were rebuilt with buckets of a heavier design. A conventional type of steam strainer is used. The turbine shaft has shown no undue deflection. The machine is not multivalved for partial load economy.

The original higher pressure turbine has shown considerable corrosion of lower stage buckets, but no erosion. Considerable "carry-over" from the boiler has been deposited on the blades and nozzles of this machine, which may account for the increased water rate mentioned above.

Design Features

Boiler

The boiler tubes are in two banks, with the superheater between them and the reheater above the top bank. The lower bank tubes are 3¼ in. O.D., 11/32 in. thick, hot finished seamless steel. The two lower rows of this bank form a slag screen and are spaced vertically above each other 12 in. on center. The upper row is spaced 12 in. below the lowest row of the six upper rows of the lower bank. These six upper rows are staggered and spaced 8¼ in. on centers. The tubes in the upper bank are 2 in. O.D., No. 4 B.W.G. hot finished seamless steel.

The boiler drum is 38 ft. 4 in. long, 48 in. I.D., 4⅝ in. thick, of forged steel with heads forged integral with the shell.

The superheater consists of four approximately concentric loops, the ends connected into the upper and lower headers and is arranged for three steam passes. The tubes in the first and second passes are 2 in. O. D., No. 4 B.W.G., "Enduro A," the latter being a heat resisting alloy containing about 17 per cent of chromium. The superheater is designed for a pressure drop of 32 lb. from the boiler drum to the superheater outlet at 200,000 lb. per hr.

In the furnace, the side and rear walls are water cooled (Bailey type) and contain altogether 1235 sq. ft. of surface.

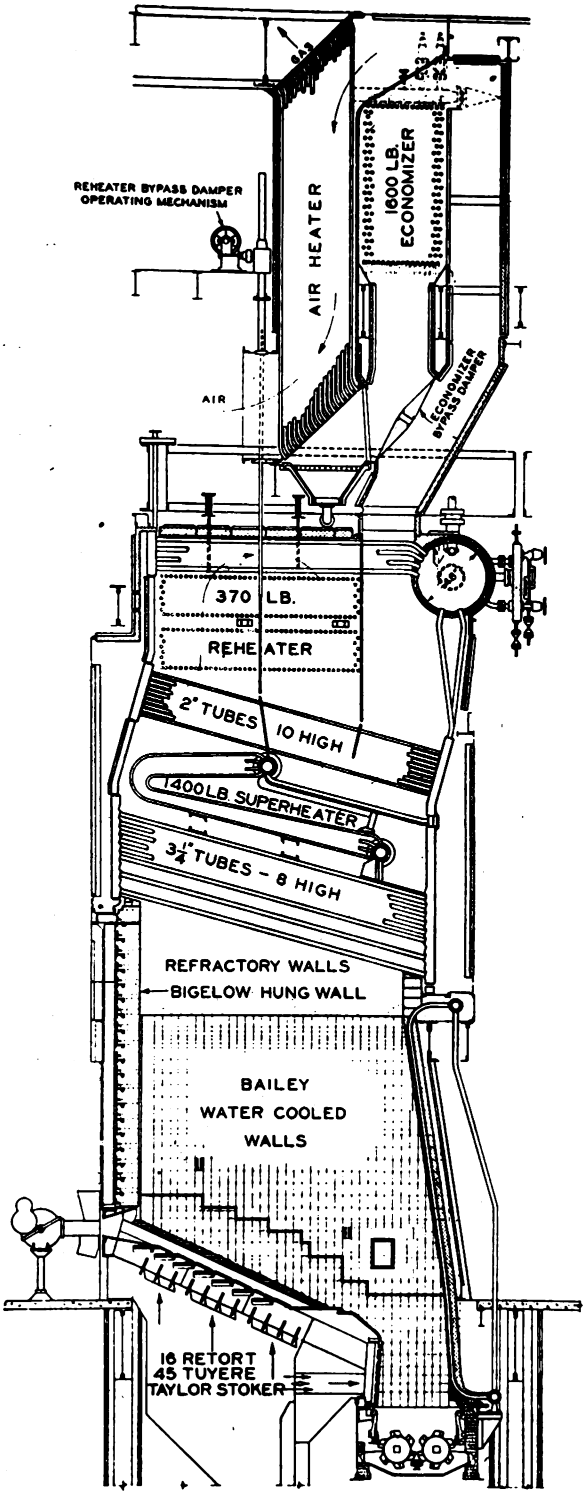


FIG. 11—Cross Section of 15,093-Sq. Ft., 1400-Lb. Boiler, Edgar Station Expansion.

The fuel burned is ordinary run-of-mine New River bituminous.

Turbine

The reheated steam discharges into the common 360-lb. per sq. in. header for the lower-pressure turbines. This arrangement is used for flexibility.

A drop of approximately 10 lb. is expected between the exhaust of the higher-pressure turbine and the throttle of the lower-pressure turbines.

On the lower-pressure machines an improvement of approximately 750 B.t.u. per kw-hr. gross is experienced with extraction operation over non-extraction. The effect of the extraction heater taking steam from the higher-pressure turbine exhaust is to increase the ratio of high pressure turbine output to lower-pressure turbine output with the same heat input to the boilers and consequently to better the station economy. The final temperature by extraction from the lower-pressure turbine is approximately 300 deg. fahr. at full load. A temperature of 420 deg. fahr. is expected with the high pressure turbine exhaust extraction heater in operation. With the exception of the deaerator, which is an open heater, the heaters are all of the closed surface type. No special material was used in the tubes of any of the heaters.

Piping

A flexible arrangement of headers is used, there being a 1300-lb. header, an exhaust reheater header, and a 360-lb. header to supply the lower pressure turbines.

All piping is designed for a flow of approximately 250,000 lb. of steam per hr. per boiler. Velocities of approximately 7500 ft. per min. are reached in the 1400-lb boiler leads and 10,000 ft. per min. in the leads to and from the reheater.

Sargol joints are used for high pressure steam and water piping.

Fig. 11 shows a cross section of the new 1400-lb boiler at Edgar Station.

Statement by the Union Gas & Electric Co., Cincinnati, Ohio

Operating Experiences at Columbia Power Station

Boilers

During the interval between the time the boilers first went into service and January, 1929, the boiler load factors have been as follows:

	Per Cent
Reheat boilers........	54.3
Standard boilers......	41.6 based on maximum boiler output
Standard boilers......	50.1 based on normal rate of operating

The limiting factor of these values has been the system night load. In the case of the standard boilers, the spare boiler capacity has resulted in a value lower than that of the reheat boilers.

With the feed water treatment used it is possible to keep the boilers on the line indefinitely. Make-up water equivalent to 2 per cent of the total steam generated is treated and fed into the system. A cold intermittent softener using lime, ferrous sulphate, and soda ash is used in the treatment of raw Ohio River water. This results in a water of no more than 17 p.p.m. hardness, and 170 p.p.m. total solids. In addition, a value of 50 p.p.m. of sodium phosphate is maintained in the boiler water. By limiting the total boiler water concentration to 1000 p.p.m. by blowdown, satisfactory operating is obtained. No scale is formed and no foaming or priming occurs.

No difficulty has been encountered in maintaining the correct water level in the boiler drums during extreme and rapid changes of the plant load.

It has been difficult to collect data for obtaining the per cent moisture in the steam leaving the boiler drums. Values ranging from 0 to a maximum of 0.3 have been obtained. It has been found that at boiler water concentrations as held in this station, water level and rating have no measurable effect in changing the moisture content of the steam leaving the drums.

Difficulty in maintaining tight joints between the economizer hand-hole caps and headers has been corrected by using 1/16 in. asbestos sheet gaskets on these joints. At the present time, some leakage is developing at the rolled joints of some of the economizer tubes which is causing corrosion at the tube ends. Rerolling the tubes and eliminating tube expansion strains should correct this leakage.

The longest continuous turbine run has been for 54 days, while rebuilding the second turbine from a 45,000 kw. tandem compound unit to a cross compound unit of 63,000 kw. capacity. During this same period, the reheat boiler for the turbine operating had a continuous run of 26 days. It was taken off the line due to an economizer tube leak.

Boiler Maintenance

Since initial plant operation in January, 1926, five boiler tubes have been replaced. Three of the failures were due to steam cutting from a leak in a superheater tube. Tube replacements in the 600-lb. boilers have not been greater than in 250-lb. boilers. While it takes more time to roll a tube in a 600-lb. boiler, the total time for replacing a tube is practically the same as the time required for replacing a tube in a 250-lb boiler, due to the factors of accessibility and smaller diameter tubes.

The operating experience to date has indicated that the tube material for economizers, boilers, and superheaters has been satisfactory.

The boiler and superheater safety valves have given entire satisfaction. Since the plant has started operation, the station load has suddenly dropped sufficiently on three different occasions to make all the safety valves operate. After each operation, the valves seated properly without leakage.

Feed Pumps

Motor driven boiler feed pumps are installed for normal operation and two steam driven pumps are installed for reserve. The station was designed for the operation of the motor driven pumps. These are single cylinder, six stage pumps operating against a head of 750 lb.

The pump thrust bearings have been satisfactory. The pumps are hydraulically balanced and proper pump operation is checked by a pressure gage installed in the leak-off of the pump discharge end-balancing chamber. If the pressure in this chamber indicates values above normal due to interstage leakage, the pump is unbalanced and it is taken out of service for inspection and repair. The pressure gage reading is an indication of the thrust action of the pump and serves as a safeguard for the bearing.

Each unit has three motor driven pumps, two operating and one reserve. Sufficient pumping capacity therefore is available in case of a pump outage which does not result in a drop of boiler output.

Driving motors and turbines have been entirely satisfactory.

Pump Maintenance

The boiler feed pumps are inspected annually. At this time new packing is installed in the glands. The stage impellers have shown no wear or erosion, and with the exception of packing gland sleeves no parts required renewals.

Turbines

Due to a salt deposit forming on the blades and nozzles of the high-pressure turbines, a loss of capacity of approximately 1200 kw. per week has been experienced. Improved sealing of the boiler drum steam circulating baffles and reducing the maximum total boiler water concentrations have improved this condition very much.

The turbines have operated without vibration, and good performance has been had from operating governors, thrust bearings and packings.

The steam is reheated between the high- and low-pressure cylinders in a separate reheat boiler. No difficulty has been encountered with excessive or insufficient reheat with light loads on the turbine since the rate of firing the reheat boiler is regulated to give the proper reheat temperature. The rate of change of reheat temperature is slow due to the large number of reheater tubes and large steam space, and it is, therefore, possible to obtain very uniform reheat temperatures.

Extraction heater performance has been satisfactory, and results obtained are meeting the guaranteed values.

Turbine Maintenance

Turbine inspections have indicated that no undue erosion is had on turbine blades due to the higher steam density. A number of stages in the exhaust end of the low-pressure turbines were originally bladed with thin-edged blades. Cracks developed in these blades, and they were replaced with ones of greater cross-sectional area and redesigned dovetails.

The blades have been free from the battering action of foreign material passing through the turbines. Two screen strainers are used, one in front of the control valves and the other around the first stage bowl. The screen strainers are made of No. 14 gage wire and are 7 mesh.

STATEMENT BY THE SUPER-POWER CO., PEKIN, ILL.

Powerton Power Plant

The first section of this new 650-lb. plant, a description of which will be found in the 1927-28 Report of the Subcommittee on Pulverized Fuel (N. E. L. A. Publication No. 278-85), went into service in the latter part of 1928.

A duplicate of the above installation, consisting briefly of a 55,000-kw. General Electric turbine and three pulverized coal fired Babcock & Wilcox boilers, one of which is a reheat boiler, has been ordered.

As the equipment has already been described and has just gone into service, no official statement or operating data were obtained.

STATEMENT BY THE STATE LINE GENERATING CO., STATE LINE, IND.

State Line Power Station

The above 600-lb. station is now under construction, the first section consisting briefly of a 208,000-kw. General Electric turbine-generator unit, made up of one 76,000-kw. high-pressure unit and two 66,000-kw. units, so connected that the units can be operated independently if desirable.

A steam reheater will be used between the high-pressure and the low-pressure units.

The boilers are Babcock & Wilcox cross drum, single pass type with the convection superheater set above the boiler tubes.

The furnace is water-cooled by Bailey wall construction and fired by eight Calumet type burners receiving coal from two No. 70 Lehigh pulverizing mills.

A B. & W. steaming economizer and a B. & W. vertical tubular type air heater completes the main part of the unit.

No official statement was obtainable from the operating company.

STATEMENT BY THE ELECTRIC MANAGEMENT & ENGINEERING CORP.

There is being built for the Jersey Central Power & Light Co. at South Amboy, N. J., on the Raritan River, a plant equipped with three 1400-lb. boilers and two turbine units for operation at a throttle pressure of 1250 lb. It is expected that this plant will go into operation in March, 1930.

The principal items of equipment to be installed in this plant are:

2—25,000-kw. G. E. steeple compound turbine generator units, each unit consisting of—
    1—5100 kw., 80 per cent power factor, 3600 r.p.m. high-pressure element, and
    1—19,900 kw., 1800 r.p.m. low-pressure element.

The low-pressure element drives the exciter for both the high-pressure and low-pressure elements. The low-pressure element of each unit is served by

1—20,500-sq. ft. Foster Wheeler, single pass surface condenser.

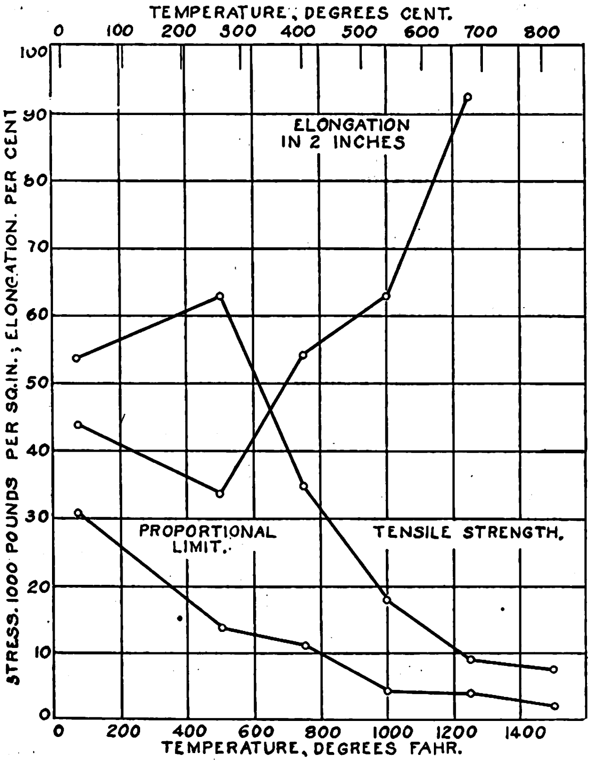


FIG. 12—Properties of 0.13 Carbon Steel at Elevated Temperatures as Determined by Short Time Tensile Tests.

The boiler plant will consist of:

3—Babcock & Wilcox boilers arranged for an output of 250,000 lb. of steam each, with a total temperature of 750 deg. fahr. and a maximum pressure of 1400 lb. The normal gage pressure will be about 1310 lb.

Each boiler is equipped with both a gas and a live steam reheater. The heating surfaces are as follows:

	Sq. Ft.
Boiler	7,250
Primary superheater	5,900
Desuperheater	225
Gas reheater	12,900
Steam reheater	2,190
Water walls	2,036
Economizer	4,420
Air heater	32,052

A notable feature in the boiler equipment is a provision for keeping constant initial and constant reheat temperatures. The boilers will be fired with pulverized fuel and equipped with Bailey water walls with slag tapping furnace. The unit system of firing will be installed.

The turbines will be bled at five points, and at the best point the turbine room heat rate is estimated to be from 9280 B.t.u. to 9290 B.t.u. The heat balance calculations have not as yet been completely worked out.

Properties of Metals at Elevated Temperatures

Statement by A. E. White and C. L. Clarke, University of Michigan

The increasing use of metals at temperatures and pressures that were unthought of a few years ago necessitates an understanding of the physical properties of the metals when at elevated temperatures. Even though many investigators have undertaken studies concerning the high-temperature behavior of metals, the field as a whole, due to its vastness, is hardly yet scratched.

Metals used at elevated temperatures may be divided, roughly, into ferrous and non-ferrous groups. The main divisions under the ferrous group are the plain carbon steels and alloy steels, while subdivisions of the non-ferrous group would be non-ferrous metals and non-ferrous alloys. Although both non-ferrous metals and non-ferrous alloys have applications in high-temperature work, their use is rather limited, due to their cost.

Results obtained from both the short-time tensile and long-time creep tests show the limitations of plain carbon steel, especially at temperatures much above 750 deg. fahr. Short-time tensile tests conducted on a 0.13-per cent carbon steel, Fig. 12, show the tensile strength of the steel to fall off rapidly at temperatures above 500 deg. fahr., while the same is true of the proportional limit at temperatures above 750 deg. fahr.

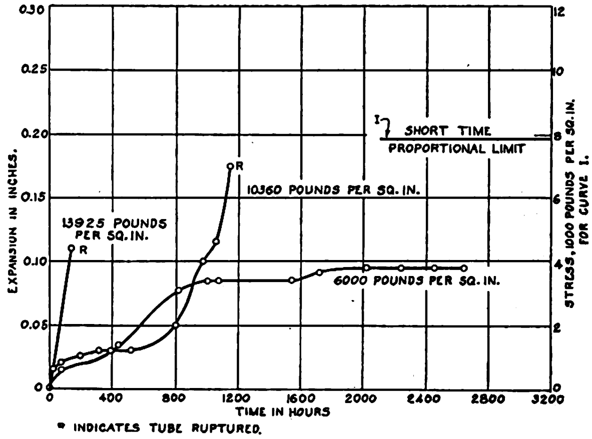


FIG. 13—Expansion Test on 0.38 Carbon Steel at 1000 Deg. Fahr. (538 Deg. Cent.).

Results obtained from expansion tests on a 0.38-per cent carbon steel, Fig. 13, show a stress of 6000 lb. to produce marked deformation over a period of 2500 hr. From these and similar tests, White and Clarke computed the stress to produce rupture of this steel at 1000 deg. fahr. in a period of 100,000 hr. as being 5600 lb. For 0.13 per cent carbon

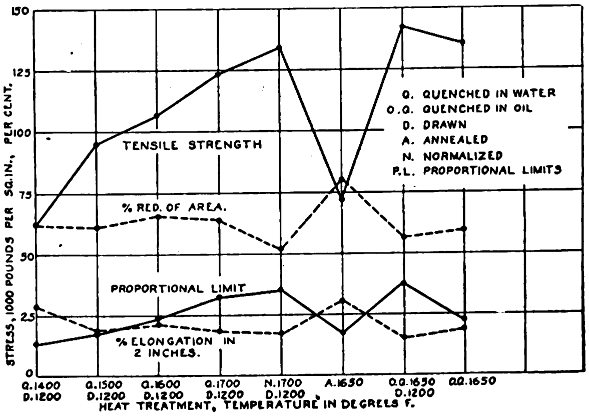


FIG. 14—Effect of Heat Treatment on the Tensile Properties of 0.60 Per Cent C, 1.43 Per Cent Cr., 2.19 Per Cent W Steel at 1000 Deg. Fahr.

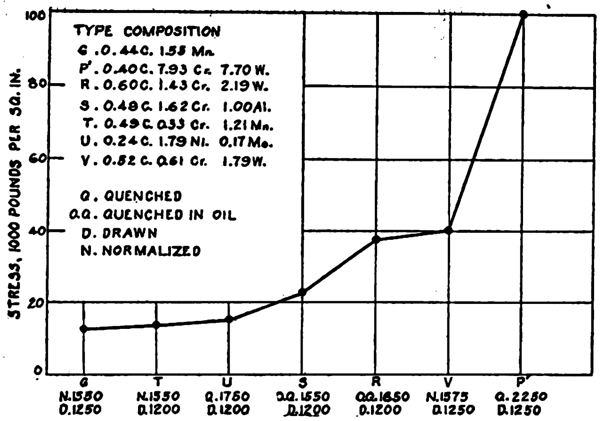


FIG. 15—Maximum Proportional Limit Values Obtained at 1000 Deg. Fahr. (538 Deg. Cent.) with Various Selected Steels.

steel under the same conditions, the necessary stress was found to be 5200 lb. per sq. in.

Since it appears necessary to resort to alloy steels for high-temperature duty, the question is raised as to which of these are the most suitable. Here again the alloying additions must be kept as low as possible, or else the cost becomes prohibitive.

In the author's opinion, the chromium-tungsten steels, to which attention was first directed by Mr. Malcolm, are believed to be among those best suited for high-temperature duty. If the temperatures to be employed are not above 1000 deg. fahr., the steels of this class containing relatively low percentages of these two elements will, if properly heat treated, give satisfactory load-carrying ability.

Short-time proportional-limit values obtained with this steel at 1000 deg. fahr., after various heat treatments, Fig. 14, vary from 17,500 to 40,000 lb. per sq. in. Fig. 15 also shows the chromium-tungsten steels to exhibit the highest proportional-limit values at 1000 deg. fahr. of any of the steels considered.

The results of creep tests conducted upon a steel of this type, Fig. 16, show this steel capable of withstanding relatively large stresses for long periods of time.

Higher Pressures and Temperatures

Statement by C. F. Hirshfeld, The Detroit Edison Co.

In America we have gone about the increase of steam pressure in a perfectly characteristic way. We have assumed that we wanted to take as few steps as possible into the unknown or the untried. Therefore, we have advanced rather slowly, first confining ourselves to pressures which did not involve reheating. Then we advanced to about 600 lb., the lowest pressure which appeared to justify the additional expense of reheating equipment, and finally we advanced to the 1400-lb. region, at which we appear to have halted for the time being. In all cases we have found only slight modifications of existing boiler types to be necessary.

In all of this advance we have been more or less unconsciously guided by the maximum steam temperature that we believe it safe to use, namely a value between 700 and 750 deg. fahr. A very brief study of steam charts will show that the thermal advantage of increasing the initial steam pressure is definitely tied to the assumed maximum steam temperature. At any given assumed initial steam temperature, either with or without reheat, increasing the steam pressure from a low value causes a thermal saving, but the rate of increase of this saving decreases as the pressure rises, until there is finally reached a pressure beyond which improvement is insignificantly small. This point moves up to higher pressures as the assumed initial temperature is increased. We have temporarily halted at about that pressure which corresponds to an optimum value with our presently assumed upper limit of temperature.

Were we now to assume it possible to operate with steam temperatures of the order of, say, 900 deg. fahr., we should obtain new values for the pressures giving optimum results with and without reheating. If we assume as possible 1000 deg. fahr. we should obtain a new set of values, and so on.

In continental Europe the move toward higher pressures has been made along different, but equally characteristic, lines. There the engineers endeavored to analyze in advance all the new factors which might be expected to enter the problem, and to then produce designs which would properly take account of these new factors. They anticipated certain difficulties as the result of such analyses. Briefly, the principal considerations were as follows:

1. As the pressure rises the saturation temperature also rises and, therefore, the temperature of heat trans-

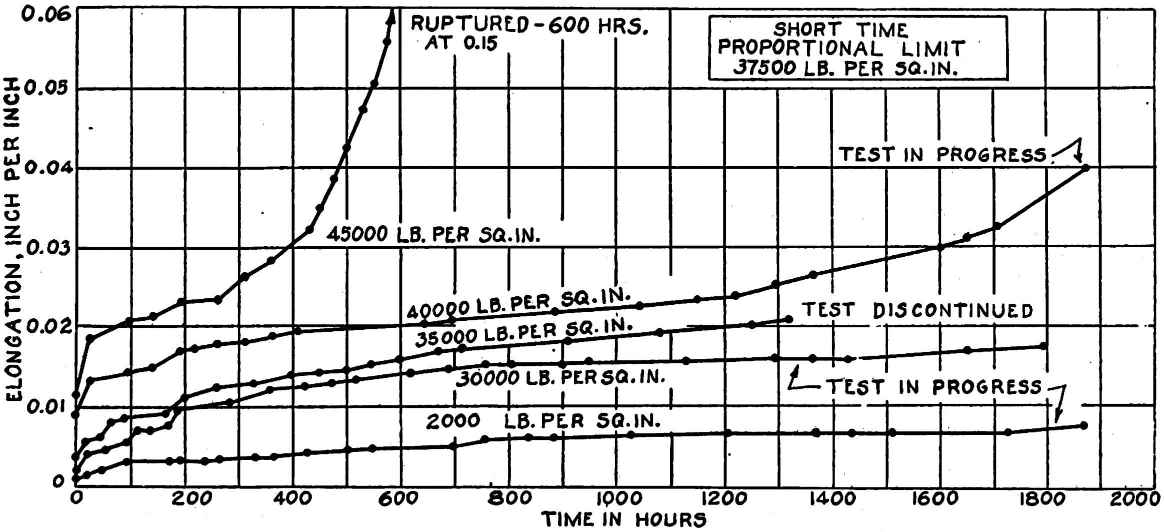


FIG. 16—Flow Tests on 0.6 Per Cent C., 1.43 Per Cent Cr., 2.19 W Steel at 1000 Deg. Fahr. (538 Deg. Cent.).

ferring metal in the boiler also rises. This leads one to anticipate more difficulty in preventing burning of such surfaces, particularly in boilers operating at high rates of output.

2. With the metal thus endangered, a very thin film of scale may be expected to threaten the life of the tube to the same degree as much thicker scale at lower temperatures.
3. As the pressure rises, the specific volume of saturated steam decreases rapidly, and the difference of density of steam and water in the boiler decreases. This threatens the circulation in boilers of the ordinary type in which density differences in different parts cause the "natural" circulation on which we depend.
4. The latent heat of vaporization also decreases as the pressure rises, so that the anticipated decreased rate of circulation is accompanied by a phenomenon which tends to make each pound of water flowing over the heating surface less effective as a heat remover.
5. The chemistry of boiler waters at high pressures and temperatures is practically unknown, so that many unsuspected opportunities for trouble may be hidden in high-pressure boilers of the ordinary type.
6. Finally, the cost of boiler drums of conventional design must increase rapidly unless the diameter is rapidly decreased as the pressure increases. This brings in new problems, both with respect to steam freeing surface and with respect to the thermal storage required to minimize pressure changes during sudden changes of demand for steam.

Some few European designers and builders have gone ahead as we have with more or less conventional types. Others have contemplated this long list of factors of unknown weight and have thought it necessary to design something new. That which they have designed has depended somewhat upon the weight which they respectively assigned to the different factors of doubtful significance.

Thus the inventor of the Atmos Boiler anticipated difficulties in heat transfer between metal and water, difficulties from the small volume of high-pressure steam and difficulties from cost of equipment depending upon the conventional method of heat transfer. So he adopted a rotating boiler tube with provision for most intimate forced contact between water and metal. He also obtained plenty of surface through which the steam might separate itself from the water, and an artificial separation through centrifugal effect as well.

The inventor of the Benson Boiler attempted a unique and striking solution. He made his boiler proper nothing but a water heater without drums or steam space. Just what properties this construction will ultimately be discovered to possess is not yet known. The results on large scale experimental plant lead the present backers of the system to believe it very promising and a direct competitor of comparatively low pressure, say 400 or 500 lb.

The inventor of the Schmidt process adopted a radically different solution. His high-pressure boiler consists of two boilers operating at different pressures. The boiler operating at the higher pressure is filled with distilled water, which never leaves it except through unavoidable leakage. This water is converted into steam and is then condensed in coils immersed in water contained in the lower pressure boiler, the condensate running back automatically to the boiler in which it was made. The distilled water then serves merely as a heat transferring device and protects the surfaces exposed to the fire from the effects of scale deposition. This immunity is purchased at a considerable difference between the pressure at which the steam is made in the high-pressure boiler, and the pressure at which steam is made available for use in the low-pressure boiler.

Since the higher pressure boiler evaporates only distilled water which travels around in a closed circuit, the tubes of which it is composed may be given very small diameter, as it is not expected that they will ever have to be turbined. Also, it makes no difference if this boiler delivers wet steam and drums are not necessary to obtain freeing surface. All parts may, therefore, be made of small diameter and hence low cost.

The lower pressure boiler may consist of a simple, cylindrical shell, big enough to contain the desired quantity of water and the heat transfer coils. It can be so constructed that few or no openings are made in the cylindrical wall and, therefore, it can be made comparatively cheaply, particularly in the case of comparatively long drums.

A locomotive embodying this principal has been constructed for use on the government-owned railroads of Germany and is reported to be giving remarkable thermal economy in comparison with the older types and "without any great increase of first cost."

Loeffler system is still different. In this, steam which has been highly superheated is blown into water in a simple drum and generates saturated steam from that water at the desired pressure. This saturated steam is passed through a separately fired superheater equipped with air preheater and economizer to obtain high efficiency of the combustion part of the cycle and with a regenerator to obtain high efficiency of the prime mover. Part of the steam which is superheated goes to the prime mover, and the remainder is returned to the water-containing drum to keep up the production of saturated steam. It is obvious that steam made in this drum could not be made to flow through the superheater and then return to the drum because of the pressure drop which it would experience. A steam pump of some sort is, therefore, necessary. This pump is inserted in the saturated steam line. It receives the steam made in the drum and pumps it through the superheater.

The characteristics of this system are peculiar. At low steam pressures the required pumping work would be so great as to make the method worse than unprofitable. But, as the pressure rises, the pumping work rapidly becomes a much smaller percentage of the work that can be obtained from the useful steam made. At pressures above about 1500 lb., the system appears to acquire real commercial promise, but the inventor prefers a pressure of about 1800 lb. or higher.

It is self-evident that the heat of superheat is all that is effectively transferred from fire to generated steam. Therefore, a superheater of large size is required, and a high superheat temperature must be used if financial economy is expected. The inventor uses a steam temperature of about 900 deg. fahr. and claims to have had "complete success" with large size experimental equipment.

One familiar with our practice will immediately question the use of 900 deg. fahr., particularly when told that Dr. Loeffler uses the same metal that we use at 750 deg. fahr. temperature. The answer lies merely in a different evaluation of the necessary factors of safety. By this is meant both the factor of safety with regard to unit fiber stress in the metal at normal working temperature and the factor of safety with respect to abnormal operating conditions. It is self-evident that comparatively large economies could be made with present American plant design if we were willing to adopt such temperatures.

Some may feel that a superheater can be built to operate satisfactorily when delivering steam at 900 deg. fahr., but that the prime mover might be expected to give trouble. The Loeffler system presents a ready answer to such, since the steam intended for use in the prime mover could, if desired, be tapped off at an intermediate point in the superheating equipment.

Numerous other evolutionary and revolutionary suggestions and designs have been produced, but those mentioned above appear to have had the most serious practical consideration in Europe. They do not appear to have been given sufficient study in this country, as yet, to enable us to determine what, if any, commercial value they may have under our conditions. If, after such study has been given them, it should develop that they are not promising for use in central power stations, or are definitely not adapatable to such use, it may be discovered that they do open up very desirable possibilities in industrial plants of various sorts. Some of them certainly disclose promising opportunities for very flexible arrangements in connection with old plants, process steam requirements and other considerations of particular interest to many plants of these sorts.

It is thus too early to evaluate these products of a different method of attack. It is not, however, too early to study them in the light of our requirements and to see whether they hold anything of promise or portent to us.

The Relation of Embrittlement to Higher Steam Pressures and Temperatures[1]

STATEMENT BY FREDERICK G. STRAUB, ENGINEERING EXPERIMENT STATION, UNIVERSITY OF ILLINOIS, URBANA, ILL.

Recent data collected from power plants which have experienced embrittlement indicate that the subject of boiler feed water for higher pressure boilers must receive more attention. During the last year extensive cracking has been detected in two plants, operating at 380 and 450-lb. steam pressure. Much cracking has also been found at lower pressures, but these two instances serve to illustrate what will take place at the higher pressures.

One of these plants used a natural sodium carbonate well water low in sulphate content, while the other used a surface water which, when internally treated, resulted in too low a sulphate alkalinity ratio.

Neither of these plants was adhering to the ratio of sulphate to alkalinity as recommended by the A. S. M. E. for 250-lb. pressure. Both plants were having regular analyses made of the boiler waters which showed the ratios to be low.

The higher pressure plant had the boilers crack after two years' operation, while the other operated about three years.

Since investigating these interesting cases of embrittlement, the writer has had occasion to inspect the analyses of a large number of waters from boilers operating at pressures over 400 lb. These analyses indicate that a great many of these plants have not been maintaining the sulphate to alkalinity ratio recommended for 250-lb. pressure. The question is often asked whether the ratio for 250 lb. is protective at higher pressures. It is felt that at higher pressures this ratio should be changed so as to have higher sulphate to alkalinity ratios. The research conducted by the writer has shown that at 500-lb. pressure, a ratio of 2.8 was not protective, while a ratio of 3.6 was. These results were obtained from accelerated laboratory tests and should be considered as minimum protective values. In operating plants, the ratios should be held at values greater than this.

The laboratory tests, in addition to giving the ratio which might be used, also show that, unless the entire desired ratio is maintained, there is no protection. Thus, if spasmodic attempts are made to maintain the desired ratios and only ½ or ⅔ of the desired sulphate is maintained, the boiler is no better protected than if no sulphate were present. Thus ½ of the ratio is no better than none.

It would be well at pressures above 250 lb. to carry the ratio over 3. At pressures around 600 lb., this ratio should be at least 7. This should be a minimum value to be maintained at all times.

Experimental laboratory work has shown that soluble phosphates are effective in preventing embrittlement. The use of phosphate depends upon the ability to maintain sufficient soluble phosphate in the boiler water at all times. Data are being collected from power plants using phosphate for this purpose. These plants are not attempting to maintain the sulphate ratio. Until more definite plant data are available, it would be well to proceed rather slowly in the use of phosphate to prevent embrittlement.

When higher boiler pressures such as 1300 lb. are reached, the danger of embrittlement is eliminated to a large extent through the absence of riveted joints. Certain highly stressed areas such as where the tubes are rolled into the drums might be subject to this trouble. If the joints between the tube and drum are made so as to be tight from the inside and properly vented at the outside, the potential danger should be reduced to a large extent. Practically all boilers operating at these pressures are using evaporated make-up, and if condensers are kept tight they should be able to operate with an extremely low alkalinity, which would also be of material help in eliminating the possibility of embrittlement.

STATEMENTS BY POWER COMPANIES IN REFERENCE TO RELATIVE CONSTRUCTION COSTS OF PLANT UNITS DESIGNED FOR 1200 AND 400 POUND STEAM PRESSURE

A number of statements have been contributed by power companies, and these are published as a part of this report for the purpose of indicating the difference in cost of construction for plants of 1200 and 400-lb. steam pressure. These statements fall into two groups, one giving costs from plants which are actually built and the other from estimates made for plants which were contemplated.

Since it is difficult to reduce the various studies to an identical basis of comparison, the figures do not lend themselves well to a general summary. Involved with the costs in the ordinary case, there are differences due not only to steam pressure, but also to difficulties of construction and to features of design made to fit local requirements and policy.

A net figure has been reached in each of the statements for the difference in cost due to pressure as a result either of actual experience or of comparable estimates. It is to be noted that the various net figures reported for plants actually built do not fall far apart.

The several statements follow:

STATEMENT BY THE MILWAUKEE ELECTRIC RAILWAY & LIGHT CO., MILWAUKEE, WIS.

High-Pressure Versus Low-Pressure Plant Costs

The greater cost for 1300 lb.-300 lb. over all 300-lb. pressure installation was found to be $204,410 on the basis of an addition of 39,100-kw. capacity to an existing station. This represents $5.28 per kw.

Greater costs for boiler plant equipment and electric plant equipment were found to be $235,523, and credits of $28,113 were taken for tunnel and circulating water system and for coal handling system. The 1200-lb. turbine is non-condensing, and an equivalent tunnel capacity is available for future 300-lb. condensing turbines. A credit is taken for coal handling and preparation equipment made available for future installations because of greater thermal efficiency of the 1200-lb. equipment.

Of the greater cost for boiler plant equipment and electrical plant equipment, 51.5 per cent is due to boiler alone, 11.8 per cent to increased superheater and reheater costs, 16.3 per cent to increased piping costs, 8.6 per cent to increased boiler feed pump costs, 7.6 per cent to increased electrical plant costs, and the balance of 4.2 per cent is due to engineering, tools, meters and instruments, safety valves, trap system, etc.

High-pressure installation costs are those of an initial installation, but 300-lb. pressure costs are based upon considerable experience. In the latter case advantage was taken of all improvements available to reduce costs; yet in the high-pressure costs appear figures later found unnecessarily high. The above difference of $5.28 per kw., therefore, should be maximum.

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[1] This article is an elaboration of part of the material that has appeared in Bulletins 155 and 177 of the Engineering Experiment Station of the University of Illinois. The publication of this article has been authorized by Dean M. S. Ketchum, Director of Engineering Experiment Station.

Present design of a second high-pressure installation indicates that this margin will decrease.

STATEMENT BY STEVENS & WOOD, NEW YORK, N. Y.

Table III shows the relative unit costs of the 400-lb. pressure station at Toronto, Ohio, and the 1400-lb. pressure station at Deepwater, N. J.

TABLE III

RELATIVE COSTS OF 400-LB. AND 1400-LB. INSTALLATIONS—STEVENS & WOOD

	Cost—Dollars per Kw.	
	Toronto 140,000 kw. 400 lb. Pressure	Deepwater 159,000 kw. 1400 lb. Pressure
Land	$0.82	$1.57
Preparation of Site	1.64	0.21
Yard work	4.42	4.48
River front work	......	2.68
Foundations	15.93	4.16
Building	10.78	10.11
Piping (not including circulating water)	4.75	5.09
Boiler room equipment	23.41	31.01
Turbine room equipment	26.47	21.34
Electrical switching equipment (in station)	12.11	8.98
Service equipment	2.43	5.37
Coal handling	4.67	3.19
Step-up substation	6.68	6.62
Preliminary operation	0.74	0.50
Total	$113.85	$105.31

The costs shown for the Toronto Station are the practically final actual costs for a balanced plant having four 35,000-kw. turbine (the nameplate rating of these units is 30,000 kw., but they have demonstrated in actual service that 35,000 kw. can be carried continuously in summertime within safe temperature limits). These costs include all known expenses in connection with the station up to and including engineering and engineering fee, but do not include interest during construction nor any other corporate expenses of the owning company.

The Deepwater costs here shown are from estimates only. However, over half the total cost has been incurred, and a careful survey of the situation indicates the project can be completed within the figures shown. These figures include the same complete costs as mentioned above for Toronto.

The actual project at Deepwater consists initially of the installation of two main power units with their boilers, each compound unit having a nameplate rating of 53,000 kw. Building space and boilers for a third such unit are also provided, but in place of a third main power unit, there is installed a high-pressure turbine element only which, with several evaporators, supplies a large amount of industrial service steam. It has, therefore, been necessary to adjust the estimate covering the actual project to make it applicable to three complete power units or 159,000 kw. of nameplate rating. (It is anticipated these units will safely carry at least 55,000 kw. continuously and quite likely 58,000 kw. However, the figures given above are based on the nameplate rating.)

Referring now to the individual groups in the above table, that of land needs no comment, being independent of pressure and governed by the locality and acreage purchased.

Toronto is high in preparation of site on account of having to move a highway formerly across the site as well as an interurban traction railway.

Toronto is directly on the Ohio River front, and the condensing water intake structures are a part of the building substructure, their costs coming under foundations: whereas at Deepwater the building is set back some 200 ft. from the edge of the Delaware River, and certain water-front structures are separated from the building proper.

Referring to the item of foundations, Toronto not only had a greater plan area per kw., but a river rise of over 40 ft. had to be provided for, so that the Toronto foundation structure is a relatively costly one as compared with the simple pile and concrete mat foundation at Deepwater.

The following summary comparison gives some information on the relative foundation and building costs:

	Sq. ft. per kw. Plan Area	Cu. ft. per kw. Building Volume above Basement Floor
Toronto	0.49	63
Deepwater	0.40	40

In regard to piping, presumably the true relative cost between 400-lb. and 1400-lb. pressure stations is greater than here shown for the latter. In both stations, the piping is relatively simple, but in Toronto, it covers four units and eight boilers, while in Deepwater it covers three units and six boilers only.

Presumably, the difference shown in boiler room equipment is fairly correct for the different pressures.

This is probably also true for the item of turbine room equipment where, with the larger compound units at the higher pressure, part of the unit has a speed of 3600 r.p.m. These comparative costs are also affected by the relatively smaller condensing equipment required on account of the better water rates on the high-pressure units.

Referring to electrical switching equipment, these costs, of course, vary with the type and complexity of the auxiliary equipment selected and are not in any way affected by the difference in pressures.

Similarly, the remaining groups of costs shown are not affected by pressure, except possibly in coal handling, where the quantity of coal per kw. is slightly less at the higher pressure.

Unfortunately for comparative purposes, the true total relative unit costs for the two pressures are overshadowed in these figures by the greater differences caused by size of units, foundation conditions and type of auxiliary equipment, but these figures and other studies lead us to the belief that a 1400-lb. pressure plant should cost, not to exceed, 5 per cent more than a 400-lb. pressure plant.

STATEMENT BY W. S. BARSTOW & CO., READING, PA.

In considering the relative construction cost of 400-lb. vs. 1200-lb. plants, it is believed that for stations having approximately 50,000-kw. units or larger, a plant designed for 1200 lb. will cost $6 more than a plant designed for 400 lb. This figure is based on experience in designing and constructing several 400-lb. stations during the past few years and upon studies in connection with the Holland Station when 400, 600 and 1200 lb. were considered.

STATEMENT BY STONE & WEBSTER, INC., BOSTON, MASS.

Table IV gives a summary of the relative costs of a 1200-lb. station and a 400-lb. station taken from a recent analysis.

This analysis is given in the discussion, by Frank S Clark, of the paper, "Some Economic Factors in Power Station Design," by H. Boyd Brydon, Trans. A. S. M. E., page 169, Fuel and Steam Power, May-August, 1928, Vol. 50, No. 15.

TABLE IV

RELATIVE COSTS OF A 400-LB. AND A 1200-LB. PLANT—STONE & WEBSTER

	Per Cent of Total Station Cost	Increase for 1200 lb. Plant
General improvements, coal and ash handling	13.0%	None
Buildings and foundations	17.5	—5%
Turbine generators	17.5	5
Boilers, furnaces, and heat absorbing accessories	20.0	10
Fuel preparation, condensing and draft system	15.0	—15
	83.0%	balanced
Piping	6.0	25% 1.5%
Feed water system	3.0	50 1.5
Switching	8.0	20 1.5
Contingencies	....	1.0
	100.0%	5.5%

STATEMENT BY THE EDISON ELECTRIC ILLUMINATING CO. OF BOSTON

When the Edison Electric Illuminating Co. of Boston came to the construction of the Edgar Station at Weymouth, Mass., an exhaustive study was made to determine the most economical steam pressure and temperature.

The studies showed that it is economical to use steam at as high a temperature as possible, irrespective of the pressure employed. No estimates were made as to the exact increase in cost due to the use of the higher steam temperatures.

The studies as to the most economical pressure showed that for stations employing the regenerative cycle, but no reheating of the steam during its expansion from throttle to condenser pressure, there is no commercial economy in going to pressures higher than about 350 or 400 lb. at the turbine throttle. In other words, the fixed charges on the additional cost of the high-pressure equipment would be greater than the fuel savings due to the higher pressures.

When studied from the standpoint of the regenerative-reheat cycle, however, the studies indicated that there would be a decided commercial advantage in raising the operating pressure to somewhere between 1200 and 1500 lb.

Equipment for such pressures had never been built, and it was, therefore, impossible to estimate the cost of construction with a high degree of accuracy. Conservative estimates of the cost of construction indicated that 1200 lb. was justified, and one boiler and one turbine for this pressure were installed.

In 1926 it became necessary to start construction of an extension to the Edgar Station. In the light of construction and operating experience with 1200-lb. equipment, a careful study was again made to determine the most economical pressure for the extension. Three schemes were studied, as follows:

1. All 350 lb.
2. All 1200 lb.
3. One-half 350 lb. and one-half 1200 lb.

The actual cost of construction of a 1200-lb. installation was available, and the only unknown factors were how much the manufacturers had charged to development on the first 1200-lb. installation and how much could be saved by better design. When prices were obtained on the new equipment, it was found that by better design it was possible to reduce the unit cost of the high-pressure equipment, and that the estimates of the unit cost of construction of a 350-lb. and a 1200-lb. extension were closer than the probable accuracy of the estimates. The expected increase in economy, due to the 1200-lb. installation, had been realized, and it was, therefore, decided to install boilers for the extension designed to deliver all the steam at the turbine throttle at 1200 lb.

Experience in building the extension has confirmed the opinion that a properly designed 1200-lb. station need not cost any more per unit of capacity than a 350-lb. station. The increase in operating pressure, therefore, is justified.

Relative Cost of Various Parts of Steam-Electric Generating Station

The commercial economy of increasing the operating pressure has been questioned by many engineers almost every time in the past when the operating pressures have been raised. Probably the reason for this questioning lies in the fact that these engineers do not realize that the cost of a particular part of a station is less important than the actual unit cost of the complete station.

Fig. 17 shows the approximate split-up of the cost of the various parts of a normal pressure steam-electric generating station. A study of this chart throws a great deal of light on the reason why it is possible to build a 1200-lb. station for approximately the same unit cost as a 350-lb. station.

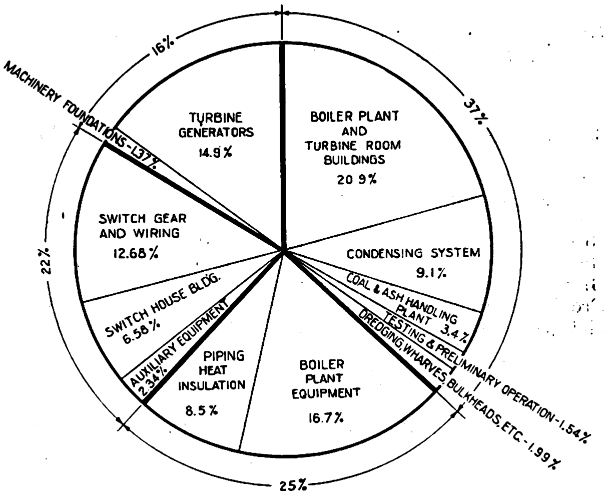

FIG. 17—RELATIVE COST OF VARIOUS PARTS OF STEAM ELECTRIC GENERATING STATION, EDISON ELECTRIC ILLUMINATING COMPANY OF BOSTON.

It is obvious that the unit cost of the switchgear and wiring, switch house and auxiliary equipment, which constitute 22 per cent of the cost of a station, have practically nothing to do with the operating pressure.

The cost of the turbine generators and equipment foundations will amount to slightly more for 1200 lb. than for 350-lb. equipment. These items only represent 16 per cent of the cost of the station, and the increase in unit cost is very small. Probably this slight difference in cost will disappear in the future.

The figures for boiler plant equipment and station piping, which constitutes 25 per cent of the cost of the station, will amount to more for a 1200-lb. than for a 350-lb. installation. The increase in unit cost is not as great as might be imagined, because of the fact that a 1200-lb. boiler will generate more kw. than a 350-lb. boiler of the same size. Furthermore, the cost of such equipment as fuel-burning equipment, ducts, cinder catchers and some piping, is much less per unit of capacity in a 1200-lb. plant than in a 350-lb. plant, and goes a long way toward balancing the higher cost of the pressure parts.

The boiler plant and turbine room buildings, condenser system, including intake and discharge tunnels, and coal and ash-handling equipment, which constitute approximately 37 per cent of the cost of a station, cost materially less per unit of capacity in a 1200-lb. than in a 350-lb. plant.

The additional cost of the various major parts which cost more in a high-pressure station was estimated and this sum was divided by the capacity of the high-pressure elements of the cross-compound turbine-generator units. This unit cost, roughtly obtained, is less than the unit cost of a normal pressure plant.

In conclusion, it can be said that our construction and operating experience shows that a properly designed 1200-lb. station need not cost any more per unit of capacity, and that it will show a material improvement in economy when compared with a 350-lb. plant.

Statement by E. B. Ricketts, The New York Edison Co., New York City

Table V gives an estimate of the relative costs of stations having varying steam pressures, other factors remaining constant. The writer has never built a high-pressure station.

Table V

Increased Costs per Kw. of High-Pressure Plants Over 400-Lb. Plants—E. B. Ricketts, The New York Edison Co.

Steam pressure, lb	1200	1200/400	1400
Capacity basis, kw	100,000	100,000	100,000
Greater cost for boiler and superheater,	$6.00	$3.60	$7.50
Greater cost for piping	4.09	4.09	4.24
Greater cost for turbine	1.00	0.80	1.25
Greater cost for feed water heaters	0.054	0.054	0.059
Credit for circulating system	0.52	0.51	0.52
Net greater cost	10.85	8.17	12.82

Statement by the Kansas City Power & Light Company

Relative Construction Costs of a 1400-Lb. and a 300-Lb. Installation

In considering the relative construction costs of a 1400-lb. and a 300-lb. plant, many problems arose to make it evident such a comparison was very much of a local one, and the difference in costs shown in Table VI are those which existed in this particular case and not necessarily what might exist elsewhere.

In this study a 45,000-kw. addition to an existing 300-lb., 130,000-kw. plant was considered, this to be either one 10,000-kw., 1200-lb unit, exhausting to a 35,000-kw., 300-lb. unit, or one 45,000-kw., 300-lb. unit. The figures do not include all the items that would appear in a new plant, but they do express the difference in cost per kw-hr. of the two pressures for the above installation.

No charges were made in either case for the building to house the 1200-lb. turbine and the two 1400-lb. boilers, or the three 300-lb. boilers, which were to be placed in an existing extension. The three 300-lb. boilers would have occupied more space, as the 1200-lb. turbine fitted into an unused space immediately adjacent to the 1400-lb. boilers, which simplified piping.

No credit was given the 1200-lb. unit for the reduction in coal handling and pulverizing costs.

These items are cited to show that the 300-lb. unit was favored, if anything.

Table VI

Relative Construction Costs of 1400-Lb. and 300-Lb. Installation

(Based on a 45,000-kw. addition to an existing station)

Item	1400 lb. Increase (+) Decrease (−)
Boilers, settings, economizers, air heaters, fuel burning equipment and soot blowers	+$7.39
Coal bunkers and coal conveyors	− 0.13
Building steel, foundations, floors, breeching, ducts, steel and pipe and duct insulation	− 0.19
Fans, motors and boiler feed pumps	+ 0.01
Piping connections	+ 0.42
Auxiliary power extension	+ 0.73
Miscellaneous electrical labor and material, instruments and painting	+ 0.08
Total	+$8.31
Contingencies, engineering, insurance and interest	+ 1.10
Boiler total (no building)	+$9.41
Turbine, generator and generator air cooler	+ 1.34
New building and foundations	− 0.63
Condenser, auxiliaries, circulating water connections, tunnel and auxiliary power extension	− 1.18
Piping connections	+ 0.12
Miscellaneous, instruments, and crane	+ 0.10
Extraction heaters	− 0.04
Switchboard and switches	− 0.22
Total	−$0.51
Contingencies, engineering, insurance and interest	− 0.09
Turbine room total	−$0.60
Plant total	+$8.81
Estimated B.t.u. per kw-hr. of 300 lb. plant	16,800
Estimated B.t.u. per kw-hr. of (45,000 kw.) 1400 lb.—300 lb. plant	13,810
B.t.u. saving on 1400 lb.-300 lb. plant	2,990
Load factor necessary to allow additional investment of $8.81 for 1400 lb.-300 lb. plant	33.8%

(Based on 15 per cent fixed charges and a fuel cost of 67,000 B.t.u. for one cent.)

The difference in condenser auxiliary power, boiler-feed pump, fan, coal handling and pulverizing power, is expressed in the net B.t.u. difference.

The summary indicates the 1400-lb. installation in this case would cost $8.81 per kw. more than the 300-lb. unit.

The table also shows the difference in B.t.u. for each of the installations and indicates the saving made by the 1200-lb. unit would pay 15 per cent fixed charges on the additional investment if it operated at only 33.8 per cent load factor. The actual load factor is, of course, dependent on the available load and the ability to keep equipment in service.

The load factor of the 1200-lb. unit should not drop off as rapidly as that of a 300-lb. unit over a period of years, as the obsolescence factor is undoubtedly lower.

The most economical point of operation of a 1200-lb. unit is at full load, and if the load is available a 70 per cent or 80 per cent load factor is entirely possible. Whether this or a 50 per cent load factor is used, the saving of a 1200-lb. unit over a 300-lb. unit is quite evident.

MANUFACTURERS' STATEMENTS

The Prime Movers Committee does not accept responsibility for any manufacturers' statement in this report.

STATEMENT BY THE GENERAL ELECTRIC COMPANY

The year 1928 has seen a remarkable increase in the use of higher steam pressures. This increase is shown graphically in Fig. 18 for both 600-lb. and 1200-lb. In the last two years about the same capacity of turbines has been ordered for each pressure, with the difference that the use of 600-lb. has been decreasing, while the use of 1200-lb. has been increasing rapidly.

The General Electric Co. has now installed, or on order, 19 units for 600-lb. and 9 units for 1200-lb., or a total of about 1¼ million kw. in 600-lb. units, and ¼ million kw. in 1200-lb. units.

A pioneer station designed exclusively for 1250-lb. is to be built by the W. S. Barstow Co., Inc., at Holland, N. J. The turbine is a 55,000-kw. cross-compound, 3600/1800 r.p.m. unit for steam conditions of 1200-lb., 725 deg. fahr., with boiler reheat to 750 deg. fahr. This turbine and the two 53,000-kw. units for the Deepwater Plant of the American Gas & Electric Co., and the United Gas Improvement Co., are similar in all essential respects.

A steam pressure of 1200 lb. for the turbines is working out so satisfactorily in the Edgar Station at Boston that a third 1200-lb. turbine is to be added. In order to obtain improved economy at light loads and better overall station efficiency, a 12,500-kw. turbine with multi-valve admission was selected rather than a duplicate of the recent single valve 10,000-kw. unit which, together with a 3000-kw. unit, is now operating in this station.

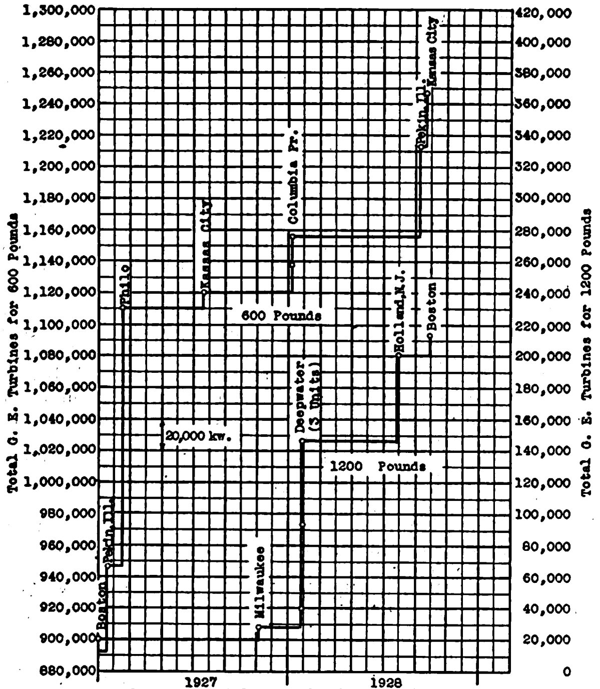

FIG. 18—COMPARATIVE SALES OF 600-LB. AND 1200-LB. UNITS, GENERAL ELECTRIC COMPANY.

The 208,000-kw., 600-lb. unit with steam reheat for the State Line Generating Co. has been tested and shipped and is now being installed.

A 165,000-kw., 600-lb. triple cross compound turbine is being installed in the Philo Station of the Ohio Power Co.

The 55,000-kw., 600-lb. unit of the Super Power Co. of Illinois is in service, operating satisfactorily, and a duplicate unit is under construction. The generators of these units were the first to be designed for 22,000 volts, and no difficulty has been experienced due to the high voltage.

In Buenos Aires the first of the two 52,000-kw. tandem compound turbines is in service. The second machine is about to be put in service. The steam conditions of 550 lb., 750 deg. fahr. with reheat to 750 deg. fahr. will result in an economy in this foreign station comparable with performance in the United States.

The Kansas City Power & Light Co. has in operation an unusual 10,000-kw. "reducing valve" turbine that receives steam at 590 lb. and 700 deg. fahr. and exhausts into the 190-lb. station mains. A 35,000-kw., single cylinder turbine for steam conditions of 590 lb., 700 deg. fahr., is being constructed for this company.

Steam Table Development

The demand for steam data at higher pressures and temperatures has been growing steadily. At the request of the A. S. M. E. Committee on Steam Research and the Extension of the Steam Tables, contributions were obtained from various operating companies and from manufacturers of turbines and boilers and others interested to finance the experimental work.

With the help and assistance of the Committee, the General Electric Co. has developed a steam chart which has been put at the disposal of the A. S. M. E. and is an additional contribution made by the General Electric Co. This was published in the February, 1926, issue of *Mechanical Engineering* for a range up to 1200 lb. and 750 deg. fahr.

Since then the additional experimental data obtained at the Massachusetts Institute of Technology and at the Bureau of Standards have made possible the extension of the steam tables and diagrams to 3500 lb. per sq. in. and 1000 deg. fahr. These were published in *Mechanical Engineering* for February, 1929, and copies can no doubt be obtained from the Committee having the matter in charge. The new charts meet the demand for a tabulation of the properties of steam covering the critical region and offering both thermodynamic consistency and faithfulness to reliable experimental data.

STATEMENT BY THE WESTINGHOUSE ELECTRIC & MANUFACTURING CO.

Supplementing the information furnished last year concerning the 10,000-kw., 1200-lb. turbine for the Kansas City Power & Light Co., Fig. 19 shows the unit assembled in the shop; Fig. 20, the method of fastening and adjusting the clearance of reaction blading, and Fig. 21, sectional views of the thrust bearing, showing the means provided for adjusting the axial position of the rotor.

Fig. 19 illustrates the method of applying electrical heater elements to the large cylinder joint bolts to facilitate tightening to obtain definite bolt-stresses. The box wrench is shown in place on one stud, and two of the heater elements in place and a third partly withdrawn.

The blading shown in Fig. 20 is of the end-tightened type, but the fastening is a modified form of the old and well-known Westinghouse "hook type" root. The blades are made with an upset foot on the root which fits into a supplementary groove and extends under the packing piece. Packing of "shoulder-type" has superseded the old dovetail packing. Alongside the blades and the regular packing, special circumferential packing pieces are fitted, provided with a shoulder which projects above the rotor. This shoulder is turned after assembly to provide a surface for

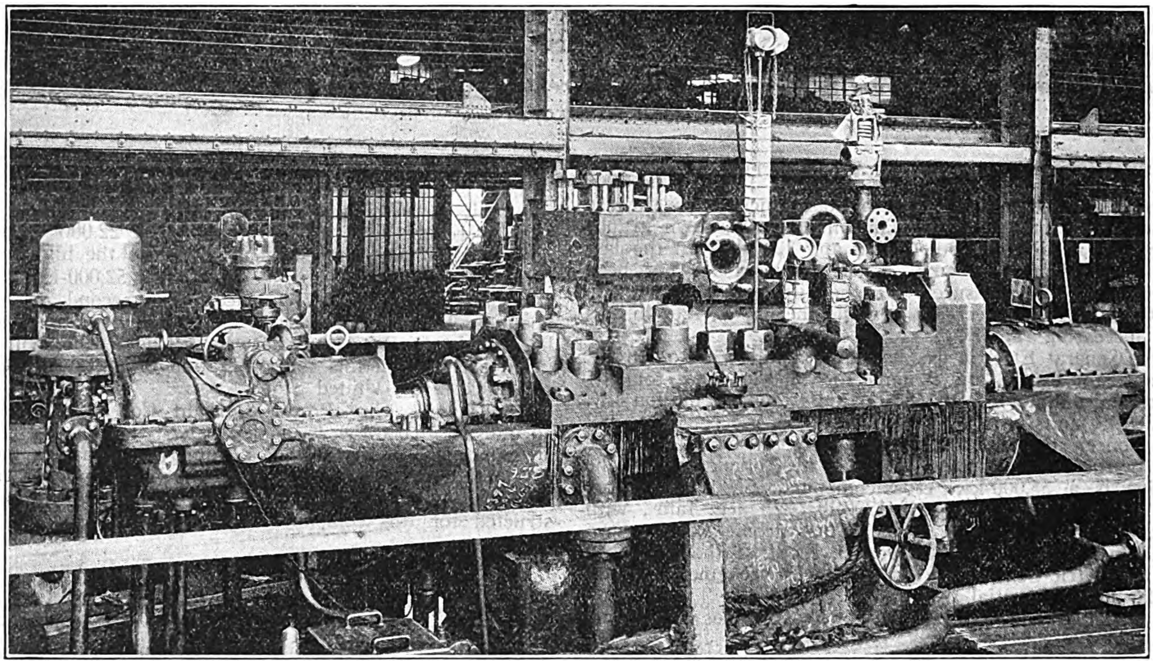

FIG. 19—10,000-KW., 1200-LB. WESTINGHOUSE TURBINE FOR THE KANSAS CITY POWER & LIGHT COMPANY.

the end-tightened shrouding of the complementary blade row to come up against.

Fig. 21 illustrates the construction of the thrust bearing, which is arranged to be capable of quick and easy adjustment, either to the running clearances, or to larger clearances, suitable for starting and stopping the turbine. This adjustment is facilitated by the provision of a hand wheel and indicator and by stops, located with the aid of shims when the shrouding is first ground in, to prevent excessive motion in either direction.

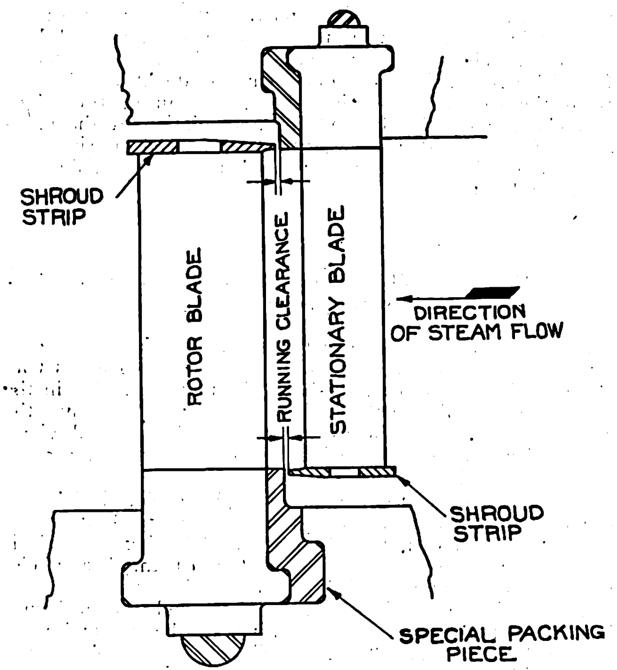

FIG. 20—METHOD OF FASTENING AND ADJUSTING CLEARANCE ON REACTION BLADING, WESTINGHOUSE ELECTRIC COMPANY.

STATEMENT BY THE BABCOCK & WILCOX CO.

Since the 1927-28 report, the Babcock & Wilcox Co. has received orders for a number of boilers for pressures above 600 lb.

The American Gas & Electric Co., United Gas Improvement Co. and Stevens & Wood have purchased for their Deepwater, N. J., Station six units built for 1400-lb. working pressure. Four of these units are standard boilers, Fig. 5, while two are reheat boilers, Fig. 6. All boilers are equipped with economizers, the standard boilers having economizers of the steaming type.

W. S. Barstow, Inc., has purchased for its Holland, N. J., Station two units built for working pressure of 1400 lb. Both of these are reheat boilers, the reheaters in this installation being a combination of convection and live steam reheaters in series to regulate reheat temperature under varying loads.

The Edison Electric Illuminating Co. of Boston has placed an order for two additional units for its Edgar Station built for 1400 lb. Both of these units are equipped with convection reheaters.

For process work the Masonite Corp. of Laurel, Miss., formerly the Mason Fibre Co., has placed an order for one additional unit of 3800 sq. ft. of heating surface, built for a working pressure of 1400 lb.

The drums of all of the boilers listed above are of forged seamless steel.

The Super Power Co. of Illinois has purchased for its Powerton, Ill., plant three additional units built for working pressure of 732 lb. Two of these units are standard boilers, while the third is a reheat boiler. The drums of these boilers are riveted.

With reference to superheat temperatures in practically all of the central station boilers purchased during the year, such temperatures have been in excess of 700 deg. fahr., the majority of the units being designed to give between 725 and 750 deg. fahr. In the case of the reheat boiler unit, the temperature of the reheated steam has also been above 700 deg. fahr. Such temperatures have ordinarily been 750

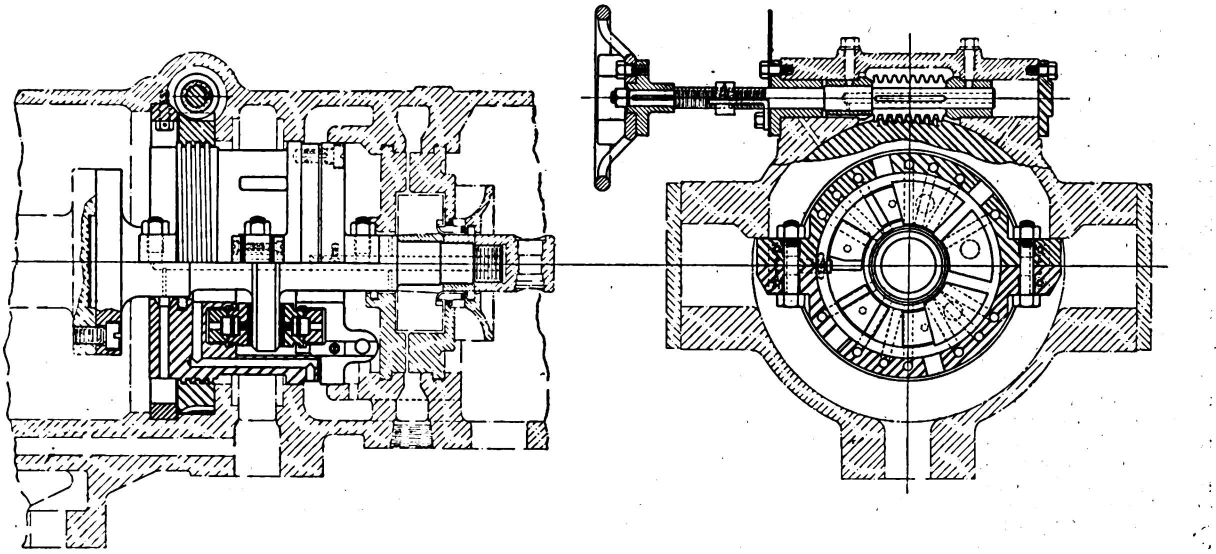

FIG. 21—THRUST BEARING, SHOWING THE MEANS FOR ADJUSTING AXIAL POSITION OF ROTOR, WESTINGHOUSE ELECTRIC COMPANY.

deg. fahr., and in some instances 775 deg. fahr., whereas for a few contemplated installations 800 deg. fahr. reheat temperatures are being considered.

The maximum ultimate temperature of the primary superheat that has been used up to this time in this country has been 750 deg. fahr., though here also higher temperatures are being considered for contemplated installations.

One exception to this statement should be made. A separately fired superheater for experimental work has been purchased and installed during the year, designed to give an ultimate temperature of 1100 deg. fahr. This unit has not as yet been placed in service.

In industrial plants ultimate temperatures in excess of 700 deg. fahr. are rare, except in such installations as combine high-pressure turbines with the use of process steam.

A great number of superheaters are in service today giving steam temperatures in primary superheaters of 750 deg. fahr., and in a few reheater units giving temperatures of 775 deg. fahr. Plain steel has been found satisfactory in superheaters where the ultimate temperatures have not exceeded 700 deg. fahr., or slightly more. Above this temperature, where superheaters have been placed in zones of high temperature and high rates of heat transfer, an alloy steel known as Enduro KA-2 (formerly known as Enduro 18-8, 18 per cent chrome, 8 per cent nickel steel) has been used for the past year. This material has given very satisfactory results in service.

Enduro KA-2 billets are manufactured for this company by the Central Alloy Steel Corp., which, with the Ludlum Steel Co. and the Babcock & Wilcox Tube Co., are licensed under the Krupp Nirosta patents, the material being produced under the supervision of Prof. Benno Strauss of Krupp, A. G., Germany.

As a result of the increasing demands for high temperatures, the superheaters have been redesigned so as to make it possible to satisfactorily increase the total steam temperatures with plain steel tubes, and if the limits of such metals are reached, to permit the use of special materials for a smaller percentage of the superheater.

In this design there is but a single row of tube holes in the inlet and outlet headers, each tube being continuous from the inlet to the outlet without intermediate boxes. This permits the total pressure drop to be expended in the flow of steam through the tubes without intermediate points interfering with the distribution thus obtained. Further, this construction eliminates the necessity of distribution baffles or ferrules.

With the new design of superheater short radius tube bends, which would maintain a proper cross sectional area through the tube in the bend and also maintain the proper tube gage on the bend, are required, and a new method was developed by the company to make possible this construction.

While it is appreciated that the majority of superheaters in high-pressure plants seldom, if ever, require cleaning, the evidence is that occasionally, when something unforeseen occurs, such cleaning is necessary, and the new type of superheater is designed to permit thorough turbine cleaning. This is accomplished by the use of a Y-type return bend on one end of each loop, each Y being fitted with a valve of simple and approved design which can readily be opened for turbining when necessary. The location of these valves is such as to be outside of the range of stresses caused by heating and cooling, and the entire fitting is protected from soot and ashes. The superheater as arranged is completely drainable.

Where temperatures are beyond the limit where expanded joints will remain tight, the outlet superheater tubes can readily be welded to the header.

One of the problems in connection with the design of superheaters to give a minimum pressure drop is that of proper steam distribution. A step in advance, in this respect, in the new design of superheaters is made by bringing the steam from the drum to the inlet header through a number of tubes along the length of the header, these tubes being located inside of the tube doors. This method of bringing the steam to the inlet header gives an improved distribution of the steam. Further improvement in distribution is obtained by making use of a large diameter outlet header, a source of supply for such headers now being available. A combination of these features results in a design of superheater that has practically no distribution problem.

By bringing the steam to the superheater tubes exposed to the greatest amount of radiation and to the hottest products of combustion, it will be possible to maintain the superheater in relatively close proximity to the furnace with a resulting flat superheat-output curve, still have a considerable margin of safety with this design over previous designs, and still permit of ultimate steam temperatures higher than those now in use with plain steel tubes, and still higher if alloy tubes are used.

It is felt that the combination of the shutter steam drum baffle, described in a statement in the 1928-29 Report of the Subcommittee on Boilers, Superheaters and Economizers, the arrangement for taking steam from the drum along its length through tubes instead of steam pipes, the supplying of steam to the inlet header entirely within the setting and throughout its length, brings together the development of steam separation, minimum pressure drop and maximum superheat for any location in the boiler, all of which factors have resulted in the most satisfactory type of unit for high-pressure service.

A development in economizer design of last year was a change in design of return bends. Formerly these bends were made of seamless steel tubing with threaded flanges on the ends having female facings. Now they are forged from round bar stock with the flanges integral. The flanges are produced on the ends of the bar by the upset forging process. After the flanges are formed, and before bending, the blank is drilled from end to end making it a seamless tube.

Special devices are used in forging and bending to insure the faces of the flanges being in the same plane after bending and having the same angularity, as well as maintaining uniform center distances of the ends.

The return bends for connecting the top and bottom rows of tubes to the headers were formerly made of seamless steel tubing with threaded flanges each end, one end having male and other female facing.

In order to eliminate threaded flanges throughout on the return bends, and at the same time to produce a return bend for the header connections more adaptable to the location than the solid forged bend, a type of bend has been developed having loose flanges and facing similar to the Van Stone type. These bends are of seamless tubing, upset on the ends and having loose fitting bolting flanges bearing against the upset ends, one end being faced for male and the other for female connection.

STATEMENT BY THE COMBUSTION ENGINEERING CORP.

"Two notable high-pressure installations have been placed in service since the 1927-28 Report. These are at the Grand Avenue and Northeast plants of the Kansas City Power & Light Co., Kansas City, Mo.

The Grand Avenue installation consists of three 15,160-sq. ft. Ladd boilers, designed to operate at 700 lb. per sq. in., each with 2250 sq. ft. of water-cooled wall surface, 9148 sq. ft. of fin tube economizer surface and 2550 sq. ft. of superheater surface. Each unit has 22,060 sq. ft. of C. E. air preheater surface and is fired by one 24-ft. wide and 22-ft. long Green forced draft stoker. The normal steam rate is 150,000 lb. per hr., and the maximum rate 225,000 lb. per hr. per boiler. At these ratings, the various temperatures are shown in Table VII.

TABLE VII

EXPECTED TEMPERATURES, 700-LB. GRAND AVENUE STATION BOILERS, KANSAS CITY POWER & LIGHT CO.

	150,000 lb. per hr.	225,000 lb. per hr.
Final steam temperature	740	750
Water entering economizer	210	210
Water leaving economizer	287	289
Air entering preheater	70	70
Air leaving preheater	295	350
Gas leaving preheater	280	323

The installation at the Northeast Station consists of two Ladd boilers with 16,950 sq. ft. of heating surface each, designed to operate at 1400 lb. pressure. Each unit has 3050 sq. ft. of furnace water cooling surface, 10,891 sq. ft. of fin tube economizer surface, 2650 sq. ft. of primary superheater surface and 470 sq. ft. of reheater surface. Two plate type C. E. air preheaters having 39,270 sq. ft. of heating surface each supply air for combustion. Each unit is fired by three Raymond impact mills, giving 45,000 lb. of coal per hr. total maximum capacity. At normal rating, the unit will deliver 170,000 lb. of steam per hr., and at maximum rating, 200,000 lb. per hr. The temperatures for these ratings are shown in Table VIII.

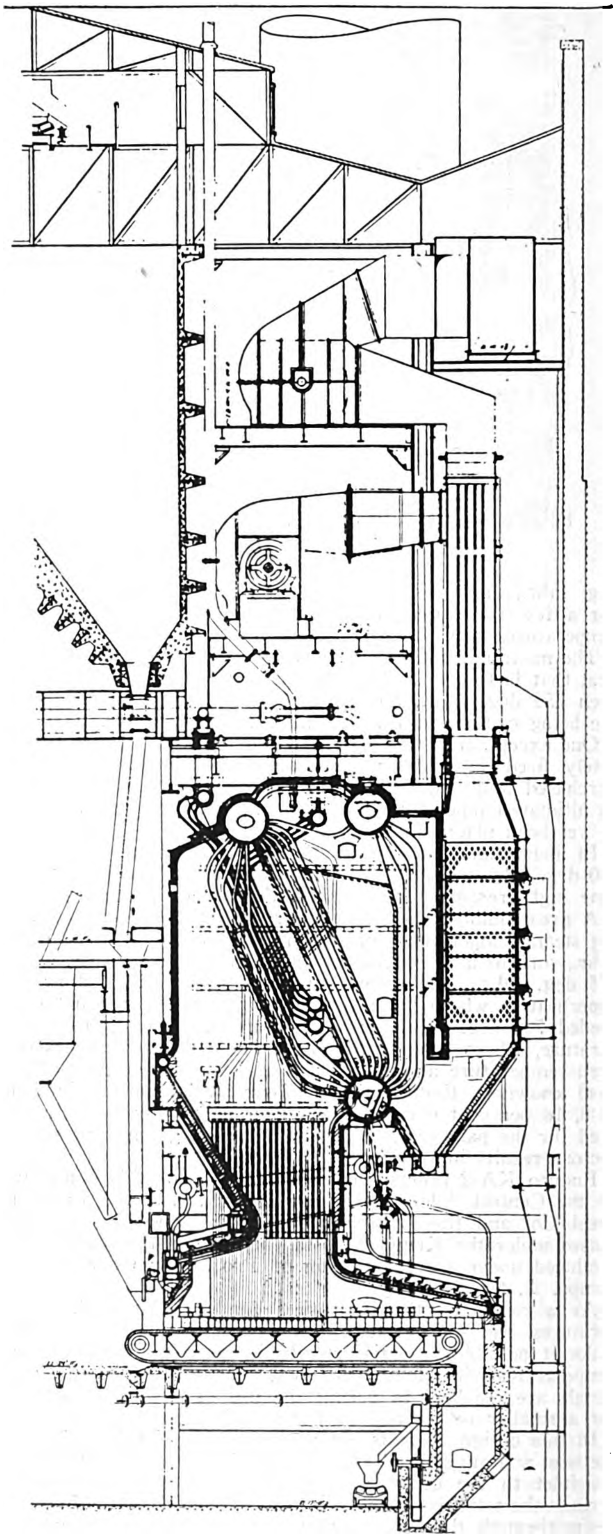

FIG. 22—CROSS SECTION OF 700-LB. UNIT AT GRAND AVENUE STATION.

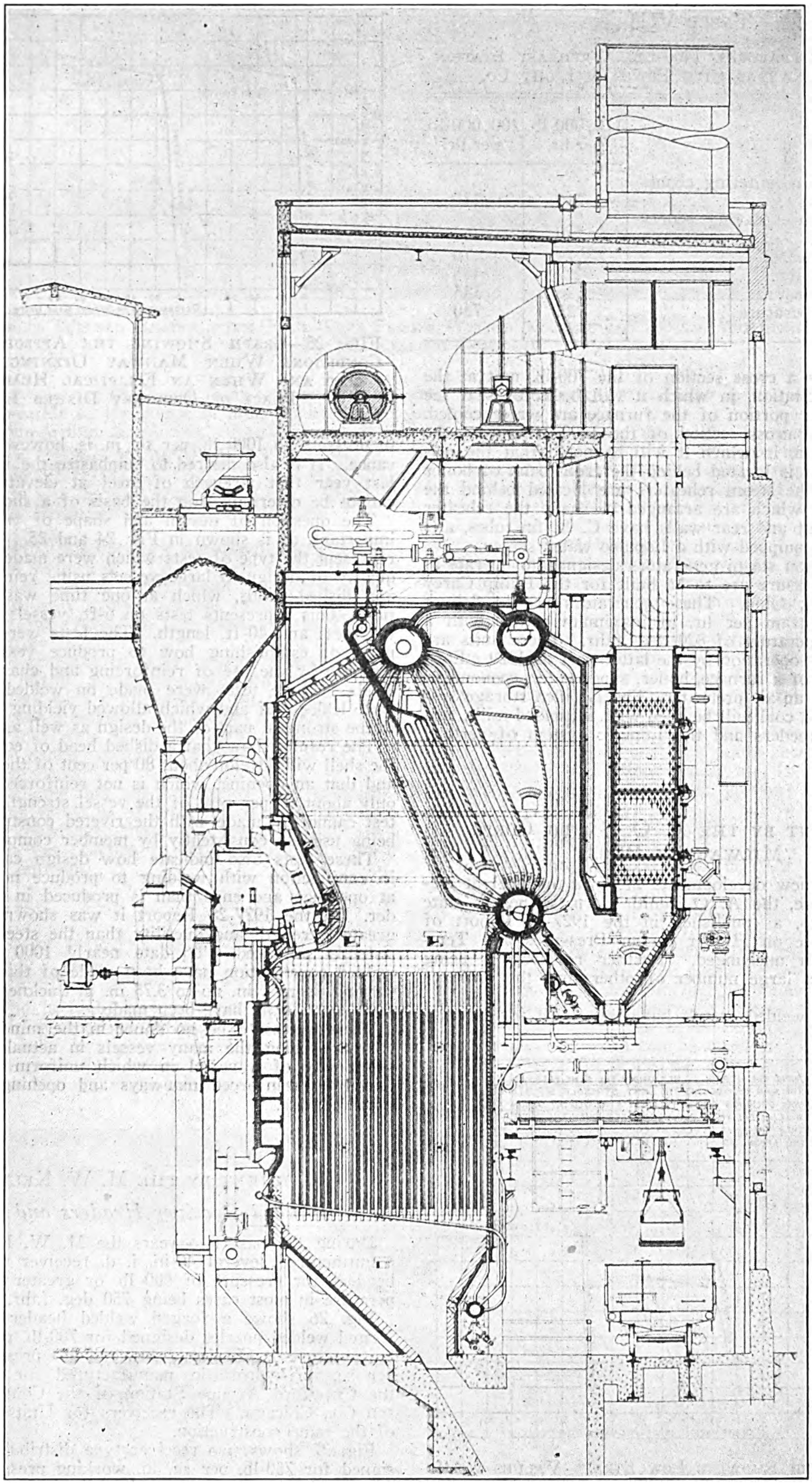

FIG. 23—CROSS SECTION OF 1400-LB. UNIT AT NORTHEAST STATION.

TABLE VIII

EXPECTED TEMPERATURES, 1400-LB. NORTHEAST STATION BOILERS—KANSAS CITY POWER & LIGHT CO.

	170,000 lb. per hr.	200,000 lb. per hr.
Water temperature entering economizer	210	210
Water temperature leaving economizer	319	324
Air entering preheater	70	70
Air leaving preheater	412	435
Gas leaving preheater	328	345
Total steam temperature	725	730

Fig. 22 shows a cross section of the 700-lb. unit at the Grand Avenue Station, in which it will be noted that the arches and upper portion of the furnace are water cooled. Fig. 23 shows a cross section of the 1400-lb. unit at the Northeast Station, in which it will be noted that the primary superheater is located behind the front bank of boiler tubes and that the steam reheaters are located behind the side wall tubes, which are arranged to shade the reheater tubes. The front and rear walls have C. E. fin tubes, and each furnace is equipped with a Lopulco water screen.

Two Combustion steam generators designed to operate at 1840-lb. gage pressure are to be built for the Philip Carey Co. at Lockland, Ohio. These generators are to deliver 150,000 lb. of steam per hr. at maximum rating with a total steam temperature of 820 deg. fahr. These units are expected to start operation by the latter part of 1929. Each unit will consist of a furnace, boiler, superheater, economizer and settings and an air preheater. The Lopulco storage system of pulverized coal will be used with Raymond mills, Lopulco Type R feeders and the Lopulco system of vertical firing.

STATEMENT BY THE A. O. SMITH CORP., MILWAUKEE, WIS.

Referring to new developments in work on steel at elevated temperature, the A. O. Smith Corp. wishes to state that the findings, as published in the 1927-28 Report of the Subcommittee on Higher Steam Pressures and Temperatures remain unchanged. Further research is being carried out on a large number of other than the ordinary carbon steels.

The fact that welded vessels have been built for increase in pressure to 1000 lb. per sq. in. is, however, a step in advance. It is also desired to emphasize the fact brought out last year that strength of steel at elevated temperatures cannot be determined on the basis of a short time test.

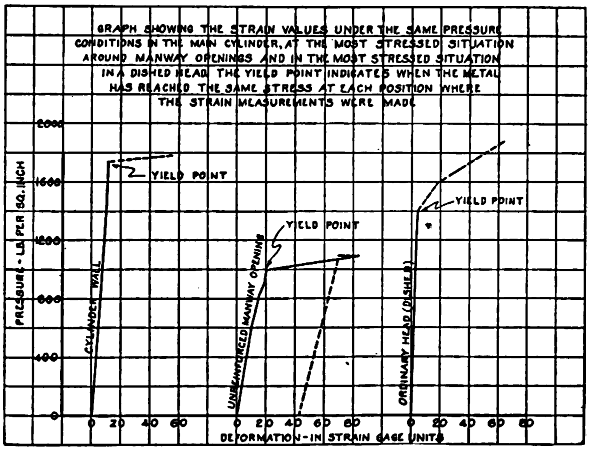

FIG. 24—GRAPH SHOWING LOW STRAIN VALUES WITH ORDINARY DISHED HEAD AND UNREINFORCED MANWAY OPENING.

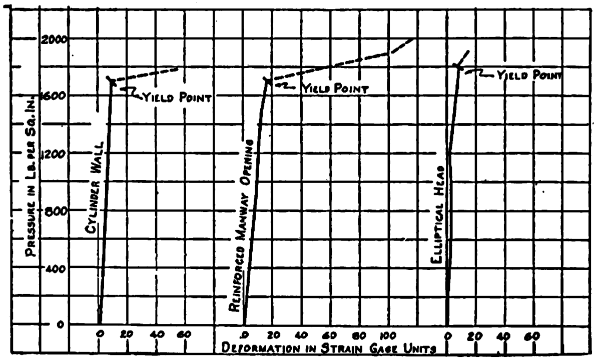

FIG. 25—GRAPH SHOWING THE APPROPRIATE STRAIN CONDITIONS WHEN MANWAY OPENINGS ARE REINFORCED AND WHEN AN ELLIPTICAL HEAD IS USED IN PLACE OF ORDINARY DISHED HEAD.

The question of design and shape of vessels is equally important, as is shown in Fig. 24 and 25. These diagrams represent the type of tests which were made to evaluate the quality of design in large vessels using reinforced openings and dished heads, which at one time was common practice. This represents tests on 6-ft. vessels with 2-in. wall thickness and 40-ft. length. The tests were carried to the point of establishing how to produce vessels uniform in strength by the use of reinforcing and change of shape of heads. These tests were made on welded vessels, which were leak-proof and which allowed yielding to be developed in the strongest part of the design as well as in the weakest.

The results show that a dished head of equal thickness as the shell will develop about 80 per cent of the vessel strength and that an opening, which is not reinforced, could develop only about 60 per cent of the vessel strength. This type of test cannot be made with the riveted construction which is being used so consistently by member companies.

These tests also indicate how design can be developed in conjunction with welding to produce no greater stress at openings and ends than is produced in the main cylinder. In the 1927-28 Report it was shown that welds of greater strength and ductility than the steel had been consistently produced. To date nearly 1000 vessels of this welded construction have been made of thick wall sections varying from 2 in. up to 3.75 in. in thickness. A few sections up to 6 in. have been made.

There seems to be no doubt in the minds of customers who are using the many vessels in actual service of the superiority of a vessel in which uniform strength is obtained by reinforced manways and openings and properly shaped heads.

STATEMENT BY THE M. W. KELLOGG CO.

Welded Receiver Headers and Drums

During the past two years the M. W. Kellogg Co. has manufactured several 40-in. i. d. receiver type distributing headers for pressure of 600 lb. or greater; operating temperature in most cases being 750 deg. fahr.

Fig. 26 shows a forged welded header with flue type forged welded nozzles designed for 700-lb. per sq. in. working pressure at 650 deg. fahr., and test pressure of 1050 lb. per sq. in. hydrostatic, manufactured for Unit No. 6 at the Crawford Avenue Station of the Commonwealth Edison Co., Chicago. The receivers for Units No. 1 to 5 are of the same construction.

Fig. 27 shows two receiver type distributing headers designed for 750-lb. per sq. in. working pressure at 750 deg. fahr. and test pressure of 1200-lb. hydrostatic, manufactured for the Philo Station of the Ohio Power Co.

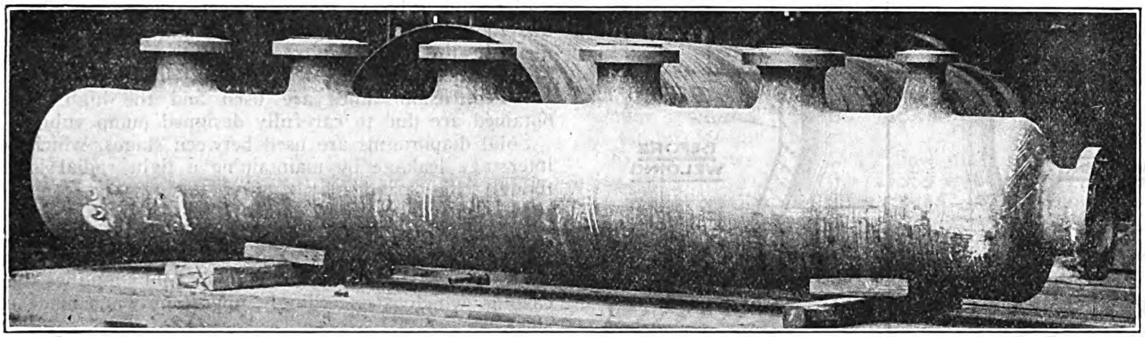

FIG. 26—FORGED WELDED HEADER WITH FLUE TYPE FORGED WELDED NOZZLES FOR 700-LB. WORKING PRESSURE, THE M. W. KELLOGG COMPANY.

Because of the weakness of the shell, it was necessary to reinforce the knuckle of the nozzle in order to keep the stresses at this point within safe limits. Fig. 28 shows details of reinforcing nozzle, the type in this case being as shown in final stage "A."

Forged and Hammer Weld Boiler Drums

In November, 1927, this company furnished to the Edge Moor Iron Co. two 48-in. i. d. x 1¼-in. thick x 31-ft. long-forged and hammer welded boiler drums, together with sixteen 36-in. i. d. unit drums. These drums were for 350-lb. boilers for the Oklahoma City plant of the Oklahoma Gas & Electric Co.

This company is prepared to build hammer welded boiler drums from steel having a minimum ultimate strength of 50,000 lb. per sq. in., with a thickness at the welds not to exceed 2 in. Maximum diameter made from one plate with only one longitudinal weld is 54 in. All materials and workmanship to be exactly in accordance with A. S. M. E. Boiler Construction Code.

This company believes that the mention of these hammer welded boiler drums would be of great interest for the reason that, to its knowledge, these are the first built in America, although the practice is very common in Germany and on the Continent.

STATEMENT BY THE INGERSOLL-RAND CO.

High-Pressure Pumping Equipment

The present trend in high-pressure boiler feed seems to be away from variable speed on the boiler feed proper, both on account of the large horsepower involved, and the high speed, 3600 r.p.m., generally required to generate the high pressures. This makes the electrical control very expensive, both as to first cost and also as to space required for installation.

The alternative is to run the boiler feed pump at constant speed and place ahead of it a booster or tank pump of comparatively low pressure and horsepower, equipped with variable speed motor and having such hydraulic characteristics that the entire regulation of the load can be accomplished through this preliminary pump at moderate cost, owing to its lower horsepower rating.

Such an arrangement has been worked out for the Deep Water plant now being designed. The equipment consists of six-stage medium pressure, adjustable speed pumps, each delivering 650,000 lb. per hr. at 670-lb. pressure, to No. 6 five-stage cast steel, high-pressure pumps, which increase the pressure to 1550 lb. All pumps will have Kingsbury thrust bearings and pressure lubrication. The boosters will have 850-h.p. motors and the boiler feeds proper 1250-h.p.

Fig. 29 shows the No. 4 Class "HT," six-stage boiler feed pump furnished the Kansas City Power & Light Co. for its Northeast Station. This pump receives its supply from the 350-lb. boiler feed header and is designed to deliver 400,000 lb. per hr. at 1500-lb. pressure and 3600 r.p.m.

STATEMENT BY THE DELAVAL STEAM TURBINE CO.

On high-pressure pumps of the type shown in Fig. 30, built to supply 800 g.p.m. at 3600 r.p.m. when operating against a discharge pressure of 1500 lb., no thrust bearing is either required or recommended. For the hydraulic balance to function properly, the clearance must be such that thrust bearing would not function; consequently no forced feed lubrication or oil coolers are necessary.

The hydraulic balancing device compensates for wear and the amount of wear can be checked without removing the pump cover. To bring the rotor back to its original operating position it is necessary to replace the balancing

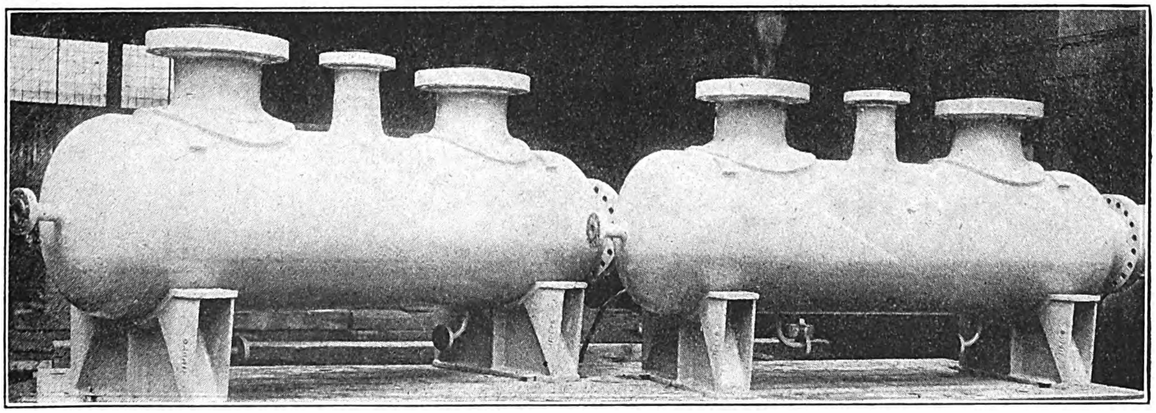

FIG. 27—RECEIVER TYPE DISTRIBUTING HEADERS FOR 750 LB., THE M. W. KELLOGG COMPANY.

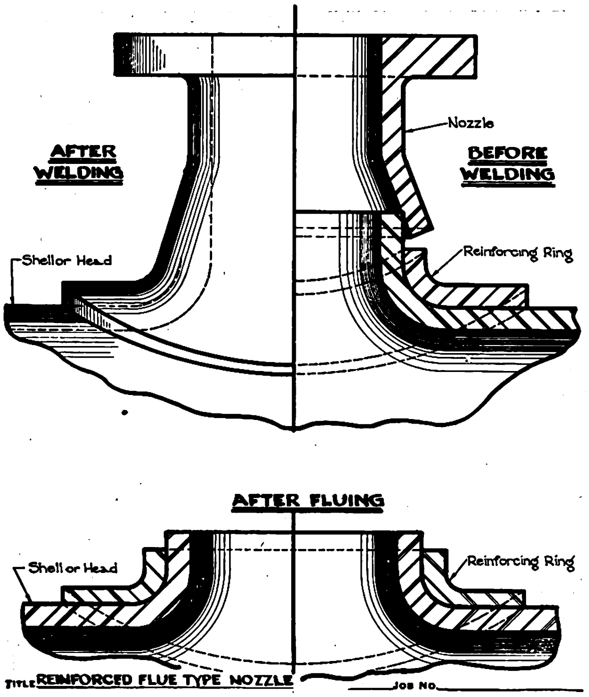

FIG. 28—DETAILS OF REINFORCING NOZZLE, THE M. W. KELLOGG COMPANY.

piston and case ring. This has never been necessary because of wear, although a large number of pumps of this type have been in boiler feed service for a great many years.

Other features of construction are cast steel center line supports for the casings and heavy pedestal bearings, mounted directly on the base plate to support the pump rotor. This construction insures proper alignment under all conditions of operation.

The stuffing-boxes are under suction pressure only. When this suction pressure is relatively high, a bleed-off arrangement in the stuffing boxes, which is patented, takes care of the external leakage.

No diffusion vanes are used and the high efficiencies obtained are due to carefully designed pump volutes.

Solid diaphragms are used between stages, which reduces interstage leakage by maintaining a tight radial joint even though the casing may expand under pressure. Fig. 31 shows one of the four turbine-driven boiler feed pumps supplied the State Line Generating Co. for 800 lb., discharge pressure, 950 g.p.m. Both turbine and pump casings are made of cast steel. The solid diaphragm simplifies the pump casting, which is exceedingly important when made of cast steel.

No matter how heavy the bolting, interstage leakage is usually present in a horizontally split pump where the complete diaphragm is a part of the casing.

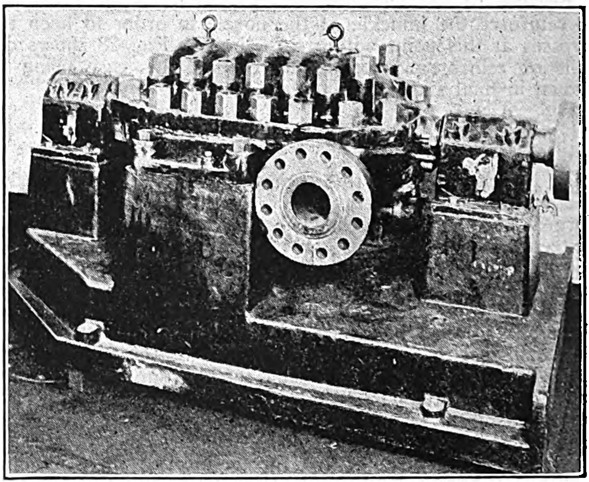

FIG. 30—1500-LB. BOILER FEED PUMP, DELAVAL STEAM TURBINE COMPANY.

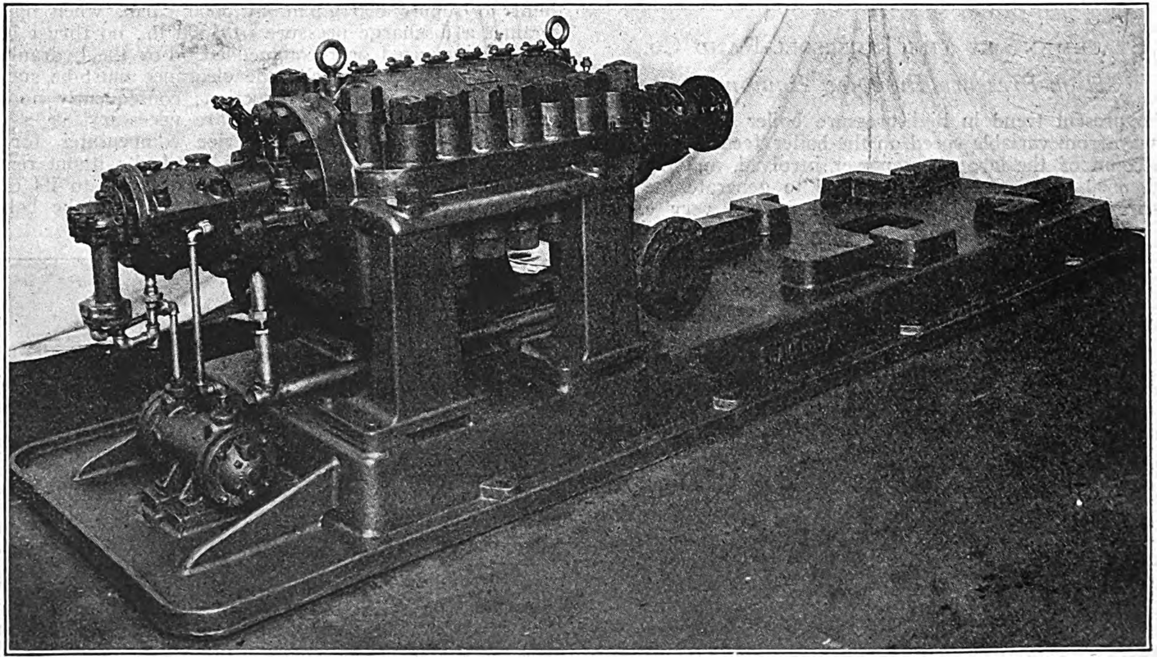

FIG. 29—NO. 4 CLASS "HT" 1500-LB. PRESSURE PUMP, INGERSOLL-RAND COMPANY.

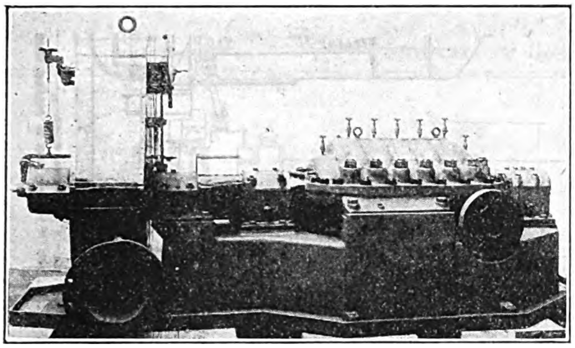

FIG. 31—800-LB. BOILER FEED PUMP, DELAVAL STEAM TURBINE COMPANY.

STATEMENT BY THE SWARTWOUT CO.

Fig. 32 shows a sectional view of the Swartwout feed water regulator furnished the Kansas City Power & Light Co. for its two 1400-lb. boilers at Northeast Station; a similar type was furnished for the three 700-lb. boilers at its Grand Avenue Station.

Fig. 33 shows a sectional view of the Swartwout Type S-E valves furnished the above stations for maintaining a constant excess pressure (above steam drum pressure) at the feed water regulating valves. The S-E valves are placed in the feed lines to the economizer and also serve to prevent excessive feed pump pressure building up in the economizer and popping the safety valves.

The Swartwout regulators installed on the Edgar Station boilers were the first regulators put on boilers of so high a pressure and are giving very satisfactory service.

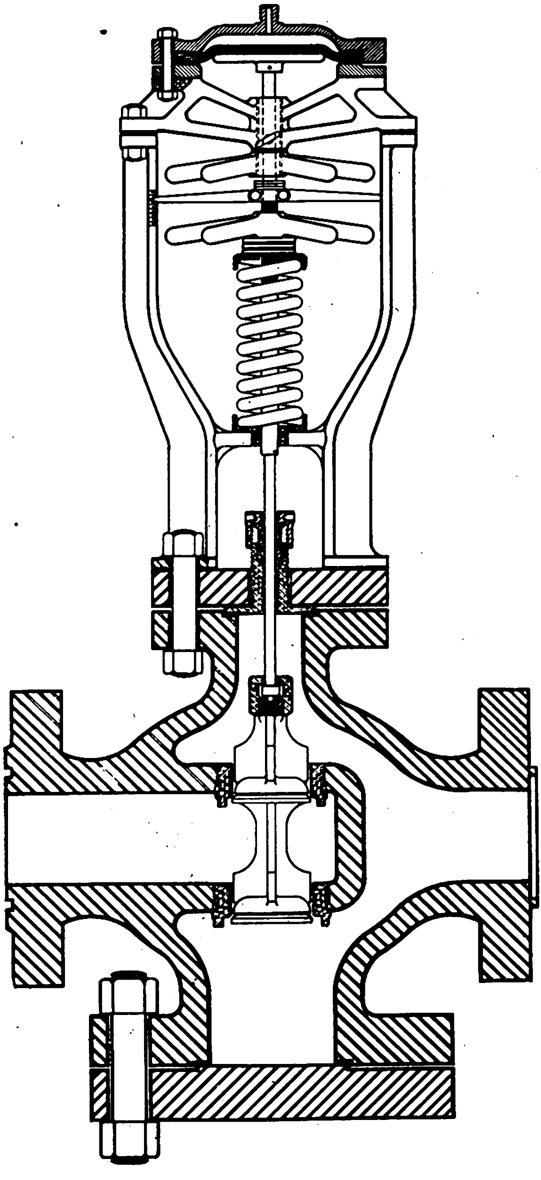

FIG. 32—FEED WATER REGULATOR FOR HIGH-PRESSURE SERVICE, THE SWARTWOUT COMPANY.

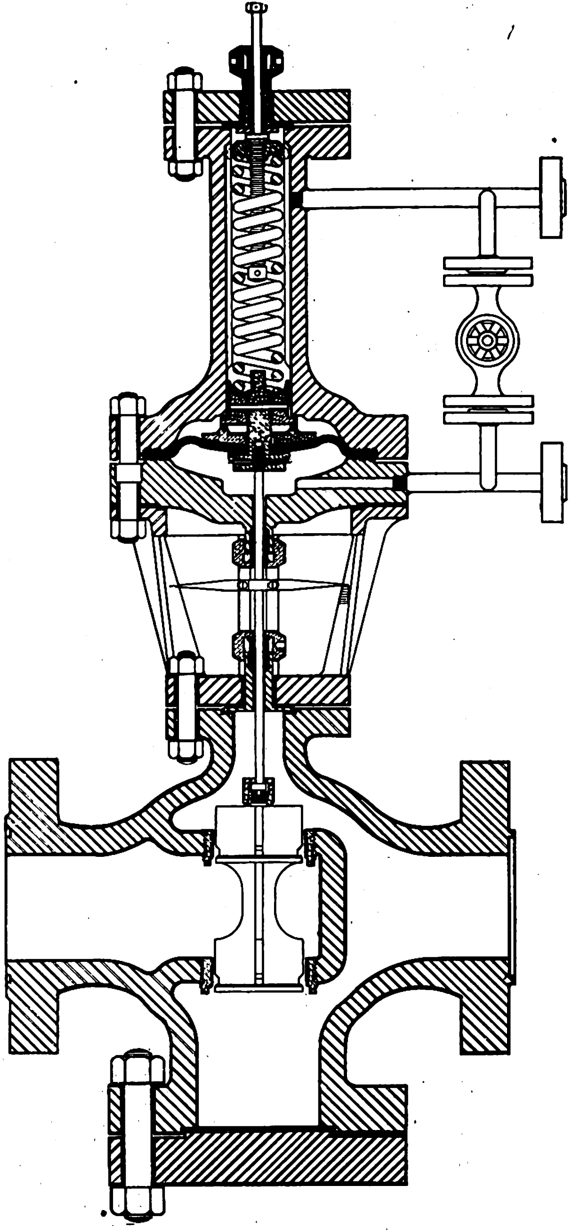

FIG. 33—TYPE S-E CONSTANT EXCESS PRESSURE REGULATOR FOR HIGH-PRESSURE SERVICE, THE SWARTWOUT COMPANY.

The Doble High Pressure Steam Generator

STATEMENT BY SYDNEY W. TAYLOR, JR., CONSULTING ENGINEER, SAN FRANCISCO, CAL.

The most fruitful field to explore in order to bring about notable increases in power plant efficiency is the field of high-pressure, high-temperature steam. The results of modern trends in central station practice prove the accuracy of this statement. But designers, seemingly, are reluctant to depart from conventional boiler types with their steam drums and attendant metallurgical difficulties; their natural circulation and priming propensity. Obviously, the generation of steam within the walls of a single tube, coiled and placed in series with the counter-flowing gases, would eliminate metallurgical difficulties, and no entrained water could carry over to the steam line if the delivery temperature were maintained above that of saturation. But boilers of this kind, generally speaking, have fallen into disrepute for want of the development of reliable pressure and temperature controls. The following describes a practical steam generator of the single tube type and a simple, unfailing system of automatic control, developed by the Doble Steam Motors Corp. of Emeryville, Cal. The generator is in successful use in the power plant of that concern's steam automobile.

Design

Fig. 34 shows a diagrammatic vertical section of the Doble automobile boiler, and Fig. 35 a similar view of a boiler proposed for a locomotive of main line proportions, designed to deliver 80,000 lb. of steam per hr. at 1500-lb. pressure and a temperature of 800 deg. fahr. The rear unit of the locomotive, which carries an air-cooled condenser, is omitted. The small automobile boiler will deliver steam at any desired temperature within reason. Service temperatures above 900 deg. fahr. are not beyond its maximum range. It has been operated in the laboratory at pressures well above the critical point and at ratings up to 2200 lb. per hr., equivalent evaporation. In normal service, however, furnishing steam for the double cross-compound engine of the automobile, its controls are set to

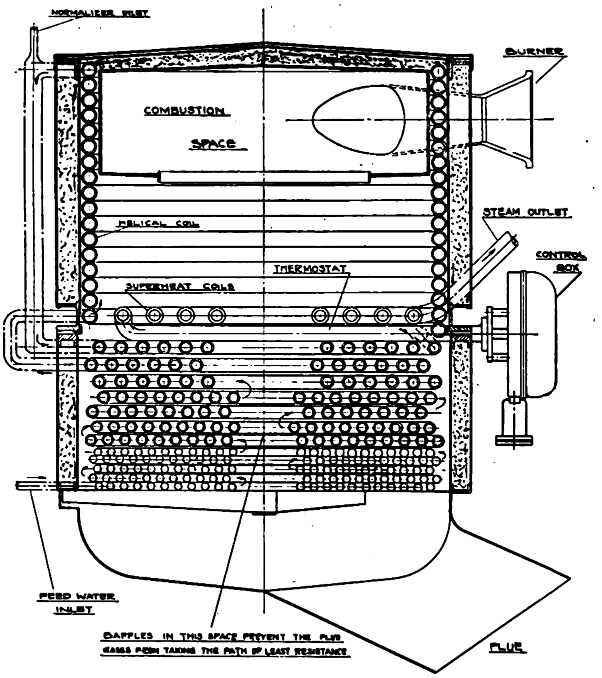

FIG. 34—DIAGRAMMATIC VERTICAL SECTION OF DOBLE AUTOMOBILE BOILER.

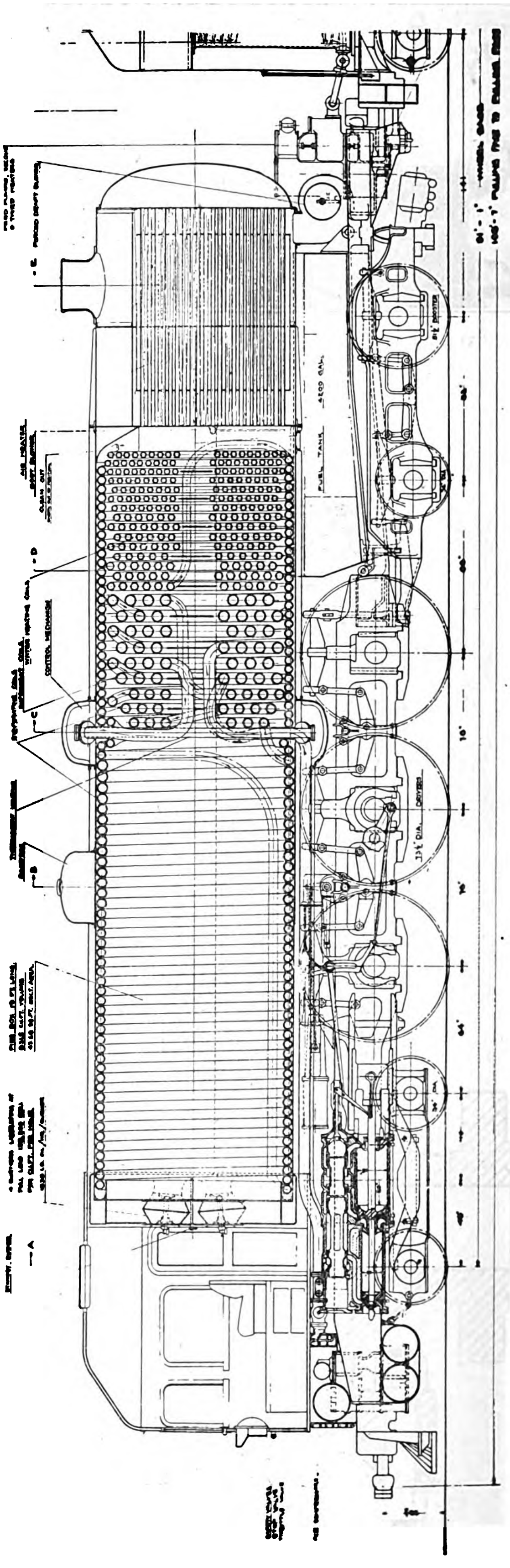

FIG. 35—LONGITUDINAL SECTION OF DOBLE LOCOMOTIVE BOILER, TYPE D-E

TABLE IX

SUMMARY OF DOBLE LABORATORY TEST NO. 186

	Run No.					
	3	9	13	14	15	16
1. Steam pressure, lb. per sq. in. (gage)	460	535	605	765	860	980
2. Actual evaporation, lb. per hr	600	760	886	1,153	1,343	1,532
3. Equivalent evaporation per sq. ft. of total surface, lb. per hr	10.78	13.63	15.87	20.58	23.92	27.19
4. Heat absorbed by the fluid, B.t.u. per hr. (000 omitted)	842	1,065	1,238	1,606	1,876	2,124
5. Fuel, lb. per hr	50.1	65	77.6	103	120	138
6. Heat liberated in the fire box B.t.u. per hr. (000 omitted)	1,002	1,300	1,552	2,060	2,400	2,760
7. Heat liberated per cu. ft. of fire box volume, B.t.u. per hr. (000 omitted)	400	520	620	825	960	1,105
8. Boiler efficiency, %	84.03	81.92	79.77	77.96	77.79	76.96
9. Flue gas temperature, correctea °F	430	....	.....	588	642	690
10. Excess air, %	8	15	12	9	10	11
11. Heat absorbed per average sq. ft. of total heating surface, B.t.u. per hr	10,450	13,250	15,400	19,950	23,300	26,420
12. Weight of flue gas, lb. per hr	860	1,190	1,380	1,790	2,100	2,440
13. Gas per average sq. ft. of gas passage area, lb. per hr.*	1,310	1,810	2,100	2,730	3,200	3,720

*The average gas passage area is 0.656 sq. ft.

deliver at 850 deg. fahr. and, usually, not more than 850 lb. Its heating surface is 80.4 sq. ft. (See Tables IX and X for other data.) The Doble boiler is adapted to use of liquid or colloidal fuel and dry, powdered coal. The locomotive unit is designed for oil; the small unit burns gasoline, since gasoline is always readily obtainable at filling stations.

The boiler consists essentially of a single tube of seamless steel, gradually expanding in diameter from the inlet to the discharge as the separate tube lengths are welded together. Fig. 34 and 35 show this tube formed into a series of open-wound flat coils and a single close-wound helical coil, the arrows indicating the direction of circulation. The coils are disposed in an insulated cylindrical casing in such a way that the working fluid in its progress through the tube is constrained to flow counter to flow of the gases. The draft and the feed are both forced. The flat coils occupy the convection section of the boiler; the helical coil gives shape to the furnace and functions as a water-cooled lining. A thermostat element, the housing of which is placed in series with the path of the fluid near the point of steam delivery, controls the rate of heat liberation. The locomotive boiler is equipped with an air preheater.

It will be seen that the several steps in the process of steam generation, that is to say, the heating of the feed to steam formation temperature, its gradual conversion to vapor, its subsequent superheating to the temperature predetermined by the setting of the thermostat contacts—all take place successively within the walls of a single tube. The boundary planes, therefore, which mark the beginning of steam formation and the beginning of superheat, are not definitely fixed, but shift their positions automatically as operating conditions vary, the amount of movement back and forth being governed by the pressure and quality of the steam delivered, the temperature of the feed and the rate at which the boiler is driven. It would be impossible, of course, definitely to locate these boundary planes—nor are we concerned with their exact location. Nevertheless, we are able to determine the extent of the three zones of the process with fair accuracy by making certain assumptions. Fig. 36 represents an attempt at such a determination for the locomotive boiler, the assumptions made being also given. The tube itself is shown diagrammatically in development with its several diameters greatly exaggerated, and the curves indicate what is taking place within the boiler, thermally and mechanically.

Control

The operation of the control system rests upon the principle that the rate of feed in a boiler should vary with the

TABLE X

SUMMARY OF CALCULATED BOILER PERFORMANCE DATA, DOBLE CLASS D-1 AND D-2 LOCOMOTIVE BOILER

1. Actual evaporation, lb. per hr	20,000	35,000	50,000	65,000	80,000
2. Equivalent evaporation per sq. ft. of total surface, lb. per hr	7.50	13.13	18.74	24.34	30.05
3. Heat absorbed by the fluid, B.t.u. per hr. (000 omitted)	22,000	38,850	55,500	72,150	88,800
4. Fuel, lb. per hr	1,290	2,310	3,390	4,540	5,760
5. Heat liberated in the firebox, B.t.u. per hr. (000 omitted)	23,860	42,750	62,700	84,000	106,500
6. Heat liberated per cu. ft. of firebox volume, B.t.u. per hr	28,700	51,450	75,500	101,100	128,200
7. Boiler efficiency not including effect of preheated air, %	84.5	82.2	79.8	77.3	74.8
8. Overall efficiency, air heater included, %	93.2	90.8	88.5	85.9	83.4
9. Flue gas temperature, all carbon assumed burned to CO_2, °F. (temperature at air heater entrance)	580	700	810	920	1,010
10. Heat absorbed per average sq. ft. of total heating surface, B.t.u. per hr	7,270	12,750	18,200	23,600	29,200
11. Weight of flue gas, lb. per hr	22,850	40,910	60,090	80,440	102,000
12. Gas per average sq. ft. of gas passage area, lb. per hr.*	1,180	2,110	3,090	4,140	5,260

*The average gas passage area is 19.4 sq. ft. The gas velocity is 70 ft. per second at full rating.

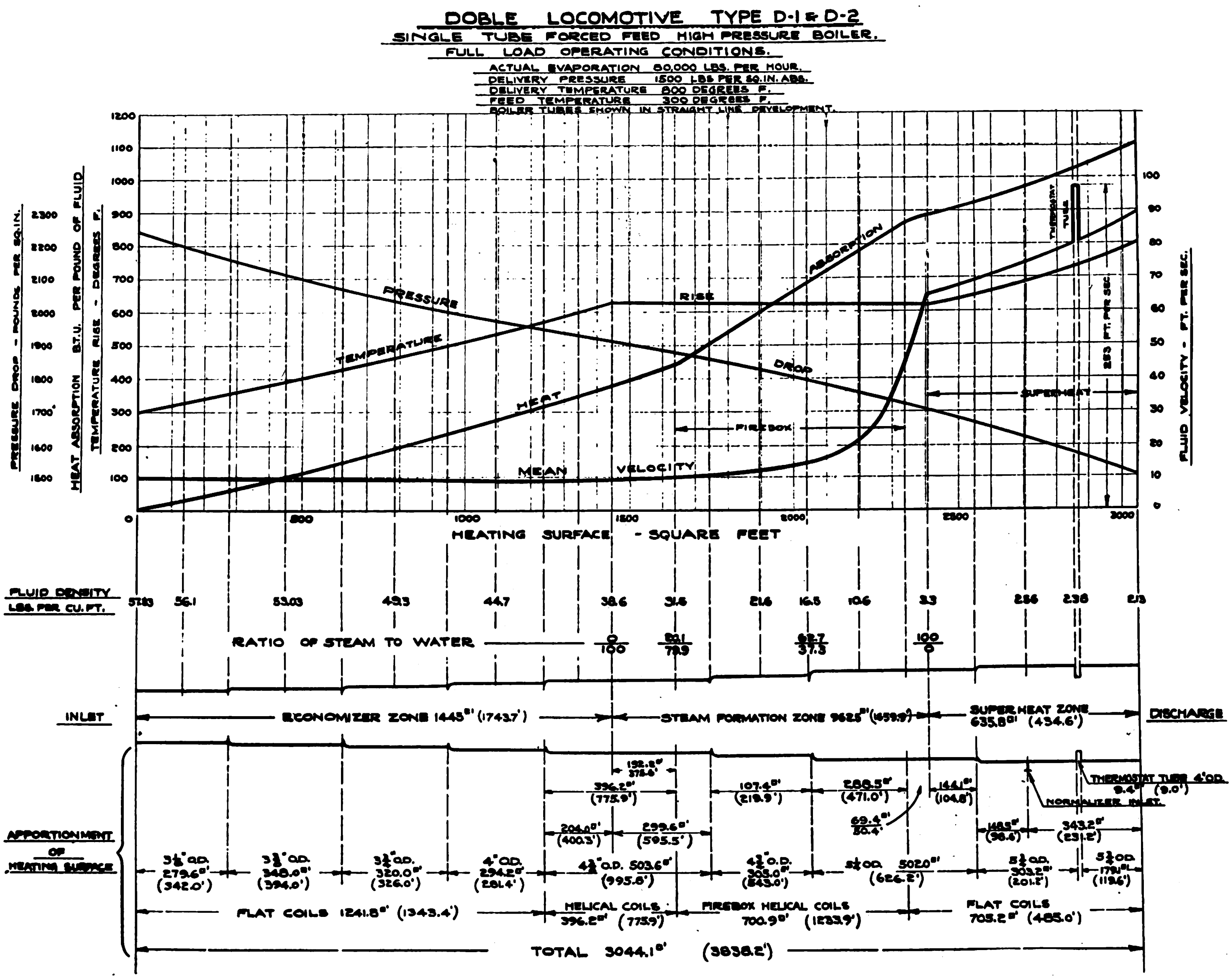

FIG. 36—DOBLE LOCOMOTIVE, FULL LOAD OPERATING CONDITIONS. APPORTIONMENT OF SURFACE AND STATE OF FLUID.

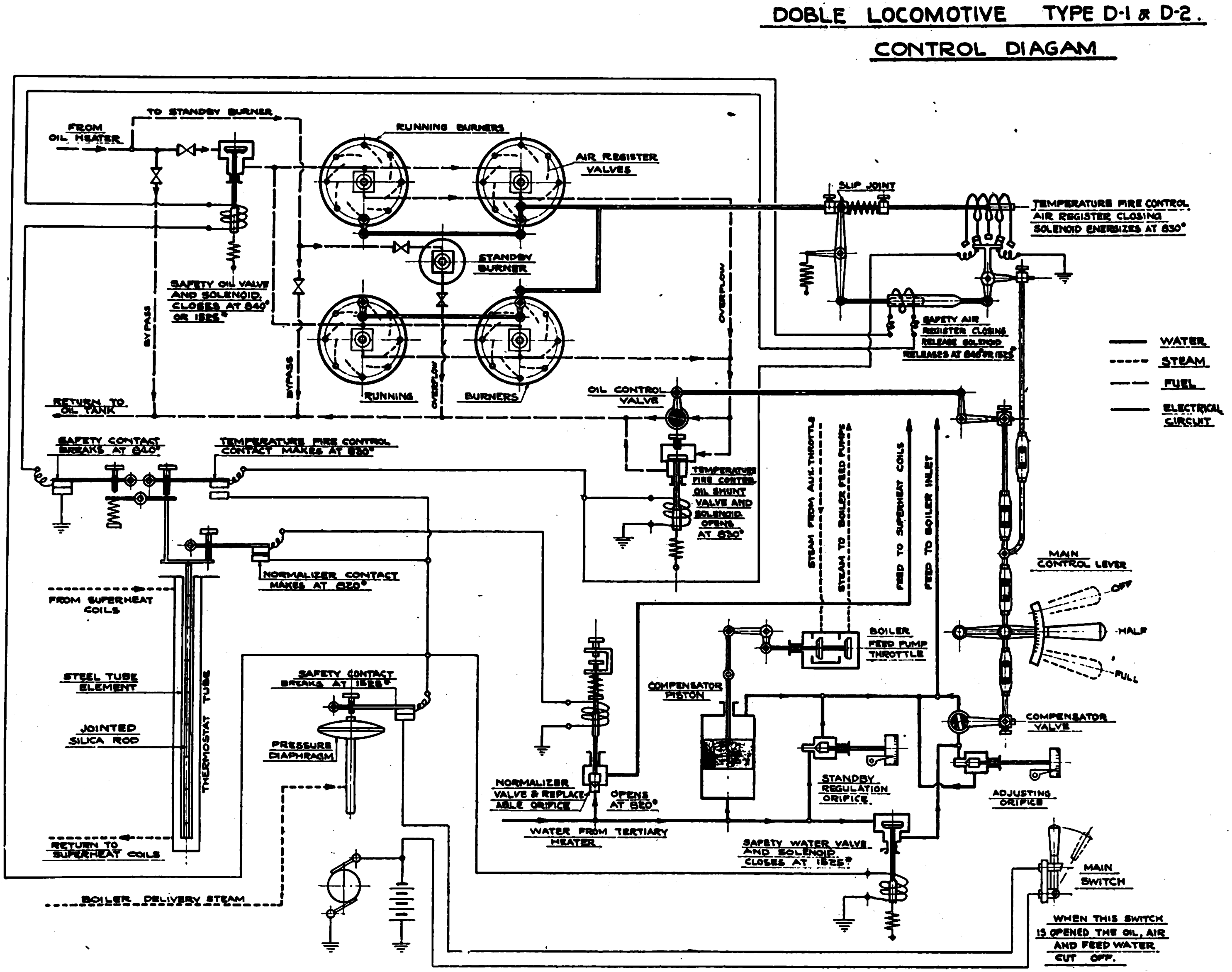
DOBLE LOCOMOTIVE TYPE D-1 & D-2.
CONTROL DIAGAM
FROM OIL HEATER
TO STANDBY BURNER
RUNNING BURNERS
AIR REGISTER VALVES
STANDBY BURNER
SAFETY OIL VALVE AND SOLENOID, CLOSES AT 640° OR 1525°
BYPASS
BYPASS
OVERFLOW
OVERFLOW
RUNNING
BURNERS
RETURN TO OIL TANK
SLIP JOINT
TEMPERATURE FIRE CONTROL AIR REGISTER CLOSING SOLENOID ENERGIZES AT 630°
SAFETY AIR REGISTER CLOSING RELEASE SOLENOID RELEASES AT 640° OR 1525°
WATER
STEAM
FUEL
ELECTRICAL CIRCUIT
OIL CONTROL VALVE
TEMPERATURE FIRE CONTROL OIL SHUNT VALVE AND SOLENOID OPENS AT 630°
SAFETY CONTACT BREAKS AT 640°
TEMPERATURE FIRE CONTROL CONTACT MAKES AT 630°
NORMALIZER CONTACT MAKES AT 620°
FROM SUPERHEAT COILS
STEEL TUBE ELEMENT
JOINTED SILICA ROD
THERMOSTAT TUBE
RETURN TO SUPERHEAT COILS
BOILER DELIVERY STEAM
SAFETY CONTACT BREAKS AT 1525°
PRESSURE DIAPHRAGM
STEAM FROM AUX. THROTTLE
STEAM TO BOILER FEED PUMPS
FEED TO SUPERHEAT COILS
FEED TO BOILER INLET
MAIN CONTROL LEVER
OFF
HALF
FULL
BOILER FEED PUMP THROTTLE
COMPENSATOR PISTON
COMPENSATOR VALVE
ADJUSTING ORIFICE
STANDBY REGULATION ORIFICE
NORMALIZER VALVE & REPLACEABLE ORIFICE
OPENS AT 620°
WATER FROM TERTIARY HEATER
SAFETY WATER VALVE AND SOLENOID CLOSES AT 1525°
MAIN SWITCH
WHEN THIS SWITCH IS OPENED THE OIL, AIR AND FEED WATER CUT OFF.

FIG. 37—DOBLE LOCOMOTIVE BOILER CONTROL DIAGRAM.

heat liberated, the ratio of the two being in proportion at any given load to the boiler's operating efficiency at that load. Fig. 37 shows the control diagram of the locomotive boiler. With a single exception, which is noted in passing, the system is in all respects similar to the one in successful operation on the small automobile boiler. The following numbered paragraphs clarify the notation and symbols of the diagram.

1. Connections and mechanisms are diagrammatic only; they merely illustrate the method and sequence of operation. For this reason solenoids are shown rather than apparatus perhaps more appropriate, and relays are omitted for the sake of simplicity.
2. The standby burner is entirely independent of the main controls. It serves as a pilot, and, in addition, delivers the fuel necessary to offset standby radiation and other heat losses; and it keeps the compressors in operation when the locomotive is standing or drifting.
3. The forced draft blower turbine throttle (not shown), is manually operated to maintain suitable pressure in the windbox, the amount of throttle opening being dictated by the color of the stack gases.
4. The main control levers and rods are adjustable both as to leverage and linkage. Once adjusted, they should require only infrequent changes
5. The temperature fire control solenoid is set to cut the air supply to half of whatever quantity happens to be passing at the time of its functioning. The temperature fire control oil shunt valve is set to pass half of the normal full-load requirement of oil.
6. Mechanical burners of the constant orifice pressure type are employed.

The main control lever in the diagram happens to be shown at half load, although any other setting would serve to illustrate the principle of operation just as well. Assume that all adjustments of leverage and linkage have been made. The air and fuel controls, then, permit the delivery, as nearly as may be, of oil and air at rates sufficient to sustain the fire at half load. The compensator valve at any setting of the control lever passes an amount of water just short of sufficient to satisfy the boiler's need, the deficiency being regulated by the adjusting orifice of the compensator. The delivery temperature rises, therefore, and when it reaches 820 deg. fahr., the normalizer contact of the thermostat makes and causes the normalizer valve to open and admit small quantities of water into the superheater coils. These injections of water into the superheater tend to bring the temperature of the steam delivered down to normal again, and a red light on the control board indicates that the normalizer is in action.

The action of the normalizer under ordinary conditions maintains a practically constant delivery temperature. If, however, the adjusting orifice valve has been improperly set and the deficiency of water supplied to the boiler is too great, the temperature will continue to rise. As the temperature rises, the temperature fire control contact, which is set at 830 deg. fahr., makes and energizes the oil shunt valve and air-closing solenoids which, respectively, cut the oil and air supplied to the burners in two, the water supply remaining the same. A blue light indicates that the fire has been curtailed, and this is a signal to the fireman to increase slightly the amount of water passed by the adjusting orifice. The correct setting of this value is shown by off and on indications of the red light (normalizer). Off and on indications of the blue light, with steady red light, show a deficiency of boiler feed.

If for any reason the temperature still continues to climb, the maximum-temperature contact of the thermostat, which is set at 840 deg., breaks, and this brings about the complete shutting off of the fuel and the air from the main or running burners, the boiler feed continuing unchanged. A pressure diaphragm provides against undue pressure rise and the breaking of the pressure contact cuts off the main burners, the air and the boiler feed completely, the standby burner, however, together with the standby water regulating valve, still remaining in action. The functioning of the controls constitutes a normal and orderly part of the operation of the boiler. Central station design, too, it should be noted, is exhibiting a marked trend toward automatic control at the present time, supplemented, of course, by manual control.

The feed pump throttle is controlled by the weighted piston of the compensator, and the feed water delivered varies with the amount actually required as determined by the position of the main control lever and the amount of opening of the regulating orifices of the compensator. By this means a constant pressure is maintained at the regulating orifices; hence, the rate of delivery to the boiler is determined solely by the total passage area of these orifices; for, should more water be delivered by the feed pump than the orifices can pass at this constant pressure, the weighted piston rises and the pump throttle is partially or completely closed. The reverse effect opens the pump throttle. The adjusting orifice is installed to provide a measure of adjustment to the compensator valve independent of leverage and linkage. It determines the normal boiler feed deficiency. The settings of the standby orifice and burner are determined by standby needs.

It will be seen that the control system of the locomotive boiler, as designed, calls for manual regulation of the boiler feed. The fireman must adjust his main control lever from time to time to satisfy the fluctuating demand for steam; increasing the supply with falling pressure; decreasing the supply with rising pressure. In the automobile boiler, however, the rate of admission of feed water is controlled automatically by a pressure diaphragm, and the driver of the car is relieved of responsibility for the maintenance of proper boiler pressure.

The tube in which the thermostat element is housed is positioned at the rear of the firebox immediately in front of the first bank of flat coils, although its connection with the superheater section, like that of the normalizer inlet, is some distance ahead of the point of steam delivery, Fig. 36. The thermostat housing is placed within the firebox so that, in the event of the stoppage of steam flow, the heat of the firebox will bring about the shutting down of the fire. The bore of this tube is smaller than the superheater tube, and the velocity of the steam correspondingly increased. This, by augmenting the rapidity of heat transfer, increases the speed of response of the element to temperature change.

Performance

Fig. 38 shows a performance curve for the small boiler developed from four tests, the data of one of which are presented as Table IX. A curve showing the performance of a modern steam generating unit recently installed in the Oakland plant of the Pacific Gas & Electric Co. is included with the Doble curve for comparison. The Oakland unit burns oil and delivers steam at 450 lb. and 725 deg. fahr., the rating being 425,000 lb. per hr. Its air heater is not given effect in the curve. Both curves are referred to total heating surface, including superheat and water walls, the total surface of the Oakland boiler being 35,000 sq. ft. Run No. 16 of Table IX records data for the highest driving rate attained during the Doble test. The boiler operated

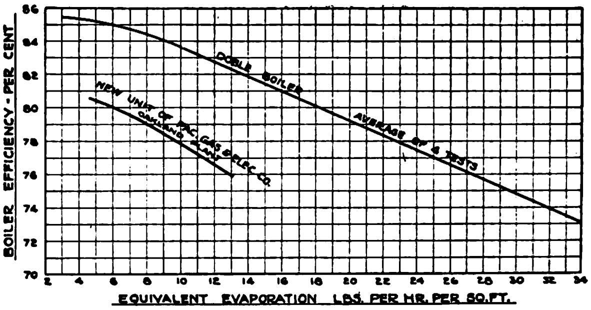

FIG. 38—DOBLE BOILER PERFORMANCE CHART.
DOBLE BOILER—GASOLINE.
OAKLAND BOILER—FUEL OIL.
CURVES ARE REFERRED TO TOTAL HEATING SURFACE.

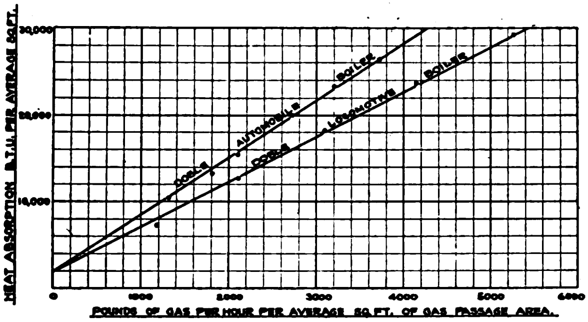

FIG. 39—DOBLE BOILER HEAT ABSORPTION RATES.

during this run at an efficiency of 76.96 per cent, the equivalent evaporation rate being 27.19 lb. per average sq. ft. per hr. This showing is all the more remarkable when it is remembered that the divisor employed to reduce evaporation to a sq. ft. basis is total heating surface and not merely evaporative surface.

Fig. 39 shows the results of the Doble test, Table IX, plotted in conformity with the general boiler heat transfer equation

$$R = a + b\,\frac{W}{A};$$

that is to say, heat absorption in B.t.u. per average sq. ft. of total surface per hr. plotted against lb. of gas per hr. per average sq. ft. of gas passage area. The tendency of the plotted points to range themselves in a straight line cutting the heat absorption axis just above the origin is well illustrated. The results of the several runs, then, exhibit a marked consistency with the experimental showings of boilers of other types. Calculated performance data for the locomotive boiler, based on the assumption that the Doble performance curve of Fig. 38 would hold for the larger generating unit, are presented in Table X, and the locomotive boiler heat absorption curve, plotted from the figures of items (10) and (12) of the table, is included with Fig. 39. The points fall below the Doble curve, and the average line ranged through them is at a lesser inclination, as we should expect; for it is well known that the inclination of such lines varies inversely with the area of the gas passage. The locomotive boiler, with its greater tube diameters, presents wider tube spaces to the flow of the gases.

Summary

It will be seen from the foregoing that the following is true of the Doble boiler:

1. A proportionally large amount of surface is presented to the radiant heat of the fire.
2. Both feed and draft are forced and, therefore, positive; each unit of working fluid in its progress through the tube passes successively over each unit of surface, and violent turbulence due to high velocity is set up alike in fluid and gas.
3. The coils in the convection section are placed across the direction of flow of the gases, and the inter-tube and inter-coil spaces are greatly reduced, while the amount of surface presented to the gases per lineal foot of gas passage is relatively large. With such an arrangement, the hydraulic mean depth of the gas passage is everywhere reduced to a minimum, a condition which, when the velocity of the gas is maintained at a high rate, promotes the rapid mixing of the gas, shortens the travel distance of the hot gas molecules between impacts with the cooler surface and increases the number of impacts per unit of time. The resultant impartation of heat, therefore, takes place at a very high rate.
4. The temperature drop of the gas and the temperature rise of the working fluid are both reasonably uniform from the burner to the stack; and this condition promotes the efficiency of heat transfer.
5. The boiler is essentially safe. There is no great reservoir of stored energy confined within the walls of a barrel of large diameter or compressed between expansive and precariously stayed flat surfaces. The explosion hazard does not exist. The accidental bursting of a tube is no more a serious matter than the blowing of the safety valve; for the sectional area of the escaping steam in either case is about the same.
6. The response of the boiler to widely and rapidly fluctuating demands for steam is practically instantaneous, and this rapidity of response does not depend upon the impounding of great reserves of heat within the unit itself, but rather upon the known ability of generators of the single tube type to convert the potential energy in the fuel instantly into steam as required.

In other words, the Doble boiler is a serviceable heat absorber of great efficiency because it combines to the very highest degree those elements of design which, in the light of our present knowledge of the phenomena of heat transfer, are known to augment the rapidity and efficiency of heat absorption.

Summary of Doble Laboratory Test No. 186

Standard Doble automobile boiler tested. Length of tube, 558.5 ft., of which 120 ft. forms the helical coil surrounding the firebox. Effective heating surface (measured outside the tube), 80.4 sq. ft., of which 10 sq. ft. was exposed in the firebox. Heating surface in the firebox is computed by multiplying the tube length by the outside tube diameter and the factor 1.4. Furnace volume, approximately 2.5 cu. ft. Fuel, gasoline; forced draft. Feed water 74 deg. fahr. Steam delivered at 850 deg. fahr.

Results of the test are shown in Table IX.

Summary of Calculated Boiler Performance Data
Doble Class D-1 and D-2 Locomotive Boiler
(Compiled from the locomotive report of Feb. 29, 1928)

Length of tube, 3838.2 ft., of which 1233.9 ft. form the water-cooled lining of the firebox. Effective heating surface, 3044.1 sq. ft., of which 700.9 sq. ft. are exposed to direct radiation in the firebox. Furnace volume, 831.5 cu. ft. Fuel, oil, mechanically atomized; forced draft with air preheated to 400 deg. fahr. 20 per cent excess, the air being heated by the flue gas. Feed water, 300 deg. fahr. Steam delivered at 800 deg. fahr. and 1500 lb. per sq. in., absolute.

Results of the tests are shown in Table X.

FOREIGN DEVELOPMENTS

Abstract

This Serial Report contains some interesting statements by American engineers, among them Messrs. I. E. Moultrop, A. D. Bailey and G. A. Orrok. Several foreign engineers have contributed some general statements, including Messrs. F. H. Rosencrants, W. H. Patchell, A. L. Mellanby, J. Mas Nieto and R. H. Andrews. A number of other prominent European engineers have submitted statements covering some detailed engineering developments. Some abstracts from foreign journals are also included. The opinions expressed in these statements are quite specific and indicate the general trend of power plant development in foreign countries.

Summary of European Development in Power Generation

STATEMENT BY I. E. MOULTROP, BOSTON, MASS.

Higher Steam Pressures and Temperatures

European engineers have gone farther in elevated steam temperatures than we have and they appear to be more interested in this step than in higher pressures. There are several installations operating or under way, with temperatures ranging from 800 to 840 deg. fahr., and the ones in operation seem to be reasonably free from troubles due to temperature. At Langerbrugge, and at one or two other places, they have standardized on carbon steel superheater tubes which are reasonably reliable for the above-named temperatures, but it is generally believed that the safe limit has been reached. Much study and research are going on to develop a commercial material which will be good for still higher temperatures.

They do not seem to be as much interested as we are in higher pressures. A small installation at the municipal plant at Bradford is designed ultimately to operate at 1100 lb., but the initial operation will be at 800 lb. The Imperial Chemical Company is building a plant near North Tees which will ultimately have a capacity of 100,000 kw. where the pressure will be 800 lb. and the temperature 840 deg. fahr. This is the largest high pressure installation of which I have any knowledge in Europe. These steam conditions were chosen because of need in their synthetic ammonia plant for a very large amount of process steam at a certain pressure and temperature, and they are superimposing a power plant on top of their process work.

The other notable development in high pressure is the Benson boiler as built by the Siemens-Schuckert Company in Berlin. They have taken the Benson ideas and developed a fair sized boiler which they had installed at their works in Siemenstadt some time ago, for the purpose of experimentation. I was advised that this boiler furnished the necessary power to operate their cable works for a month or two last winter while they were altering the works' power house. When this boiler was first promoted, the idea was to generate at the critical pressure of 3200 lb. and then reduce the pressure one-half for utilization in a prime mover. They now think that it is not necessary to cut the pressure in two as they can get prime movers that will work with pressures running from 2000 to 2500 lb. Of course, if this can be done, it makes this scheme somewhat more attractive. I am, however, not yet convinced that the Benson scheme has any advantage over the 1200 lb. development on this side, and during the long interview that I had with Dr. Gleichman, who is in charge of this development for Siemens-Schuckert, he could not show me where this system had any advantage in efficiency over ours, but he did think that the first cost was lower. This may be true, for apparently the Benson boiler can be constructed to be installed in the open which is a distinct saving of installation cost. He thought the boiler could be built cheaper as it has no large steam drum. I think there may be a little saving here, but it will not be as much as the Germans anticipate, because their experimental boiler was built of very light material and would not meet the requirements for American service.

I found with a great deal of interest that the Germans are producing boiler drums without riveted seams. They are turning out a great many welded drums, mainly forged welded. European steel interests are also giving some thought to drums forged from the ingots with no welds. One large manufacturer in England is building a forging plant to turn out solid drawn drums. They expect to produce drums at a cost very close to that of the riveted drum. If possible this will materially reduce the cost of building a high-pressure boiler along conventional designs.

Turbine Design

There seems to be little new in turbine design abroad. So far, the manufacturers have not been called upon to build very large units, and, therefore, have not run into the troublesome problems that we have encountered here on the extreme sizes, but they are all giving much attention to refinements of design. They seem to be having some of the bucket troubles which we have experienced and are searching for more suitable material for buckets. They are solving the troubles at the entrance edge of the bucket by making this edge blunt and rounded like the front edge of an airplane wing instead of a knife edge which promises to give much longer life. Buckets are subject to very fine tests after fabrication to detect cracks. Standard size units abroad seem to be about 20,000 kw. Much attention is given to efficiency which is equal to or a little better than what we are obtaining. There is no doubt but what they get better materials, their foundry work is better, and I am inclined to think that their machine shop work is equal to or a little better than on this side.

Boiler Design

It is surprising the number of different boiler designs one finds in Europe. One might say that the B. & W. is still the standard design. Outside of the Benson boiler the most striking design I think is the Loffler. Many are practically a modification of the Stirling type and others are hard to describe. Apparently they are searching for better efficiency, and out of the multitude of different designs something may be brought out which will be a distinct improvement, but it will take time to prove this.

Processing of Coal

There is quite a bit of discussion on the processing of coal in Europe. Many schemes are being advocated, but I failed to find anything of real value to the power plant engineer in the United States. As I see the situation, the whole idea depends on the by-products and their market value. With the ordinary by-products taken at their present market value, there may be a little gain by some of the carbonizing systems, but one must not forget that in any of these carbonizing systems from 20 to 25 per cent of the heat value of the coal is lost. This is quite a handicap to start with, and the market value of the by-products does not have to drop very much before the enterprise would cease to be profitable.

Publication No. 289-64, Serial Report, Prime Movers Committee.

Thermal Storage

Thermal storage seems to be getting a new lease of life in Europe, and a scheme has been developed whereby the storage energy is utilized in a special turbine of cheap construction which will operate on varying pressures down to within a few pounds of atmosphere. This seems to have some merit for certain conditions. I am advised that one continental utility is giving serious consideration to installing this system in a plant it is about to build. (This plant is now under construction at Charlottenburg.—Editor)

Fuel Burning

Following the development of powdered coal in the United States the idea appears to have been taken up enthusiastically abroad, and quite a number of powdered coal installations have been made during the past few years. This is natural when you consider their chief stokers were of the chain grate type which had decided limitations. I was surprised, however, to find a decided trend back toward the stoker. The American type of underfed stoker is being introduced and seems to be meeting with favor. Several of the latest stations to be built are equipped with stokers. It was interesting to find two new steam plants in Italy, the one country in the world where water power has been universally used up to now and where there is no coal. Until recently there were practically no steam plants in Italy, but both the Milan Edison Company and the Lombardi Company, which, between them, practically cover Italy, have found a steam stand-by a necessity with water power. The Milan Company has built a station at Genoa which is worth one's time to visit, and the Lombardi Company has built a plant near Turin. Coal from England will be burned on stokers.

The most notable power plant east of the Atlantic is the Klingenberg Station in Berlin. In my opinion, this station compares with anything in the United States, both in design and in efficiency. The cost of this station is remarkably low, something like $60 per kw. It is a remarkable station also because it was designed and built in about a year.

European Observations

STATEMENT BY ALEX. D. BAILEY, COMMONWEALTH EDISON CO., CHICAGO, ILL.

As one travels through a foreign country rather hurriedly and attempts to see as much as possible in a given time, he is able to form only general impressions, and detailed study of particular points must be left for more deliberate inspection. We know from our own experience that everyone is on his best behavior when visitors are around and the family skeletons are securely locked in the family closets. First impressions are quickly made and if we had been able to stay longer and had been able to study conditions more closely, some of these might have been altered.

Station Design and Operation

With a few exceptions, European stations generally evidence the necessity for the strictest economy, particularly in the construction of station buildings. The architectural features are generally missing. On the other hand, the Klingenberg Station, in Berlin, is probably one of the finest examples of architectural design which one could find. From a technical standpoint as well, this station is very impressive.

The water power stations of the Italian Edison Company in the northern part of Italy are wonderful examples of architecture, both in design and in the beauty of their finish externally and internally. With the investment costs as high as they must necessarily be, because of natural conditions, one wonders how this additional expense can be justified.

Both turbine and boiler units are generally smaller than in America. The largest boiler installation in Europe we were told has a maximum capacity of 300,000 lb. of steam per hour, and boilers of over half this capacity are exceptional.

The development of transmission systems is growing and spreading very rapidly, and new stations of large capacity are being planned which will compare favorably with installations in this country.

Investment costs are, of course, much lower than in this country, and when to this is added the economical construction of buildings, the resulting costs are quite surprisingly low, about sixty per cent of American costs, or possibly less.

Most of the stations which we saw are operating on load factors which we would consider very low, and in addition they carry an unusually high percentage of reserve capacity. Station outputs are correspondingly low. The largest single station output in Great Britain for last year was three hundred and twenty-five million kw-hr., and only two others were above three hundred million kw-hr.; six more had an output of over two hundred million. On the continent some of the largest stations have an output considerably in excess of this figure, but the output is invariably low when compared with the capacity installed.

In the operation of their stations it is quite apparent that they are subject to about the same kind of troubles which we encounter here, and that they are faced with about the same problems as those to which we are accustomed.

Although manufacturers and operators were loath to admit or discuss troubles with their equipment, it is quite evident that human nature and machinery are very much the same in Europe as in America, and that they are both subject to the same ills.

Higher Steam Pressures and Temperatures

Whether European engineers are more daring than their American friends may be open to question, but it is a fact that several plants, both in Great Britain and on the continent, report that they have been operating for considerable periods with steam temperatures of 800 deg. fahr., or even higher, and that super-heating equipment, piping and turbines have stood up successfully under these temperatures. Many of the newer stations being planned will operate at steam temperatures from 800 to 850 deg. fahr., and most of the turbine manufacturers seem to be ready to build turbines for this service. They all say that high steam temperatures are entirely a matter of superheater operation.

In the matter of higher steam pressures, there is an 1100 lb. installation at Bradford, England, although the turbine is quite small. This exhausts into steam headers in the older part of the station, which operate at 200 lb. A larger unit is being planned for the same station.

On the continent several turbine manufacturers state that they have built, or are building, small turbine sets for extra high pressure, in the neighborhood of 100 ats. (1420 lb.). None of them carry the steam through the entire expansion, but are super-imposed on an existing steam system or the steam is exhausted at some fairly high pressure, and used for industrial purposes.

The Benson boiler and turbine at the Siemens-Schuckert Works, in Berlin, are in continuous operation, and a new boiler installation with the same operating pressure, but somewhat different in design, is being planned by the manufacturer.

So far as turbines are concerned, the general trend of European turbine design is favorable to higher temperatures, as turbine wheels are generally small and material stresses are correspondingly reduced.

Pulverized Fuel

The application of pulverized fuel is spreading rapidly, not so much because of the increase in the size of the boiler units, as because everyone expects to burn low grade fuel at high efficiency.

The development of this method of firing seems to be at the "optimistic" stage. Reports of the success of American installations have given it a great impetus. There were the usual discussions regarding Bin Systems vs. Direct Firing, and the exponent of each system quotes from American practice those points which will best serve his purpose. Very few have seriously attempted to catch the dust in the flue gas, and if they did catch it no one seems to know of a satisfactory means of disposal. This phase of the pulverized fuel problem has not been given as much study as it demands if this method of firing is to become more universal. So far the subject is dismissed by saying it is not yet a problem and that it can be easily taken care of whenever it becomes necessary to abate the nuisance.

The Germans and Czechs report that they can successfully burn pulverized brown coal, which has over 50 per cent moisture as mined. The Russians are experimenting with pulverized anthracite culm, brown coal and oil shale, and though they have only small installations in service now, they are planning a great expansion of this capacity in the next three years.

Coal Carbonization

Judging from the papers presented at the Fuel Conference, and the discussion which followed, there is the greatest interest in this subject, both in Great Britain and on the continent. It was quite surprising to know how many processes and projects are being tried, although none of them apparently have been commercially successful, or would be on a large scale. Most of the installations are of an experimental nature and size. It was reported that in England there were some sixteen processes being tried with installations having a capacity of over ten tons of coal per day. It is hoped, of course, that by some such means, the low grade fuels, which are at present sold below mine cost, can be utilized, and that in addition to the by-products, a smokeless fuel can be produced for the thousands of open grates which are in general use.

In Germany they are attempting to carbonize their low grade brown coal, not alone to produce a suitable fuel, but also to reclaim the by-products. In general it is hoped that this method of coal utilization will develop a source of supply of motor spirits and oils, which must now be imported due to lack of natural resources. Everyone is also mindful of the repeated warnings of the limited supply of oil all over the world.

The economics of coal carbonization were quite generally discussed, and the importance of the fixed capital charges was very properly emphasized. It was brought out in the discussion that even though a market might be found for the various products, the success or failure of this method of coal treatment would depend primarily on the cost of the installation.

Power Situation in Europe

STATEMENT BY GEO. A. ORROK, CONSULTING ENGINEER, NEW YORK, N. Y.

In the field of power generation in Europe the past year was marked by a significant improvement in the volume of energy generated, in the provisions for the future, and in the methods leading toward higher economy. Furthermore, the tangible results in economy obtained by the combined efforts of engineers and financial administrators has resulted in a certain stabilization of technical ideas, not without the cooling of certain enthusiasms.

Just as the many countries of Europe have been consolidating their financial position, stabilizing their currencies, readjusting their many channels of trade, so the power people have shaken off the inertia of financial conservatism, and on the other extreme have avoided overreaching the mark by adapting experimental designs before development work had been complete. From the maze of highly technical attempts to save heat units the industry is devoting itself to making and selling kilowatt hours. In spite of the low load factors, the old moderate pressure stations have improved their heat rates and it is quite surprising to see what could be done by the organization of combustion control and by proper load distribution.

One large concern in southern France, which operates a system of steam and water power stations, succeeded in associating the technical and financial cooperation of its large consumers and now the production of the latter is subject to the orders of the central load dispatcher. Another such concern in eastern France succeeded in linking the metallurgical and mining industry with their power plants to such an extent that blast furnace gas engines, waste heat steam plants, water power, and gas engine plants, are working as constituent units in a complex power generating system controlled by the central load dispatcher according to a plan of annual production. Apart from the technical difficulties of linking such different sources of power, these feats reflect highly on the financial sagacity and cooperation of the responsible administrations. Of course, the economic gains from such reorganizations are far greater than from any technical improvements. France is looking far into the future and her development of water power with special aid from the government is at present well ahead of what the economic conditions of the year would warrant.

Director Rehmer of the Berliner Städtische Electrizitäts Werke has published a plan of the future extensions of the Berlin system calculated for ten years ahead. The significance of such plans on a national scale for the better development of industry is patent. The long distance transmission lines in Germany have gradually reached the point in development in which the water power of the South, the bituminous coal of the West and the brown coal of Mid-Germany is being utilized to the best advantage. Of course, the fluctuating coal prices will be taken care of by the load distribution as well as the peak power demands. With the thoroughness peculiar to the Germans, many smaller concerns seek to utilize the local economic differentials even on slim margins by installing power plants of the mixed type, special peak load units, steam and hydro accumulator stations. But as a firm ground for the better future is seen the unceasing effort of improving the operating conditions, particularly combustion, in the existing plants.

The export and import of power between the countries exceeded that of the previous year. The greatest possibilities of improving the performance of old plants is in England, and the efforts of the Electricity Commissioners will be watched with great interest. The development will begin, probably by a wholesale shut down of the smaller plants and proper loading of the larger ones. The short transmission distances favor the construction of super stations, the program of which is under study.

Probably there is no other country where the utilization of the major water power source is pushed to such an extent as Italy. There we can see the steam plants as well as the majority of water storage plants, built to increase the total output from the costly hydroelectric developments. Some of their steam peak load stations present the finest examples of the sound blending of economical and technical principles in designing a station for the specific conditions.

In Belgium, Czechoslovakia and Holland, where the individual electrical outputs of the stations are small, we see the boldest steps taken to secure thermal economy. The Langerbrugge and the Witkowitz stations are operating at 850 and 930 deg. fahr. steam temperatures; the Merwede Canal station and the Maurits station represent the highest and most complete technical developments for a small station. It is interesting to note that parts for these stations were purchased from England, Germany, Switzerland, France and the United States, besides those which were made at home.

The purely technical situation as concerns the steam stations presents three main items of interest. First, the reduction in cost of the high pressure equipment which goes hand in hand with the acquired experience, increased volume of orders and reduction in the number of paths for development. Second, the fractionation of fuels, peculiar to European countries where the shortage of native liquid fuel, smoke nuisance, the short hauls and the ability to get along with low capital returns favors the different ways of processing the raw coals. Third, due to the increased size of their power plants the European engineers are realizing the economics coincident with the larger sized machinery and the size of their units are steadily increasing. Not a small part of this must be attributed to their annual visits to this country, where they become familiar with machinery on a much larger scale.

Concerning the water power situation, we can notice a sustained interest in the low head developments, the better sites being already developed. Tidal power in England is quite likely to soon become an accomplished fact.

Notwithstanding the increasing number of powdered coal installations it appears that a reaction toward stoker firing has set in. The quiescent status of the stoker business has been changed and the current year probably will see a great revival in its use which in Europe has lagged far behind its American contemporaries. The return to stoker firing in Europe is perhaps connected with the flying ash nuisance and the strict smoke ordinances vigorously enforced. The attempts to obtain complete ash precipitation have not been successful. The unwieldy European stokers have given way to more flexible designs and together with the water cooled furnace walls the flexibility of firing inherent to the powdered coal will be attained with stoker firing even for the most difficult classes of European coals.

STATEMENT BY F. H. ROSENCRANTS, INTERNATIONAL COMBUSTION, LIMITED, LONDON, ENGLAND

This company states, with considerable gratification, that in comparison with previous years' reports, in which new forms of equipment were described, there have been few changes made in the past year. This applies specifically to the activities of the firm with which the writer is officially associated and also generally to England as a whole, in so far as information is available. We are content with the fundamental design of equipment now in use.

The argument as between direct firing and the bin and feeder system remains unsettled, though at the moment those in favor of the former system will probably outvote the latter, those favoring it preferring to accept its hazards and disadvantages rather than the complications represented by existing installations of the other system. In this the writer observes a consistency with the growing sentiment for simplicity in design, construction, and operation as applying to steam electric generating stations. In the bin and feeder system we have unquestionably reached, and are now receding from, a pinnacle of complications. Driers as such are rapidly ceasing to be considered an essential part of a pulverized fuel fired system, the scheme of drying in the pulverizer circuit with highly preheated air having rapidly taken its place.

Vents to the atmosphere with their consequent dust nuisance have ceased to exist on new installations. The close association of the pulverizing units with the boilers which they serve is eliminating the need of elaborate transport equipment, which has been reduced to that required for transferring fuel from a given mill to adjacent boilers, operated only in emergency. Normally each boiler is supplied by its own mill direct to the storage bin. The capacity of the storage bin may be and is being reduced to only a few hours' supply with a consequent saving in space and first cost, but with the advantage of retaining the superior control and reliability incidental to the bin and feeder system.

The item now receiving the greatest attention is the further development of dust elimination from flue gases. To date this problem has been attacked through the medium of centrifugal devices and by water washing. Electric precipitation, while the subject of some discussion, has thus far made no progress in England, owing primarily no doubt to its first cost. In many instances, centrifugal dust separation in its best developed form will constitute a sufficient remedy, since by such means the most objectionable coarse material is completely removed, though the color of the issuing gases is but little cleared. In the congested districts, however, something more effective will doubtless be demanded. At the moment, developments in the water washing scheme appear most promising. Several installations designed as an afterthought and applied under unfavorable conditions are in operation, but are giving results which are most encouraging and point the way to further progress in the development of designs which, being foreseen, may be installed under favorable circumstances. Better results, therefore, may be anticipated.

The necessity and desirability of water cooling the furnace walls has been universally recognized by all suppliers of equipment, and there is a rapidly growing tendency to incorporate such walls as an integral part of the boiler, whereas in the past such walls were a growth upon the conventional design of the boiler unit. In nearly every instance existing installations with their multiplicity of downcomer water pipes, riser steam pipes, external circulating tubes, etc., have every appearance of being an afterthought. Persistency, however, in retaining the individuality of the furnace cooling system independent from the boiler unit seems, to the writer, too ridiculous to contemplate. He is sure that while past efforts in this direction may leave something to be desired, such efforts are a step in the right direction and will prove forerunners of what will ultimately become established practice. So far as England is concerned, several contracts have been placed recently for such units, and a good many more are anticipated prior to the publication of this data. The adoption of such units is resulting in more or less drastic modification in arrangement of equipment, with saving in first cost and simplification in design, construction and operation, with consequent greater reliability and less anticipated maintenance. At the moment, details of these designs are not available for publication.

Trends in European Power Development

STATEMENT BY DR. A. L. MELLANBY, ROYAL TECHNICAL COLLEGE, GLASGOW

In reviewing developments during the past year in Great Britain and on the Continent, the most noticeable changes are in the two branches of engineering usually considered to be the most conservative—those of marine and locomotive engineering. In the marine world the reaction to the success of the Diesel engine is now taking effect, and shipowners and superintendents are prepared to take risks which a few years ago they refused to face, in order to obtain that increased economy which steam engines and boilers are still capable of giving. The locomotive world has also seen remarkable departures from the almost reverenced type of steam engine, and internal combustion units, together with special types of steam engines and boilers, have been tried with encouraging results. Confidence in the use of very high pressures is most evident on the Continent, and several novel designs of locomotives have been put into service using pressures and temperatures that a comparatively few years ago would have been regarded as impracticable.

Central Station Practice

The tendency to use very high pressures in central station practice is no longer so evident, and the more recent of the larger plants are being designed for moderate pressure. This is probably due to the careful study that has been given during the last few years to thermodynamic problems associated with the boiler and engine room. Dealing with ideal engines only, it is easy to show that increased economy is intimately associated with constantly increasing pressures. But when the losses which must inevitably accompany the very high pressures are taken into account, the promised economy is not so evident. The gains to be expected from pressures beyond 1000 lb. per sq. in. are very small indeed. In Britain, where at present capital outlay has to be closely watched, very careful attention has been given to the first costs of high pressure plants as well as to the diminished fuel consumption that might be anticipated. With coal at its present moderate price, and with load factors much below those common in America, the actual economic gain to be obtained from very high pressures presents no attraction when the present cost of plant is taken into account.

British Examples

This policy is reflected in the new boiler installation for the Clyde's Mill Power Station of the Clyde Valley Electrical Power Co. Four Babcock and Wilcox cross-drum boilers will be installed. Each boiler is provided with a steel tube economizer and a tubular air heater, and at its normal rating will provide 87,500 lb. of steam per hour with a maximum rating of 116,000 lb. per hour for two or three hours. The working pressure will be 400 lb. per sq. in. with a temperature of 750 deg. Fahr. Chain grate stokers will be fitted and the preheating will raise the temperature of the admission air to 225 deg. Fahr.

A further illustration is afforded by the recent extension to the Barton Power Station of the Manchester Corporation. This station was opened in 1923, and since then has been noted for its low fuel costs and high thermal efficiency. The latest returns indicate that during last year the average coal consumption was 1.39 lb. per kw-hr. generated, and the thermal efficiency was 21 per cent. Three additional Babcock & Wilcox marine type boilers were installed, two of which are fired by chain grate stokers and the other by pulverized coal. Each of the stoker-fired boilers is capable of producing 150,000 lb. of steam per hour and the pulverized fuel boiler 170,000 lb. at 375 lb. per sq. in. and 750 deg. Fahr. The new generating set will develop 40,000 kw. and is of the tandem impulse type, with 24 stages in the high pressure and 16 stages in the low pressure cylinder.

A Continental Example

The Klingenberg station of the City of Berlin Electricity Co. illustrates the latest continental practice. Sixteen boilers operate at 500 lb. per sq. in. and 770 deg. Fahr. with a maximum rating of each boiler of 160,000 lb. of steam per hour. All boilers are fired with pulverized coal. Each pair of boilers is served by a steel chimney 230 ft. high. The turbo-generators, three in number, have each a maximum rated capacity of 80,000 kw. and are the largest units running in Europe at the present time.

Super-Pressure Plants

The only example in Britain of very high pressure units is at Bradford, where a new high pressure turbine, designed to take steam at 1100 lb. per sq. in. and 800 deg. Fahr. has been added to the old installation. The exhaust from the new turbine is led to the existing steam main pipe and from there passes to the older turbo-generator sets.

A boiler for pressures of the order of 1600 lb. per sq. in. has been constructed by Messrs. Sulzer Bros. at Winterthur, which may briefly be summarized as a combination of a low-pressure boiler acting as a feed water heater auxiliary to a high-pressure boiler where all the high temperature heat transfer takes place.

In the Loffler boiler the whole of the high temperature heat transfer is to the high pressure steam through the superheater tubes. The superheated steam so produced is partly used for outside consumption, but the greater portion passes into a drum, where it evaporates feed water as saturated steam which is, in its turn, superheated and the cycle repeated. Several boilers of this type operating at 1700 lb. per sq. in. and 900 deg. Fahr. are in service.

A number of boilers on the Atmos principle, where steam is generated in revolving tubes, have been installed in Sweden and in Germany. These boilers operate at a pressure of 1500 lb. per sq. in. and are stated to be working satisfactorily with absence of trouble from the rotating elements.

STATEMENT BY W. H. PATCHELL, CONSULTING ENGINEER, LONDON, ENGLAND

The Annual Report of the Electricity Commissioners for Great Britain for the year ending March 31 is only published late in December, so that the Report for 1927-28 is not yet available.

The Grid

The 1926-27 Report records progress in the development of schemes by the Central Electricity Board, which have been prepared and transmitted to them by the electricity commissioners.

Under such schemes the Board is constituted the central supply authority from whom authorized undertakers will generally obtain their supplies of electricity in bulk. The distribution of the supply and the commercial development of electricity is left in the hands of the undertakers, as previously.

Such schemes determine what generating stations, existing or new, are to operate as "selected" stations and provide for their interconnection by main transmission lines, either existing or to be constructed by the Board.

The principal main transmission lines will be three-phase overhead, operated at 132,000 volts between phases, with a capacity of 50,000 kw. The secondary main transmission lines will be for 33,000 volts or other approved voltage. The commissioners have based their estimates for the London district on three phase 22,000 volt cables, but are carefully watching the result of operating the 66,000 volt cables in Paris, and of the 132,000 volt cables at Chicago and elsewhere, hoping that the experience gained before the Board must issue its specification, will enable a higher voltage to be adopted without undue risk.

A model of the principal transmission towers was lately shown, and they were described as approximately 80 ft. 0 in. high, 16 ft. 0 in. sq. at the base. The conductors will be placed 12 ft. 0 in. apart vertically and will, for the Central Scottish scheme, be steel cored aluminum cable with a diameter of 0.77 in., equivalent to copper of 0.157 sq. in. section.

The schemes cover areas of the country in appropriate regions so that work may be begun in such areas in such a manner that they will eventually form a coordinated whole.

Up to date, schemes have been put in operation for the industrial regions of central Scotland and for southeast England. Several joint electricity authorities have also been formed who later on may be included in schemes for the areas in which they are situated. The vista looms heavy with questions of over-lapping and load dispatching. Schemes have also been published, but are not yet adopted for the northwest midland district and central England. Such is the "Grid."

Power Station Economy

The returns of fuel consumption and kilowatt-hour generated made by the electricity commissioners for the year ending March 31, 1928, was published in October, 1928.

Such returns are in respect to 570 generating stations, which is the same number as in the previous year.

The total number of kilowatt-hours generated was 9,927,850,630, an increase of 18.7 per cent over the previous year.

The total coal, coke, and fuel oil consumed was 9,224,151 tons, or an increase of 4.1 per cent.

The lowest fuel consumptions recorded among the steam stations are:

Name of Station	Kw-hr. Generated	Load Factor, Per Cent	FuelConsumption Lb. per Kw-hr.	Thermal Effy, Per Cent
Padihan (The Lancs Pr. Co.)...	45,176,309	36.2	1.37	21.03
Barton (Manchester Corp.)....	325,427,230	51.2	1.39	21.07
North Tees (Newcastle-on-Tyne Co.)................	249,374,810	47.3	1.39	20.49
The best internal combustion engine station are:				
Oil (Bognor)................	854,886	20.1	0.62	28.23
Producer Gas (Thirsk)........	495,959	30.0	1.45	16.60

The average fuel consumption converted to the basis of coal over all the stations is:

Steam Stations ..... 2.16 lb. per kw-hr. generated
Oil Engines .... 0.91 lb. per kw-hr. generated
Gas Producers ..... 2.24 lb. per kw-hr. generated

The steam conditions obtaining at the first three stations are interesting, and show what can be done with a moderate pressure and temperature:

Padiham......Lb. per sq. in. gage 250; temp. deg. Fahr. 620
Barton........Lb. per sq. in. gage 370; temp. deg. Fahr. 677
North Tees....Lb. per sq. in. gage 450; temp. deg. Fahr. 650

While North Tees had reheat in the earlier plant, it has not been included in the extensions.

Among novelties in new plants, a 40,000 kw., single spindle, 2 cylinder, 1500 r.p.m. turbo alternator has just been started at the Barton station.

The 1200-lb. set at Bradford has been delayed by building operations. This is the only example of compounding a station since Langerbrugge in Belgium, where the first 800-lb. boiler with a 2000 kw., 710 lb. gage pressures, 828 deg. Fahr. machine was started in 1925. They now have another 6000-kw. set also for "compounding," and have ordered a three-cylinder 20/25,000 kw., 3000 r.p.m. machine to run condensing.

Steam pressures are increasing. Several plants lately ordered on the Continent are to operate at 500-600 lb. The I. C. I. have had a 600 lb. plant at work for some time at Runcorn; their 800 lb. plant ordered for Billingham is just being started.

The last order for Yallourn, Melbourne, which plant started with 270 lb. pressure, is for 650 lb.

The London Power Company is putting in 600 lb. for the new station at Battersea, and has just ordered for it two 67,250 kw. turbo-generators to operate at 570 lb. per sq. in. gage pressure and total temperature of 850 deg. Fahr., with a feed heating system by bleeding.

The boiler position is interesting. Steel manufacturers are now supplying hollow forged steel drums 50 ft. 10 in. long, 4 ft. 6 in. internal diameter, with a finished wall thickness of 4½ in. On the Continent, gas welding has made great advances. About 700 welded drums were supplied up to the end of 1927, including 39 for the Rummelsburg station, Berlin, and are working satisfactorily at 525 lb. steam pressure.

A huge hydraulic press, which will bend plates 40 ft. 0 in. in length, 2¼ in. in thickness, to a three-quarter circle of 4 ft. 6 in. in diameter, has lately been put to work.

British insurance companies now accept welding for steam pipes and valves of large dimensions, and in view of the experience with welded drums on the Continent, may soon be induced to accept welded drums as commercial risks and put an end to the present anomaly. It may also have a steadying effect on the present rapid rise in prices when the boiler pressure exceeds 400 lb. per sq. in.

The question of dust from pulverized fuel fired boilers is not yet settled. Hackney, which is a "selected" station for London, has abandoned its pulverized fuel plant as unsuitable for London conditions.

The London Power Company are adopting stokers for Battersea. Berlin has pulverized fuel at Klingenburg and is adopting stokers for its new station, which is in a better residential quarter. Meantime, Derby is increasing its pulverized fuel installation.

The Fuel Conference in September brought up the combination of low temperature carbonization and steam raising, but so far Dunston was the only installation described at the Conference, though there are rumors of the next Newcastle installation being on the same system.

Combustion in Spain

STATEMENT BY J. MAS NIETO, CONSULTING ENGINEER, BARCELONA, SPAIN

Up to the present the combustion of coal in Spain for the purpose of producing steam has not made much progress. There are few plants that we may call modern steam plants. What we term modern plants in Spain consist merely in the use of water tube boilers, most of them of the Babcock & Wilcox type, which are now manufactured here.

In the industrial districts water is generally very hard and only now the use of water softeners has become popular. This, of course, has contributed to the use of old types of boilers with a very low efficiency.

Due to the fact that Spain has important coal sources of middle and low qualities, the combustion in pulverized form will become very important in the near future. At present very few plants of this kind are installed. Some successful tests have been made in cement kilns, and a very few trials have been carried out in steam plants. The most modern of its kind was recently adopted by "Cooperativa de Fluido Electrico" for their steam reserve plant. This plant is situated in the Pyrenees Mountains, close to the coal mines. It consists of three Garbe boilers, of 590 sq. m. (6350 sq. ft.) heating surface each, to work at 16 kilos per sq. cm. (227.5 lb. per sq. in) pressure, at a temperature of about 375 deg. Cent. (700 deg. Fahr.)

The pulverizing plant contains a raw coal bunker of 100 tons capacity. Coal is thence conveyed to rotary dryers and stored in two bunkers of 40 tons capacity each. There are two pulverizing mills of the "Hardinge" type with the necessary separators, fans and cyclone. Coal bins of 25 tons capacity each have been installed in front of each boiler. Burners, feeders, fans, exhausters, combustion chambers, water tube walls, etc., are of the "Lopulco" type. Air heaters and "Green's" economizers, together with an hydraulic system of ash removal, are also installed.

The following results have been anticipated at normal load with coal having a maximum of 7 per cent volatile matter and 40 per cent ash.

Boiler plant efficiency	81.5 per cent
CO_2 at base of chimney	12.5 per cent

As Spain is a very mountainous country, it is also very rich in hydraulic power, which is now having its maximum development. Electrification is rapidly gaining ground and railways are now electrifying their lines. It is hoped that in a few years' time almost all the railways will be electrified. This will necessarily call for important and modern steam reserve power plants.

Engineers will be interested in the International Exhibition at Barcelona, Spain, in 1929. Special electrical features will be displayed in grounds and buildings. Eleven palaces will be devoted to exhibits of industrial and engineering developments. Many international congresses will be held during the exhibition. The whole enterprise has been executed on an elaborate scale and will well repay a visit.

Recent Developments in French Central-Practice

STATEMENT BY R. H. ANDREWS, CONSULTING ENGINEER, PARIS, FRANCE

From the standpoint of heat-power engineering, the most important regions in France are the industrial districts surrounding the city of Paris and the different coal-mining districts, mainly in the north and east.

The power needs of the Parisian zone are at present sup-

TABLE I

ELECTRICAL SUPPLY OF PARIS AND SURROUNDINGS

Central Station	Operating Company	Capacity, Kw.		Steam Conditions	
		Present	Ultimate	Press., Lb. per Sq. In.	Temp., Deg. F.
Gennevilliers...	Union d'Electricite...	340,000	....	320 400	625 750
Vitry II.......	Union d'Electricite...	80,000	....	280	700
Vitry II........	Union d'Electricite...	....	400,000	550	850
St. Ouen.......	Cie. Parisienne de Distribution d'Elec.	325,000	....	280	750
Issy-les-Mouli-neaux........	Cie. Parisienne de Distribution d'Elec.	118,000	175,000	220 625	750 850
St. Denis.......	Soc. d'Electricite de Paris..............	170,000	....	240	600
Ivry...........	Soc. d'Electricite de Paris.............	60,000	200,000	310	700

plied mainly by six major generating stations, operated by three companies. A seventh plant is under construction at Vitry. The characteristics of these stations are outlined in Table I. All will soon be interconnected with the various water-power centers through the French "super-power" network now under construction.

The power needs of the coal-mining centers are principally supplied by mine-mouth steam plants interconnected with water-power stations.

Pulverized Coal Versus Stoker Firing

The respective fields of pulverized coal and of stoker firing are still indeterminate in France. As compared to American conditions, pulverized coal is under considerable handicap in this country, owing to the extreme hardness and the abrasive nature of French coals, which raise the up-keep of pulverizing equipment to several times the figures current in the United States. In the vicinity of Paris, this handicap is further increased by the unsatisfactory load factor of the central stations, which materially reduces the returns on the extra investment required for pulverized coal as compared to stokers.

In spite of this double disadvantage, "Union d'Electricite," after four years of comparative operation with stokers and with pulverized coal, in central stations aggregating over 400,000 kw., has adopted pulverized coal firing for the new station at Vitry, designed for an ultimate capacity of 400,000 kw. The reasons given for this choice are:

1. The excessive variations in the coal supply, which lower the efficiency of stoker firing and cause endless operating trouble. The coal supply is subject, without warning, to fluctuations from 32 to 9 per cent in the volatile content, and of the same order in the ash content.
2. Greater flexibility in following load fluctuations, which in Paris stations are particularly sudden and unexpected.
3. Labor saving in operation and maintenance of the boiler plant.

"Compagnie Parisienne de Distribution d'Electricite" has not yet started experimental operation with pulverized coal. A 57,000 kw. extension to their Issy-les-Moulineaux station, fired with pulverized coal, will be started up in a few weeks.

"Societe d'Electricite de Paris" has been experimenting with pulverized coal for about ten months, with eight 14,000-sq. ft. boilers in the St. Denis station. But their experience is too short to warrant definite conclusions. It is significant that the new Ivry station, placed in service about the end of 1927, is at present entirely stoker-fired.

In the coal mining districts, pulverized coal is gaining ground, in spite of the relatively small size of the individual stations, and, at present, the limited market open to them.

Coal Pulverization

Efficient pulverization is one of the most difficult problems in the use of pulverized coal in France. After prolonged tests of other types of mills, "Union d'Electricite" considers that the type best suited to handling French coals is the conical ball mill, in spite of its higher first cost and power consumption. This type has been chosen for the new Vitry station. This opinion is apparently shared by "Cie. Parisienne de Distribution d'Electricite," mills of this type having been chosen for the extension of the Issy-les-Moulineaux station. "Soc. d'Electricite de Paris" have used Fuller screen mills in their pulverized coal plants, and a number of other French stations use roller or impact mills.

Firing Methods

The policy of "Union d'Electricite" tends toward direct firing; but it is admitted that present attempts have not proved entirely satisfactory, for lack of a type of mill whose air requirements under variable loads can be made to coincide even remotely with the primary air requirements of the furnace. The solution at present favored by this company, and adopted for the new Vitry station, is semi-direct firing, with storage capacity only sufficient to take up the load fluctuations. It is considered, however, that present types of individual mills would prove satisfactory for relatively constant load conditions. "Cie. Parisienne de Distribution d'Electricite" has adopted a central pulverizing plant for the Issy-les-Moulineaux extension, with a compressed air transport system.

Pulverized Coal Furnace Construction

Completely water-cooled furnace walls are not in great favor as yet with the three Parisian power groups. It is considered that, with low volatile fuels such as they are frequently obliged to use, combined with long-flame firing, the load range for satisfactory combustion in such furnaces is too narrow to meet the exacting service conditions. "Union d'Electricite" favors a construction composed of ordinary tubes without fins, widely spaced, and set forward with respect to the refractory wall. Nevertheless, an interesting experiment is under way in the Gennevilliers station. One of the original 14,000 sq. ft. Babcock boilers has been remodeled by removing the stoker and building within the original furnace two octagonal-base combustion chambers, composed of Murray tubes. A turbulent burner of the "International Combustion" type was placed at the bottom of each chamber. This experiment is still under way, and seems to be giving satisfaction. Ash-pit water screens are used in all the furnaces of this company.

"Cie. Parisienne" has adopted for three boiler furnaces built by "Soc. Anon. des Foyers Automatiques" in the Issy-les-Moulineaux extension, the standard "Lopulco" long-flame firing system, with Murray tubes on the rear and side walls, and an ash-pit water screen. The two remaining furnaces, built by "Soc. Anon. pour l'Utilisation des Combustibles," comprise water tubes without fins on all four sides of the furnace, spaced close together, and faced with fire brick over all but a section of the side walls.

The three "Lopulco" furnaces in this plant embody a novel solution of the troublesome problem of water-screen connections under high pressures. As shown in Fig. 1 and 2, instead of using large tubes with flanged joints for the downcomers, standard boiler tubes have been adopted in sufficient number to give the required cross-section, these tubes being rolled into the lower water-screen header and into the boiler drum, so that the boiler does not include a single flanged joint. The solution is said to be both cheaper and safer than that using larger tubes.

In the St. Denis station, "Soc. d'Electricite de Paris" has adopted water-cooled walls faced throughout with refractories.

Outside of the Paris district, water-cooled walls and turbulent firing are gaining ground more rapidly. Fig. 3 and 4 show in elevation and plan an unusually compact project designed by "Soc. Anon. des Foyers Automatiques" for an industrial plant of a capacity per unit of 100,000 lb. per hr. It includes a Wood steam generator, with corner firing, an air preheater in two sections separated by the inlet air duct, the forced and induced draft fans being respectively located beneath and above the air preheater. In this case indirect firing is to be used.

Fig. 5 shows another type of furnace, designed by "Soc. Anon, des Fours STEIN," and adopted for a number of medium size boiler furnaces. Direct firing is used, with drying in the mill with hot air drawn across the bottom of the furnace, thus forming an "air screen" for the purpose of cooling the ashes. The furnaces being under forced draft, the cold air is not used for combustion until after it has passed through the mill. The furnace walls are not cooled.

Steam Pressures and Temperatures

Progress in steam pressures has been guarded in France. The new Vitry station of "Union d'Electricite" is designed for 550 lb.; a higher pressure was not adopted so as to avoid the expense of solid forged steel drums. In these boilers the drums are forge-welded, the heads being riveted. If the load factor of this station had been more favorable, a considerably higher operating pressure would have been justified.

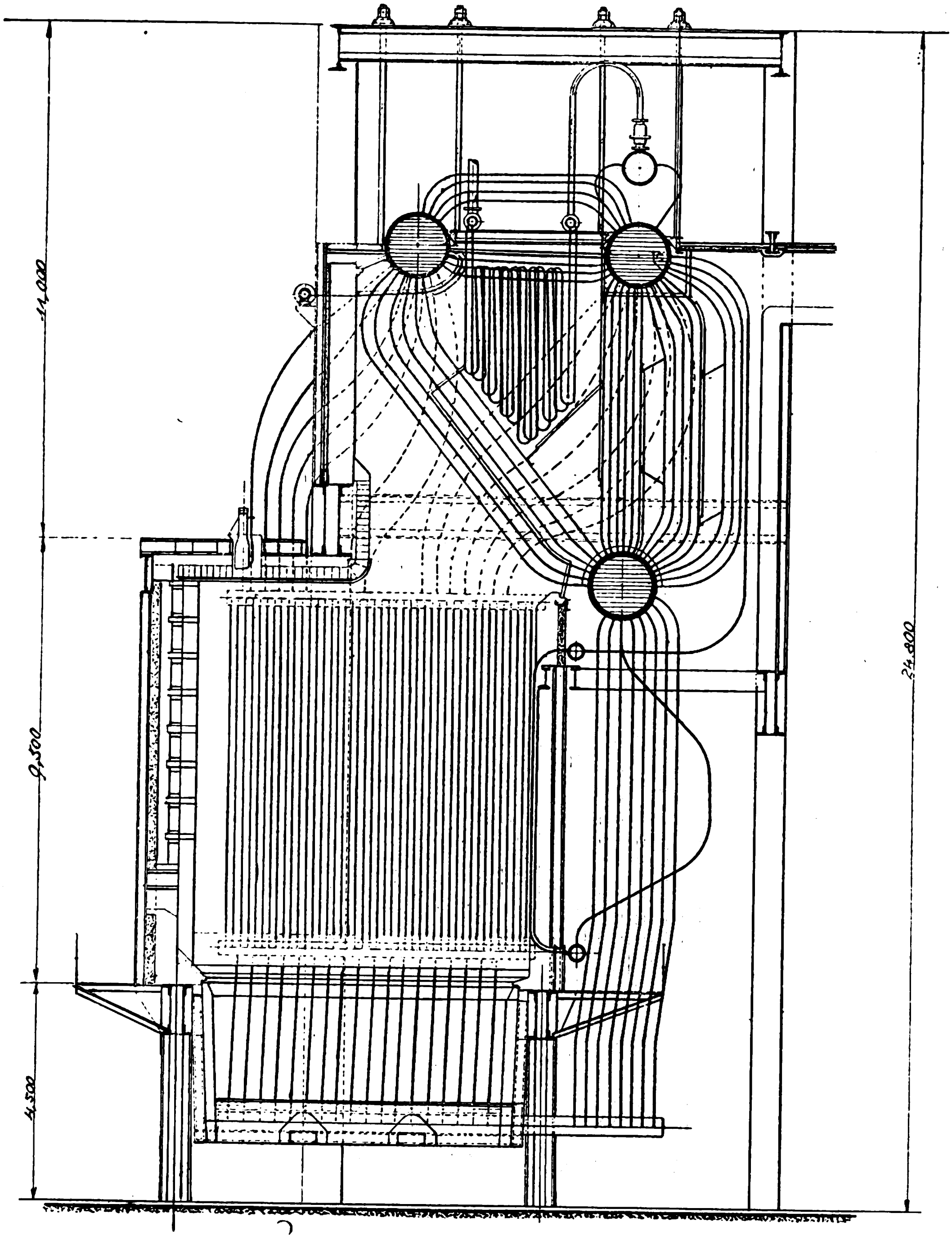

FIG. 1—"LOPULCO" FIRED BOILER FOR 625-LB. STEAM PRESSURE, IN EXTENSION OF ISSY-LES-MOULINEAUX STATION, PARIS.

The extension of the Issy-les-Moulineaux station of "Cie. Parisienne" is designed for 625 lb. at the boiler, and has solid forged-steel drums. In this case a higher pressure was not adopted so as to avoid the necessity of reheating the steam during expansion.

"Soc. d'Electricite de Paris" has as yet made no substantial advance in pressures, the Ivry station being built for 310 lb. at the boiler. But several types of steam generators adapted to higher pressures are under careful study by this company, such as the Rauber, Benson, Loeffler and Schmidt systems.

Steam temperatures are generally somewhat higher than those used in current American practice, owing in a measure to the general aversion in France to reheating. A temperature of 800 deg. fahr. at the turbine throttle is considered safe in most power circles.

Present tendencies in pressures and temperatures seem to justify the conclusion that the principal obstacle to the use of higher steam pressures in France is the high cost of the boilers and turbines. It is likely that a radical change in boiler design to reduce the cost, together with a reduction in the cost of certain existing uncorrodable alloys through improved production methods, would open the way for a considerable increase in pressure and a substantial rise in temperatures.

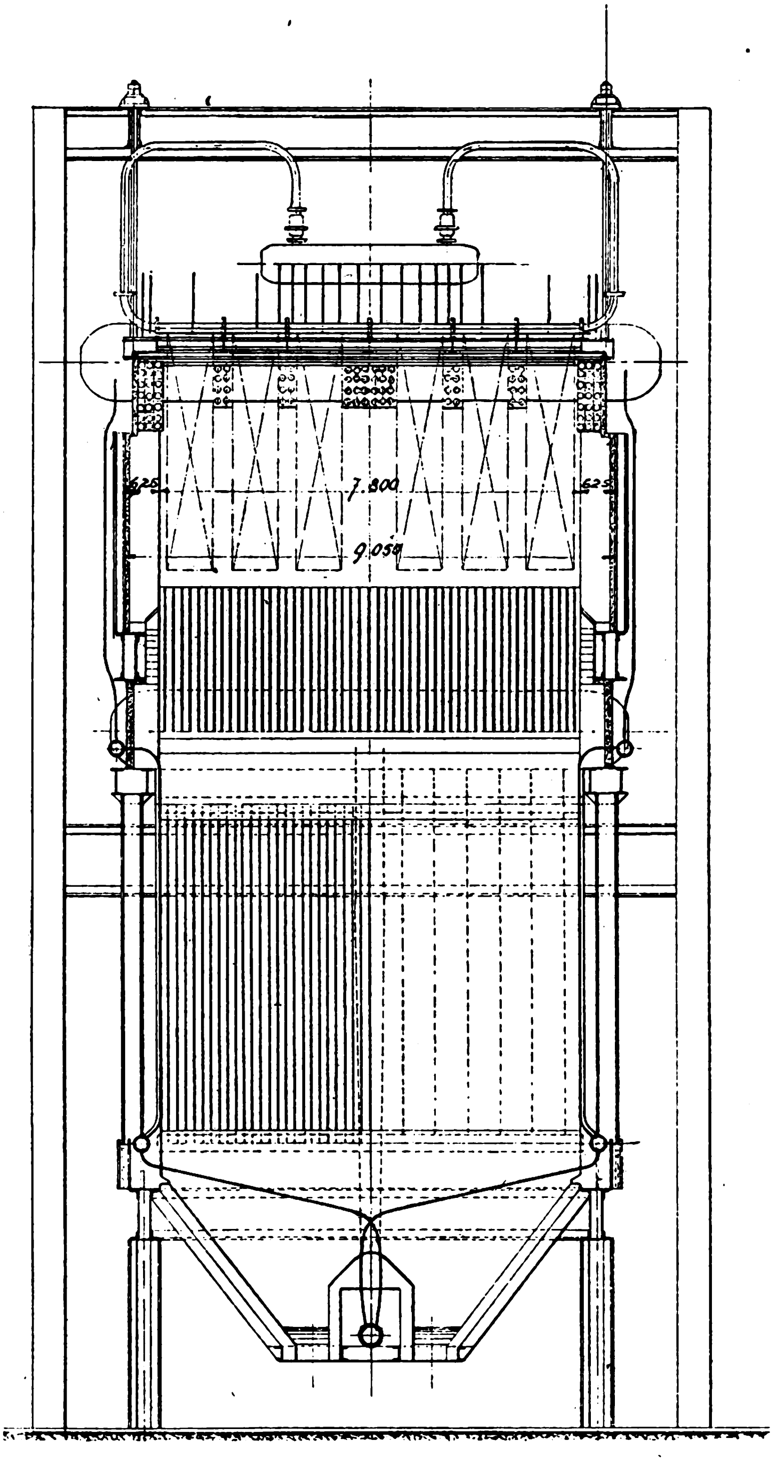

FIG. 2—ELEVATION OF FIG. 1.

Novel Boiler Designs

In general, there has not been much practical advance in boiler design. An interesting innovation is the Rauber-Babcock boiler, which extends to the boiler the use of transverse fins common in economizer construction, to reduce the resistance to heat flow at the contact surface between gases and boiler tubes, and make the convection heating surface more effective. Fig. 6 shows a cross-section of a Rauber experimental unit. Fins of different diameters are welded onto the tube surfaces, so as to make the total contact surface in successive rows of tubes approximately inversely proportional to the temperature difference between the gases and the water. Based on the area of the tube surface without the fins, average evaporation rates of over 30 lb. of steam per sq. ft., or 1000 per cent rating, have been obtained in a small experimental boiler, and over 40 lb. per sq. ft. are expected from larger units.

Two 3100 sq. ft. Rauber units are under construction for the Troyes central station. A number of other units, ranging up to 300,000 lb. capacity, 1000 lb. pressure and 930 deg. fahr. temperature, are at present under study; also a small

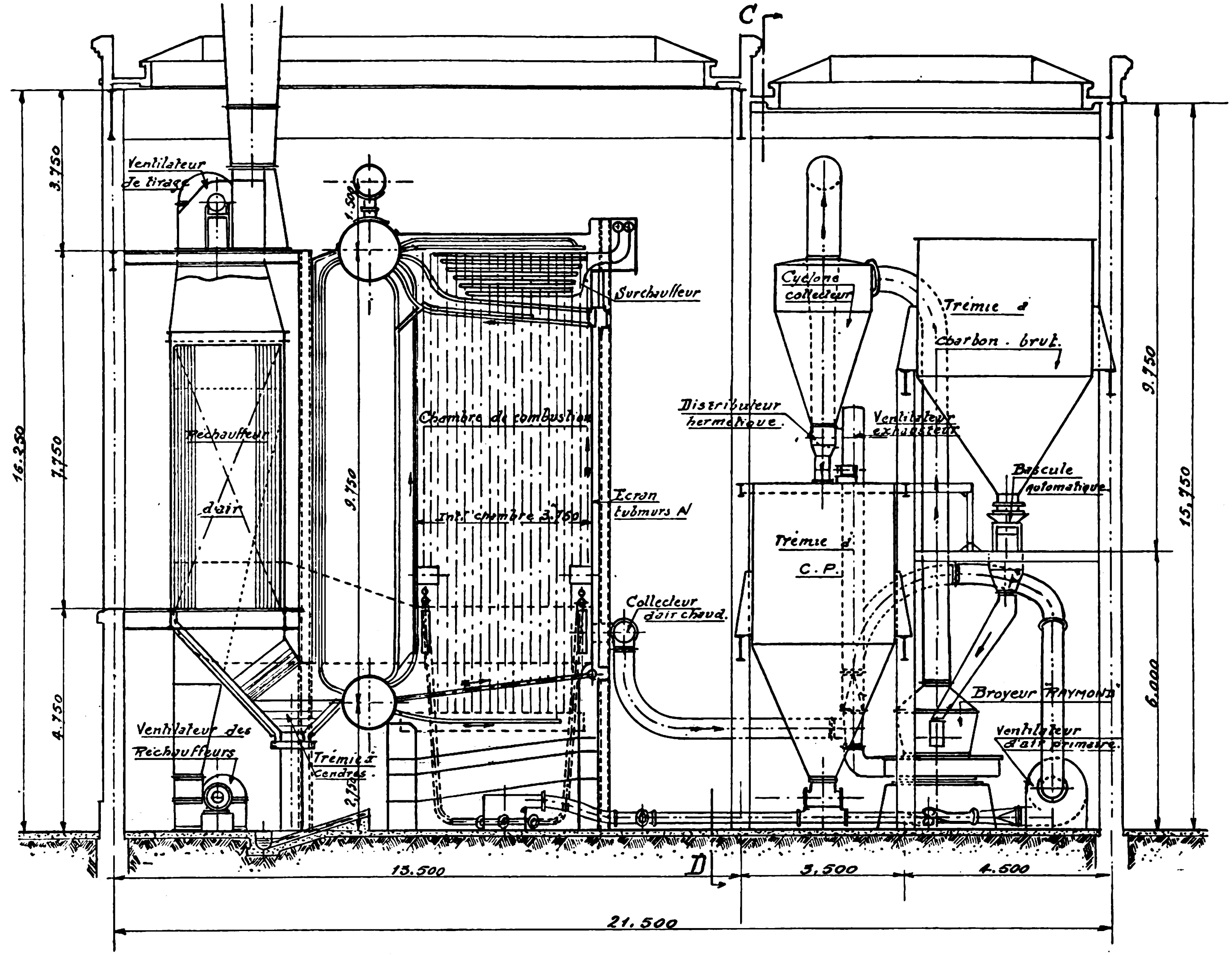
C
Ventilateur de tirage
3.750
16.250
7.750
4.750
Rechauffeur d'air
1.500
9.750
Chambre de combustion
Int. chambre 3.760
Surchauffeur
Ecran tubmurs N
Ventilateur des Rechauffeurs
Trémies cendres
2.750
Collecteur d'air chaud
Cyclone collecteur
Distributeur hermetique
Ventilateur exhausteur
Trémie d' C.P.
Trémie d' charbon brut
Bascule automatique
Broyeur RAYMOND
Ventilateur d'air primaire
9.750
6.000
15.750
13.500
D
3.500
4.500
21.500

FIG. 3—PULVERIZED COAL FIRED WOOD TYPE STEAM GENERATING UNIT FOR 100,000 LB. CAPACITY, DESIGNED BY "S. A. FOYERS AUTOMATIQUES."

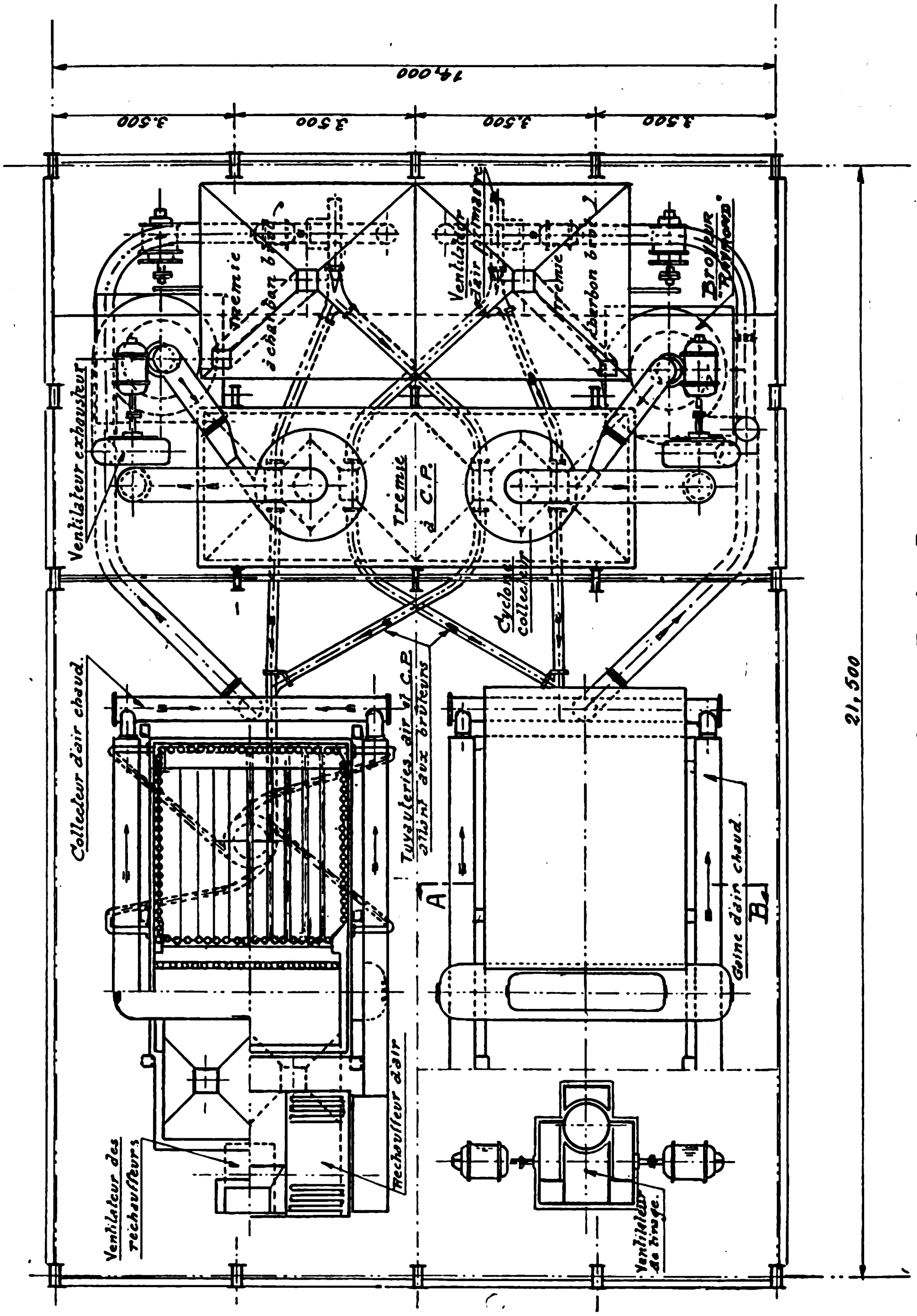
14,000
3,500
3,500
3,500
3,500
21,500
Ventilateur exhausteur
Tremie à charbon brut
Ventilateur d'air primaire
Tremie à charbon brut
Broyeur "Raymond"
Tremie à C.P
Cyclone collecteur
Tuyauteries air et C.P allant aux bruleurs
Collecteur d'air chaud
Gaine d'air chaud
A
B
Ventilateur des rechauffeurs
Rechauffeur d'air
Ventilateur de tirage

FIG. 4—SAME AS FIG. 3 IN PLAN.

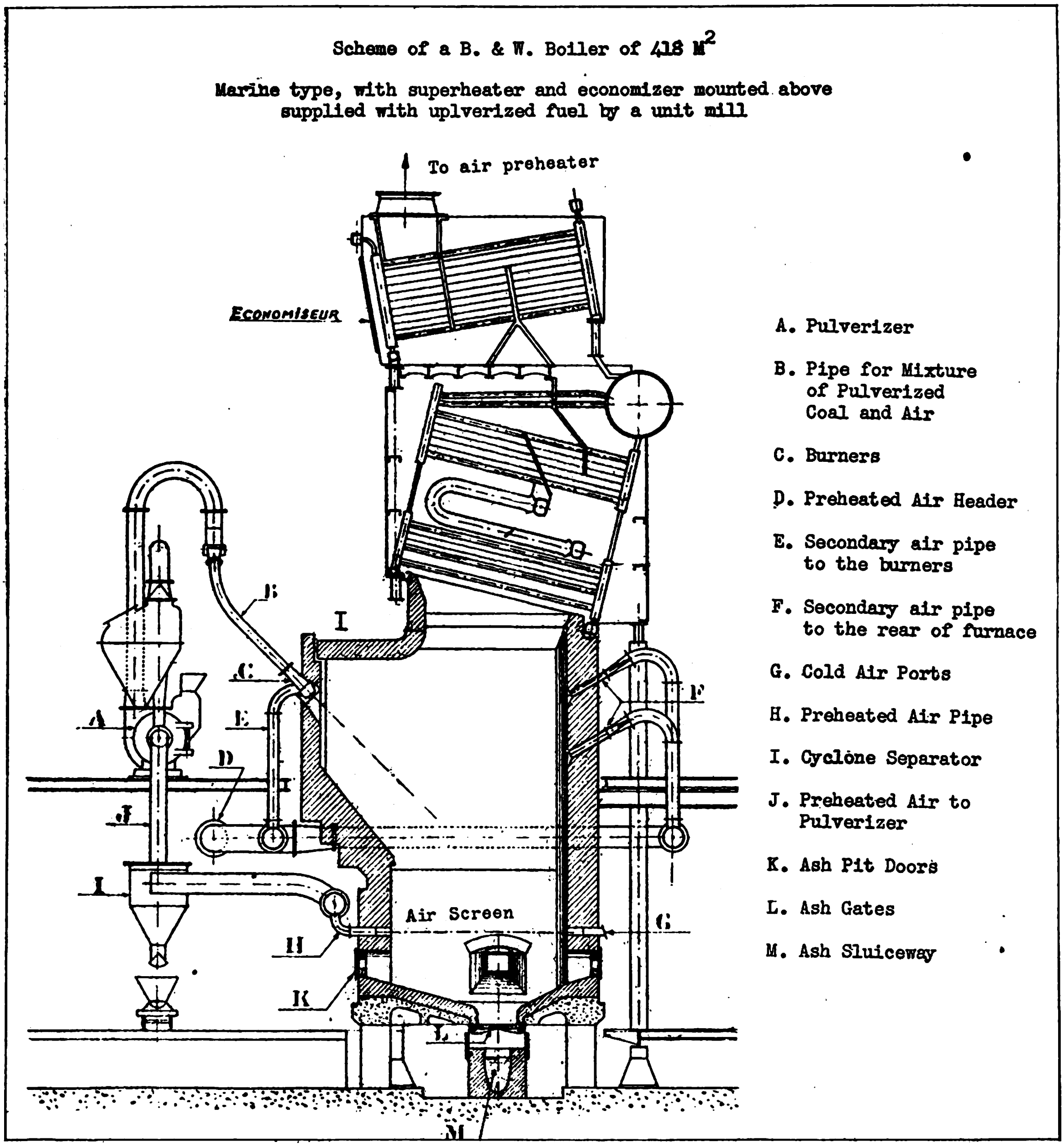
Scheme of a B. & W. Boiler of 418 M2
Marine type, with superheater and economizer mounted above
supplied with uplverized fuel by a unit mill
To air preheater
ECONOMISEUR
Air Screen
A
B
C
D
E
F
G
H
I
J
K
L
M
A. Pulverizer
B. Pipe for Mixture of Pulverized Coal and Air
C. Burners
D. Preheated Air Header
E. Secondary air pipe to the burners
F. Secondary air pipe to the rear of furnace
G. Cold Air Ports
H. Preheated Air Pipe
I. Cyclone Separator
J. Preheated Air to Pulverizer
K. Ash Pit Doors
L. Ash Gates
M. Ash Sluiceway

FIG. 5—4500 SQ. FT. PULVERIZED COAL FIRED BOILER WITH UNIT MILL, DESIGNED BY "S. A. FOURS STEIN."

experimental boiler for the very severe steam conditions of 2800 lb. pressure and 1100 deg. fahr.

Steam Turbines

The trend of turbine design in France is clearly toward improvement in workmanship and in materials, for the purpose of raising the mechanical efficiency. "Union d'Electricite" favors the three cylinder tandem design, with nozzle blocks and blading of uncorrodable materials. The machine work is exceptionally good, with the result that the last two 55,000 kw. units of the Gennevilliers station, respectively built by "Brown-Boveri" and by "Soc. Alsacienne de Constructions Mecaniques," are said to have given on test mechanical efficiencies as high as 87 and 88 per cent.

An interesting experiment is being tried in the Gennevilliers station to make use of obsolete turbines. The first ten stage impulse turbine installed in this station is being equipped with a high-pressure cylinder in tandem with the original cylinder. The throttle pressure remains unchanged, but expansion will take place in twenty-four instead of ten stages. In this way, the capacity of the unit is to be increased from 35,000 to 45,000 kw. with a material improvement in efficiency.

"Cie. Parisienne" is installing in the Issy-les-Moulineaux extension two 11,000 kw. back-pressure units exhausting either directly into two existing 40,000 kw. units, or into the existing 200 lb. mains; also one 35,000 kw. condensing unit.

Condensation

Considerable experimental work is under way in connection with condensation. Probably the outstanding innovation is the four condenser arrangement of the two last units in the Gennevilliers station. These turbines exhaust at four points on 45 deg. diameters, into four horizontal condensers arranged in two tiers, two substantially at the

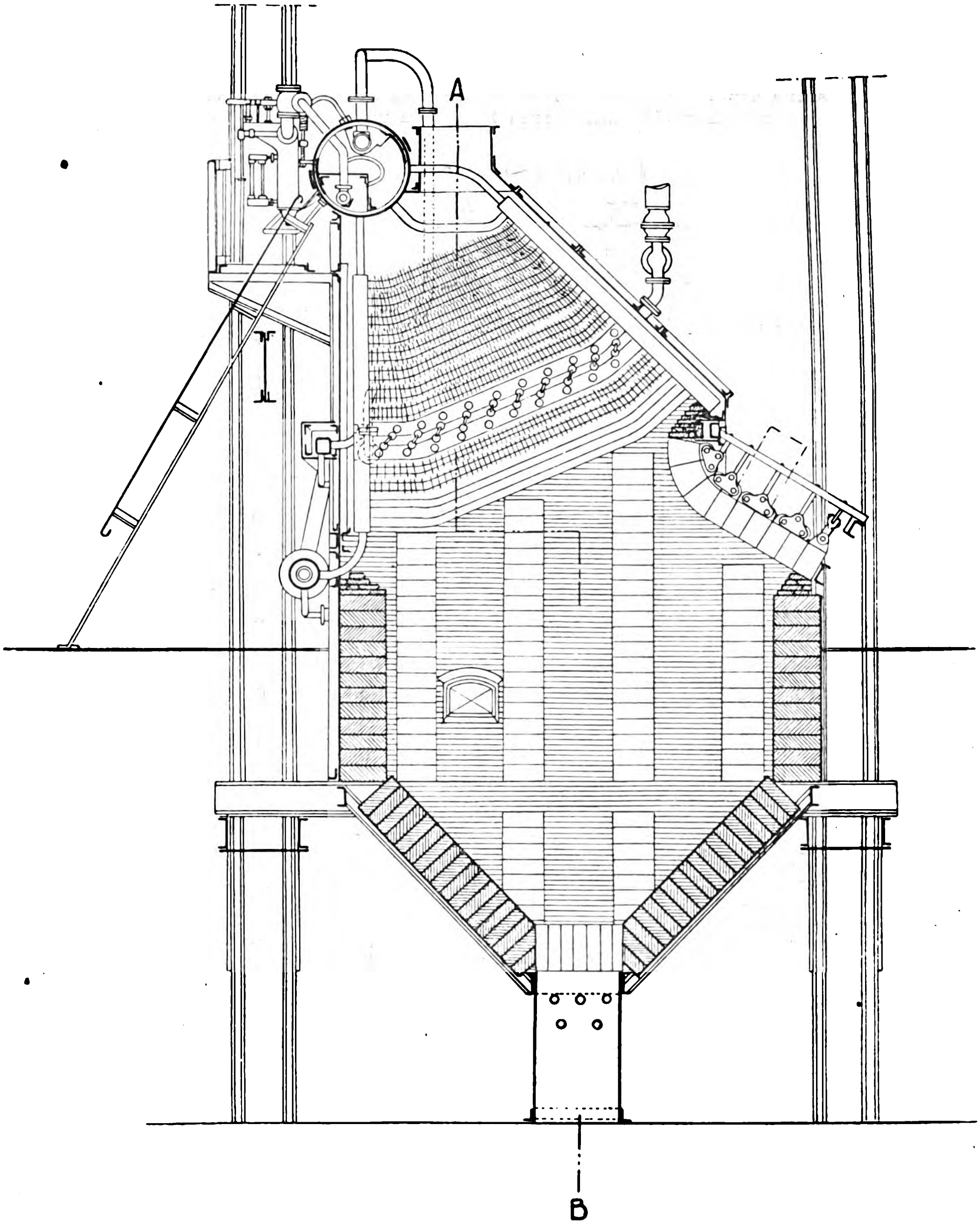

FIG. 6—EXPERIMENTAL RAUBER-BABCOCK FIN TUBE BOILER.

level of the turbine, and two in the basement. This arrangement is said to have given good vacua and a substantial reduction in the losses in the exhaust casing. However, some difficulties were encountered through the wide fluctuations in condensing water level, owing to syphon operation of the upper condensers. It seems that this arrangement should be limited to fairly constant condensing water supplies. It has not been adopted for the new Vitry station, where the variations in the Seine level are still greater than at Gennevilliers.

Dust Precipitation

Study of dust precipitation has not generally been as active as in the United States, but several systems are on trial. At the old Vitry plant of "Union d'Electricite," electrostatic precipitation has been tested, also a flue gas washing system. In the latter, the gas passes through a chamber filled with cast iron columns over the surface of which flows a film of water. The columns are so shaped as to leave between them a number of winding passages, for the purpose of bringing the dust particles in contact with the water. The results are said to be encouraging.

An interesting installation has been made in the Comines central station, in the northern coal region. This is known as the "Ostricourt-Pauthenier" system, and is a simple improvement of the electrostatic system of precipitation, which materially reduces its bulk and cost. It consists in creating in front of the precipitating plates a neutral zone of about 1¼ in. in depth, protected from the moving gases by suitable baffles, and from the induction effects by a wire netting grounded with the plates. The result is to greatly increase the rate of precipitation, and to allow a considerable increase in gas velocities.

The apparatus at Comines is installed on an 11,000 sq. ft. boiler, between the boiler proper and the economizer. Its volume is about 770 cu. ft. In six months of service, the dust separation is said to have averaged between 90 and 95 per cent. Its maximum power consumption is 2.5 kw. The voltage used is 30,000 to 50,000.

Another system of dust separation in two steps has been applied in several plants in France and Belgium, and is said to give satisfaction. It was developed by "S. A. des Fours Stein," and is based on a preliminary separation by centrifugal force, followed by washing of the gases.

The Electric Current Supply of Berlin, Germany

STATEMENT BY DIPL. ING. M. REHMER, BERLIN

(From "Elektrizitaetswirtschaft," Vol. 27, p. 278)

Berlin is supplied with electric current by seven companies of which the more important is Berliner Staedtische Elektrizitaetswerke A. G., known as "Bewag."

The large number of companies is explained by the recent history of Berlin, the formerly independent suburbs having long time agreements with the individual companies.

The Bewag supplies 88 to 90 per cent of the total energy consumed to about 80 to 85 per cent of the total area of the city and can be considered as representative for the entire energy supply.

The Bewag has had a development during the last four years which is without precedence in the German electrical industry. The system peak load has increased from 142,000 kw. in 1923 to 356,000 kw. in 1927 (see Fig. 7). The average yearly increase, therefore, was 53,000 kw. The base load increase was about half of this amount per year.

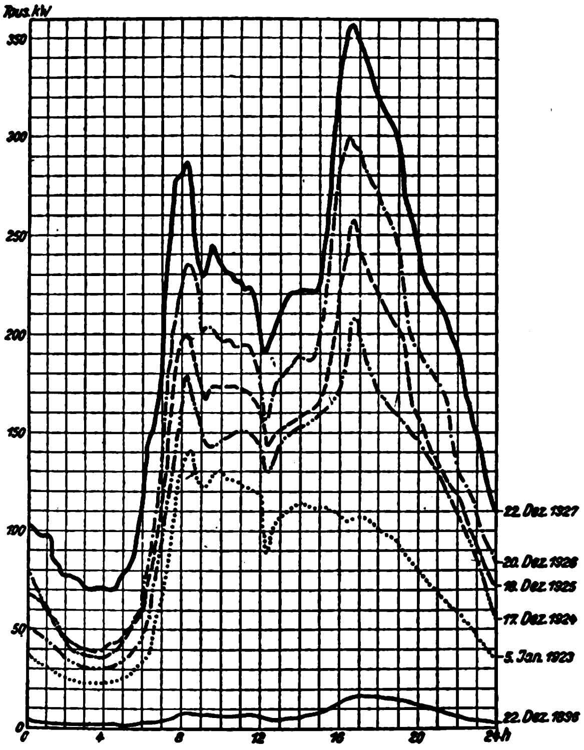

FIG. 7—LOAD CURVES ON PEAK LOAD DAYS OF THE YEARS 1896, 1923 TO 1927.

Table II shows the increase in the consumption of electric energy. The total energy generated and purchased increased from 480.7 million kw-hr. to 1,025.4 million kw-hr. within four years. There is no indication of a slowing down of this development in the near future. The consumption of electric energy per inhabitant has been doubled within four years. Since the necessary increase of the means of production cannot be secured by acquiring other companies, the future development demands a large extension of the generating capacity.

TABLE II

TOTAL ENERGY GENERATED AND PURCHASED BY BEWAG

Year	Kw-hr. Generated, Millions	Kw-hr. Purchased, Millions	Generated, Per Cent	Purchased, Per Cent
1923	151.5	329.2	31.52	68.48
1924	193.5	358.0	35.08	64.92
1925	365.2	383.9	48.75	51.25
1926	412.1	396.7	50.95	49.05
1927	686.5	338.9	66.95	33.05

Year	Total Kw-hr. Generated and Purchased, Millions	Connected at the End of the Year, Kw.	Billed Kw-hr., Millions	Number of Customers Within City	Kw-hr. per Inhabitant per Year
1923	480.7	489,749	426.7	127,873	122.8
1924	551.5	531,756	451.0	278,217	129.6
1925	749.1	741,417	651.9	362,996	183.2
1926	808.8	801,233	705.1	435,280	194.7
1927	1,025.4*	....	898.9	542,834	239.5

*This figure does not include the energy purchased from B.V.Œ.W., M.E.W. and St.u.Kr.Krftw. Spandau for Spandau, which was 53.7 million kw-hr.

In planning for this rapid expansion both generator and transformer capacity are chosen to correspond to the peak load conditions. A spare capacity of 25 per cent for the generation and of one transformer each in the transformer stations are included. The conclusion is that a total peak load of 740,000 kw. with a base load of 400,000 kw. will be the demand in 1932. About 425,000 kw. generating capacity and 408,000 kw. transformer capacity must be added to the present equipment to carry this load.

Fig. 8 shows the load curves of the Berlin system. A study has been made of the peak load problem. The solution, however, has been postponed until later, since the peak load becomes base load within about three years at the present rate of development. The problem will be more urgent when the development slows down. A solution of the peak problem by adjusting the rates has been tried out without success, as far as the load conditions are concerned. However, the influence of the short time demands can be effectively counteracted by determining accurately the range of use of the varying means of production, as shown in Fig. 9. A Ruths steam accumulator plant of 40,000 kw. capacity will be ready for service in 1929. The purchased high tension capacity will be 50,000 kw. The battery capacity available is 40,000 kw. The possibility of using Diesel engines in local peak load stations is limited in Berlin. The present economical situation does not justify the erection of a water power plant in the proximity of Berlin.

The principal problem of the next few years, therefore, is the increase of the power plant capacity and, correspondingly, of the available outside capacity. Operation at a new plant in Western Berlin is planned for 1930 and further units will be added to the older plants. Ruths steam accumulators are not only cheap peak load capacity, but also provide spare capacity available for immediate use. Furthermore, they have the advantage of decreasing the amount of smoke. The smoke problem in the cities will be brought closer to a solution by connecting the heating to the generation of power. It seems possible that a combination of heat and power generation will be of advantage, also, economically.

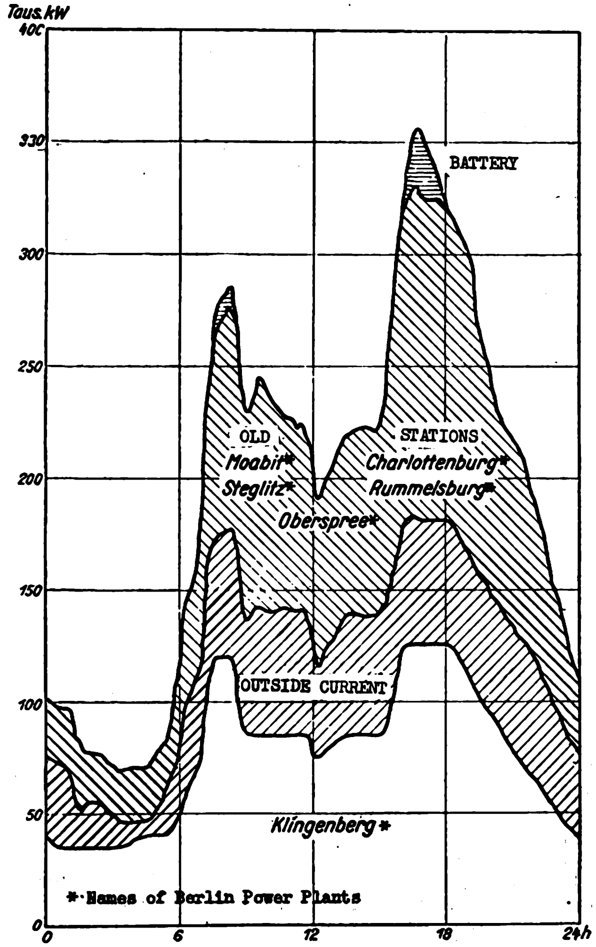

FIG. 8—TOTAL LOAD OF THE BEWAG, DEC. 22, 1927.

The load distribution for the different sources of power for 1932 is shown in Fig. 9. The different means of supplying energy are used according to their individual characteristics.

It seems probable that the demand will force the use of a larger amount of outside current after 1932. Coal mines have been acquired at the Elbe and Oder rivers and power plants will be built at these mines later on. The outside current, then, will be furnished by our own coal burning plants and by the present lignite burning stations. The main stations in the east and west of the city will be interconnected by a 100,000-volt ring cable, a 100,000- to 30,000-volt substation to be erected in each half of the ring to receive the outside current.

Recent High-Pressure Boiler and Turbine Plants in Holland

(*From "Science Abstracts"* 3—*January,* 1928)

CONFERENCE DES GRANDS RESEAUX ELECTRIQUES, PARIS (28 PP.) 1927

The report contains descriptions of the construction and tests of new boiler and turbine plants at three Dutch power stations. All the boilers are of the Babcock & Wilcox cross-drum, vertical-header type, manufactured by Stork Bros. and the turbines are also by the same firm.

At Utrecht the new boilers have a heating surface of 6430 sq. ft. each and generate at normal load 44,000 lb. per hr. at 510 lb. and 800 deg. fahr. They are fired by mechanical stokers. The efficiency at normal load was 87 per cent based on the lower calorific value. The 16,000 kw. turbine comprises one high-pressure, one intermediate and two low-pressure cylinders. The steam consumption at full load was 8.44 lb. per kw-hr.

Among the other boilers described is one of 15,500 sq. ft. working at 620 lb. and equipped with a combustion chamber on the Lulof system for powdered fuel.

The New Central Station at Buenos Aires

STATEMENT BY VON JANLET, BRUSSELS

The initial installation consists of two turbines having a total capacity of 105,000 kw., the ultimate capacity to be 600,000 kw-hr.

Before starting the station, the company engineers obtained considerable data in 1925 on a trip to the United States on such stations as Philo, Twin Branch, Crawford Avenue, and Columbia. In building the new station at Buenos Aires, it is apparent that the engineers followed the design characteristics of the above stations very closely. A steam pressure of 550 lb. was selected for the turbines, using reheat for the low pressure cylinders.

Coal Pulverization

A 45-ton per hr. Lopulco pulverizing system is installed, one mill being held in reserve. Revolving plate dryers heated by steam are used.

Boiler Installation

Six standard and two reheat boilers are provided for 650 lb., 797 deg. fahr.

The standard boilers have 15,392 sq. ft. heating surface with 5414 sq. ft. superheaters, 11,065 sq. ft. economizers and 27,007 sq. ft. air preheaters. As the boilers are provided with water walls and water screens, a maximum of 14 lb. per sq. ft. per hr. evaporation may be attained.

The reheat boilers contain 3890 sq. ft. of heating surface with 2874 sq. ft. superheaters, 6997 sq. ft. economizers and 27,007 sq. ft. air preheaters. The reheater heating surface is 19,160 sq. ft., which will reheat 400,000 lb. of steam per hr. at 131 lb. gage and 432 to 752 deg. fahr.

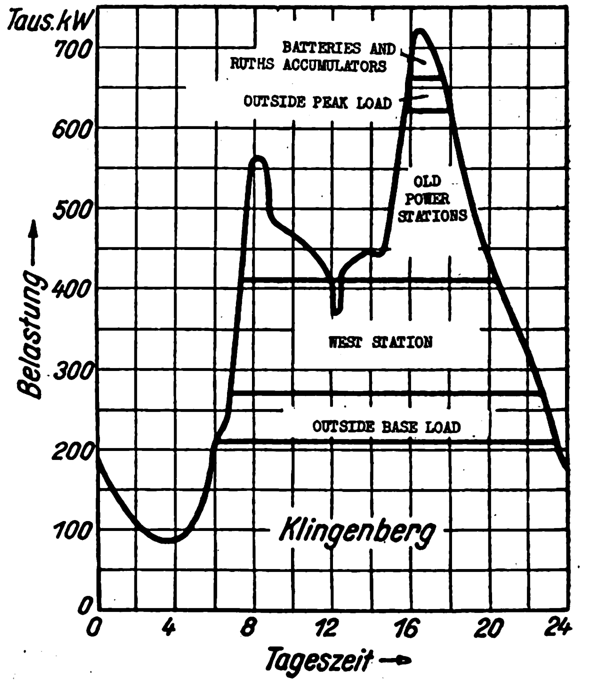

FIG. 9—ANTICIPATED LOAD CURVE OF BEWAG SYSTEM, DECEMBER, 1932.

Turbo-Generators

Two turbo generators use reheating for the low pressure cylinders and heat the condensate with extraction steam.
Turbine capacity—52,500 kw. at 1500 r.p.m.
Throttle steam pressure—550 lb. per sq. in. gage.
Steam temperature—752 deg. fahr.
High pressure cylinders have nine stages. Low pressure cylinder, 17 stages.
Reheat-Superheat—770 deg. fahr.
Steam is extracted from 12th, 16th, 20th and 23rd stages.
Worthington condenser—52,500 sq. ft.
House turbine directly connected to main generator·2500 kw.

Condensing Water

Condensing water is taken from the La Plata River and passes through screens automatically cleaned by sprays. Circulating pumps are of a vertical type and are arranged to overcome friction losses only.

Piping

American high pressure standards were adopted, using Sargol flanges. The majority of the valves are either Crane or Edwards and are motor driven.

Fuel Control in Industry

STATEMENT BY DR. F. MUNZINGER

(*Abstracted from "Engineering," Nov.* 30, 1928)

The coal consumption of many stations was higher than necessary in view of present-day technique, owing to their poor average load factor; and this was also the reason why extra high pressure feed water heating by extracted steam, pulverized fuel, etc., had not been more widely used. The principal means of obtaining cheaper electricity were: High pressures, the employment of more perfect working processes, and machines and measures for lessening the price-raising effect of peak loads on operating and capital costs. These factors were partly contradictory in their effect, and must be balanced in order to improve the overall economy.

As regards the cost of a modern generating station, it was pointed out that this was largely dependent on size, steam pressure and operating conditions, including the existence of interconnection with other stations. The total cost of the Klingenberg station, which was the most modern in Germany, was £3,148,000, and its capacity being 270,000 kw., its specific initial cost was £11 13s. per kw. About 5500 kw. of this capacity was required for "house" purposes, the cost per salable output was £12 per kw. The operating cost was only about 50 per cent of pre-war figures, and the heat consumption at full load did not exceed 14,200 B.t.u. per kw-hr. as compared with the 20,500 B.t.u. of the older stations. As regards the effect of higher steam pressures on the cost of a station of this size, taking a figure of 100 for a pressure of 500 lb., the corresponding values for 850 lb., and for 1400 lb., would be 104.3 and 109.9 respectively.

The most economical steam pressure was that at which the cost of production was lowest. For instance, with a load factor of 37 per cent, 12 per cent interest on capital, and coal at 12s. per ton, a pressure of 500 lb. would be most economical, but with coal at 24s. per ton, an 800 lb. pressure would show an advantage, though the difference was slight. In general, the economic region of 500 lb. was greater the higher the capital charges and the lower the price of coal. A pressure of 1400 lb. was only feasible when the capital charges were low, and the price of coal and the load factor high. At load factors below 30 per cent, pressures much exceeding 500 lb. were only noticeably advantageous under extreme conditions.

The high capital cost necessary to supply the peak load output might be reduced either by heavily loading the boilers or by the use of Ruth's accumulators, the latter precedure being more advantageous at high than at low pressures. The overall cost of such accumulator plant was £8 to £9 per kw., compared with £12 to £14 per kw. for boilers. Five traction stations and four ordinary stations in Germany were equipped with this type of plant. Of the latter, the largest equipment was that at Charlottenburg with a capacity of 177,000 cu. ft. and a pressure range of 185 to 7.2 lb. per sq. in., allowing 70,000 kw-hr. to be accumulated and a peak up to 40,000 kw. to be met. Accumulators and special boilers supplemented each other admirably, and even when the latter had a very small water content, dangerous surging was entirely prevented.

Boilers, Superheaters and Economizers

STATEMENT BY BABCOCK & WILCOX, LTD., LONDON, ENGLAND

During the past year we have perfected and put on the market a Babcock Low Temperature Coal Distillation System, which is of interest in the boiler world in that it is specifically designed to work in conjunction with steam raising plant.

By this process coal is first preheated and then put through a distillation retort in which the valuable tar vapors are distilled off, and from which semi-coke is withdrawn and fed straight on to the mechanical stokers under the boiler, or passed to the pulverizing mill and subsequently burned in a pulverized fuel furnace.

A full description of this process, together with numerous illustrations of the plant, which has been in successful operation for two years at the Dunston Power Station of the Newcastle Electric Supply Co., is issued in pamphlet form and can be had on application to Messrs. Babcock & Wilcox, Ltd., Babcock House, London.

Its essentials consist of a preheater, heated by means of flue gases from the boiler, in which the coal is dried. From here the coal passes to a mechanical feeder, which distributes it evenly in the retort, which is internally heated by means of a mixture of steam and hot gas from an independently fired combustion chamber. The tar vapors are taken out from the top of the retort, and after passing through a filter for the purpose of removing any coal dust, are condensed and passed through an ordinary refining plant.

A high thermal efficiency is obtained with this plant. In addition to 76 per cent of the original thermal value of the coal which is available under the boiler and the advantage of a smokeless fuel, there is obtained a valuable range of low temperature byproducts which make possible the more economical generation of electricity.

Our experience during the past year, which covers all countries, except the North American continent, seems to indicate that pressures which show a tendency to rise to 1200 lb. per sq. in. and over will not, in general, exceed 500 to 600 lb. per sq. in., with final steam temperatures up to 800 and 900 deg. fahr. To meet these conditions we have installed at our Renfrew Works a new plant, which includes what we believe to be the largest hydraulic press in the world. This will enable us to supply riveted drums for pressures up to the above limit, instead of the more expensive solid forged type. This press is capable of exerting a pressure up to 8000 tons, and will deal with plates up to 40 ft. 0 in. long, 2¼ in. thick, bending them to three-quarters of a circle up to 4 ft. 6 in. diameter. A full description of this press and the planing machines used in conjunction with it was given in the British periodical, *The Engineer*, dated Dec. 7, 1928.

In view of the increasing importance of dry, clean steam, we have developed and patented a new vane type dry pipe.

The steam, in passing through the nests of inclined vanes, is freed of its impurities and moisture, which collect in the covered troughs beneath, and are disposed of through either internal or external drains. The vanes are of mild steel, which has been found quite satisfactory in service, and the dry pipe is made up of standard sections so that it can be made in various sizes at a minimum cost.

This vane type dry pipe has proved highly successful in practice, both from the point of view of increased efficiency in the superheater and as a protection against clogging and erosion of turbine blades. In one case the replacing of a standard dry pipe by one of this vane type produced an increase of 50 deg. fahr. in the superheat, and reduced the moisture content from 4 per cent to less than 1 per cent.

Stokers

During the past year we have also developed an improved design of chain grate stoker to meet the demand for larger units. This is known as our style 28 stoker and can be made up to 30 ft. 0 in. wide by 24 ft. 0 in. long. It is of the drop-link type and is so constructed that all the load is taken on massive driving chains spaced across the width of the stoker, the links being free from any thrust or tension. Improved air distribution is obtained by damper control to the compartments, and an effective clearing action is obtained by arranging for alternate links to drop when the chain goes over the back end.

Brown-Boveri High-Pressure Boilers

Statement by Dr. Paul Faber, Brown-Boveri Co., Baden, Switzerland

High-pressure boilers from 800 to 1500-lb. pressure have been built successfully on the same principles as low-pressure boilers, using both the sectional system and the vertical tube system. These boiler designs applied to high pressures result in thick walls and, therefore, in heavy weights and high prices. Other disadvantages of the old boiler systems, such as danger of incrustation, insufficient adaptability to changing loads, priming because of uneven production of steam in the tubes, expansion through heat, etc., are still more noticeable with high pressures. It is clear, therefore, that the future high-pressure boiler will not consist in an "adaptation" of the low-pressure boiler. A series of special designs of high-pressure boilers have arisen. We mention the boilers of Benson, Brown-Boveri, Loeffler, Schmidt. It is typical of all these that they avoid evaporating the water on walls in contact with the fire. Benson heats water without actual evaporation at or above the critical pressure and temperature, and produces steam by expanding down to a lower pressure. In the Loeffler boiler steam is superheated by the heat of the fire and carried to the water where it loses its superheat in evaporating part of the water. Three to four times the steam output is circulated as a heat carrier. Schmidt uses a closed water circuit under high pressure as a heat carrier.

Brown-Boveri also employs superheated steam to transfer heat, but avoids the circulating blower and its energy losses which, from an operating and designing point of view, are unsatisfactory. The steam circulation is maintained by natural pressure drop through the various stages of evaporation. The original and simple principle of the Brown-Boveri steam generator is illustrated in Fig. 10. In a very small "exciter boiler" "1" a small percentage of the desired steam output is raised to a pressure somewhat above the delivery pressure of the boiler. This steam is heated in a first superheater "2." It then flows through a first evaporator "3" to which preheated feed water is supplied from the tank "15" by the pump "14" and injected through nozzles. The superheat of the steam serves to evaporate a certain part of the water.

The flow of steam, increased by the newly evaporated water, goes to a second superheater "4," absorbs a further quantity of heat and carries it to a second evaporator "5" turning a further quantity of feed water into steam. The volume of steam is again increased, goes to a third superheater "6" and so on, until after a number of stages the desired output of steam is reached, which then flows through a last superheater "12" to the engines. In flowing through the stages of the boiler, the pressure of the

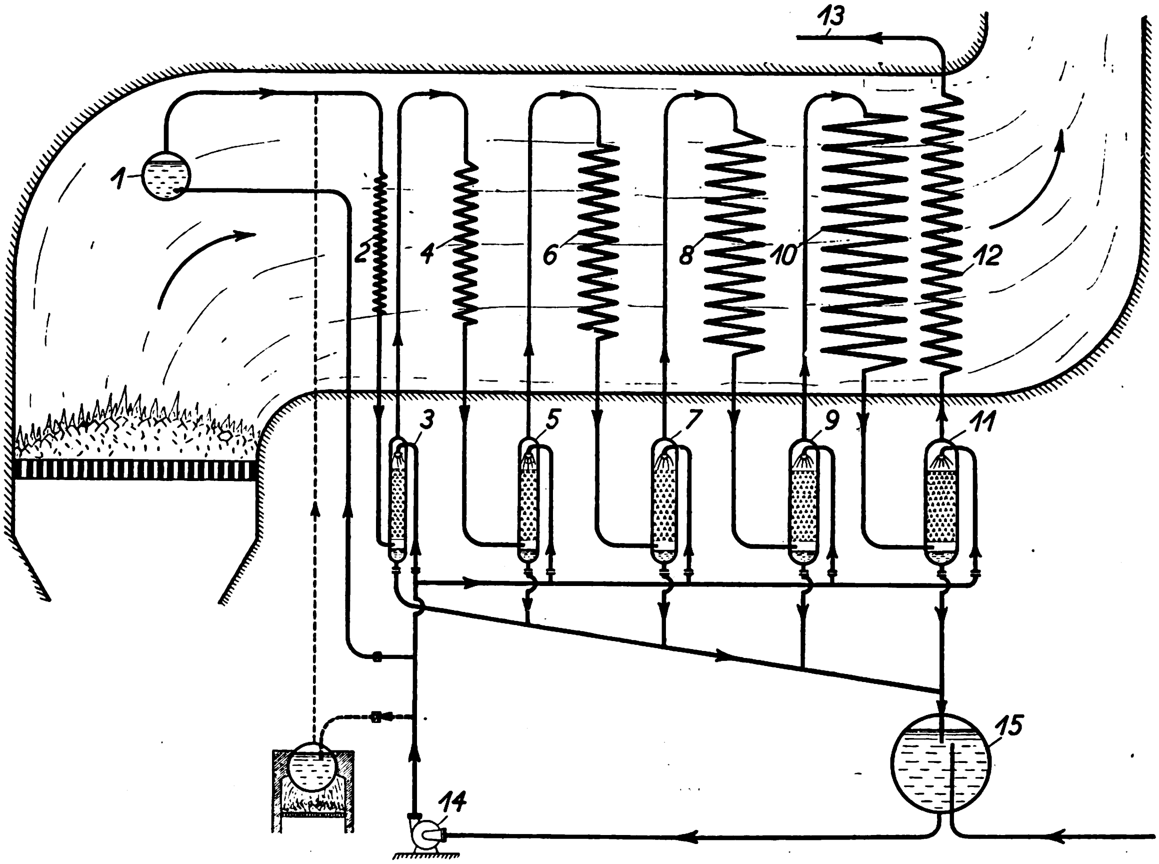

FIG. 10—Principle of the Brown-Boveri Steam Generator.

steam will drop somewhat, according to the resistance encountered through the superheaters and evaporators. However, no energy loss arises from it and, furthermore, the circulating blower is avoided.

Assuming the weight of the exciter steam to be w_1 and its total heat i_1, assuming further this steam to be superheated to a total heat i_2 and feed water of the temperature t_0 and of the total heat i_0 injected, the amount of steam evaporated in the first stage will then be:

$$\Delta w_1 = w_1 \frac{i_2 - i_1}{i_1 - i_0}$$

After n-stages, we obtain a steam output of:

$$w_n = w_1 \left[1 + \frac{i_2 - i_1}{i_1 - i_0}\right]^n$$

neglecting in the formula the small drops in pressure and temperature from stage to stage. With a pressure of 1500 lb. and a temperature raised in the superheaters to 900 deg. fahr., and with 500 deg. fahr. feed water, the amount of steam is increased by about 40 per cent in each stage. Therefore, starting with 5 per cent exciter steam, the full output is reached in 9 stages.

The principle of the Brown-Boveri stage boiler may be put into practice as shown in Fig. 11. The exciter boiler is omitted from the figure. Being small, it may be built according to any known system and heated either by the main fire or from a separate furnace. The superheater may be built of thin wall tubes of about 1-in. diameter, without regard to circulation of water or extraction of steam. The weights may be kept small. In consequence of the high steam pressure, the heat transfer coefficient from the superheater tubes to the steam is very high, reaching as much as 200 to 250 B.t.u. per sq. ft. per deg. fahr. per hr. The temperature of the tubes is, therefore, little above the steam temperature.

The evaporators consist of simple drums placed outside the furnace and are easily accessible. Means are provided for suitably guiding the injected water and the steam. An excess of feed water may be supplied or the necessary rate maintained by a float valve. The tank "15" is made larger or smaller, depending upon the desired heat accumulating capacity of the boiler. Preheated feed water may be supplied from this tank or cold feed water from a reservoir. This tank acts to a high degree as an equalizer on rapid fluctuations of load. In the combustion chamber a large portion of the heat is transmitted by direct radiation to the heating surface. The high temperatures of the tubes and of the preheated combustion air prevent the fire from being excessively chilled. Large brick settings are done away with, which results in low prices and low starting and standby losses. Due to the small masses of brick work, the Brown-Boveri steam generator is well suited to take up rapid load changes and peak loads. The water is not heated through contact with a wall. Therefore, incrustation of the heated walls from impure water is impossible. The deposits drop to the bottom of the evaporators, where they are harmless and may be removed by replacing the soiled filter pieces by clean ones.

The advantages of the Brown-Boveri stage-boiler may be summarized as follows:

1. No heat transfer from a wall to the water. Insensibility to impure feed water. No incrustation of the heating surfaces; no priming.
2. Thin tubes for heating surfaces; light weight of the boiler; rapid adaptation to load changes; low prices.
3. Light water drums away from the fire; no weakening of the walls with water tubes.
4. The water level in the drums may be varied to give a large heat storage capacity suitable for peak loads.
5. Owing to small masses of brick work, small heating and standby losses; low first costs and maintenance; boilers suitable for rapidly fluctuating and peak loads.
6. No high-pressure circulating blower required.

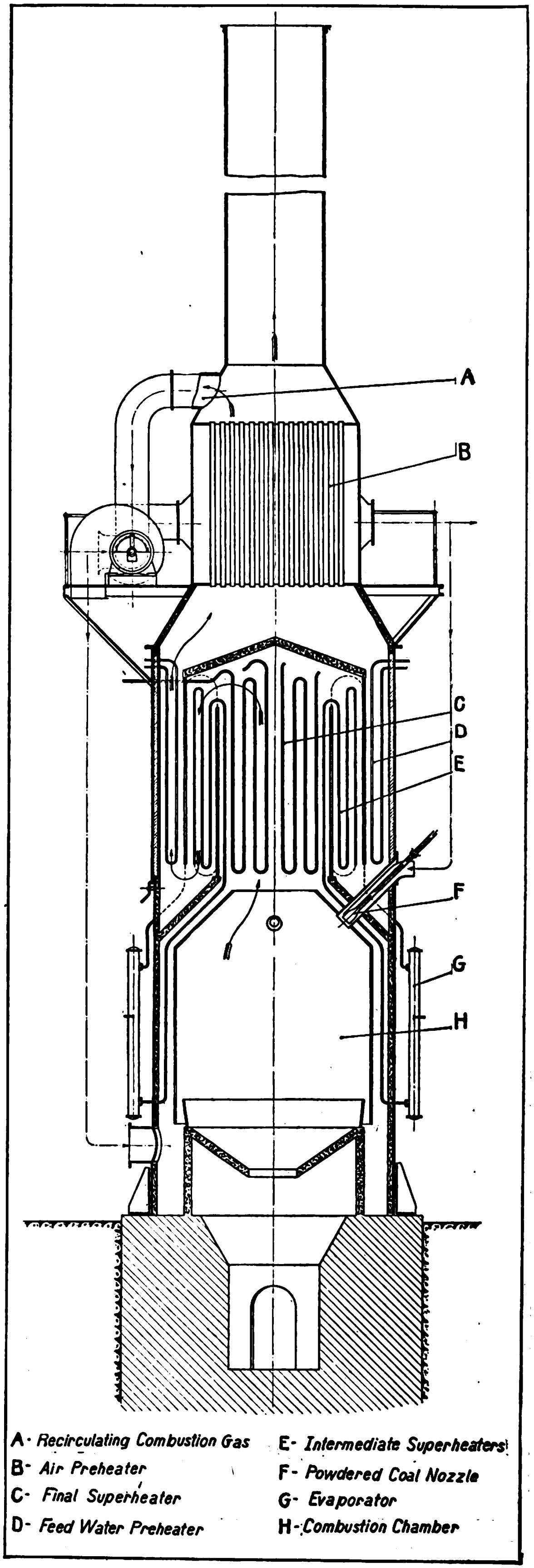

FIG. 11—ELEVATION OF THE BROWN-BOVERI BOILER.

High Pressure Steam Boilers

Statement by A. Borsig, Berlin-Tegel, Germany

Regarding high-pressure steam boilers, there is at our works at Tegel a boiler of 300 sq. m. (3228 sq. ft.) heating surface for a working pressure of 60 ats. (853 lb. per sq. in. abs.) without air preheater, but with a suitable engine. Tests made on this set by Professor Josse of the Charlottenburg Technische Hochschule showed a boiler efficiency of 80.55 per cent, based on the higher heating value of the coal. The high-pressure engine is a tandem compound unit which gave a thermodynamic efficiency of 85.4 per cent.

Two additional high-pressure boilers of 500 sq. m. (5380 sq. ft.) heating surface each and 120 ats. (1707 lb. per sq. in. abs.) working pressure are at present in the course of construction in our shops. Further details of these boilers will be available for publication at a later date.

The Benson Boiler Heat and Power Plant in the Cable Plant Gartenfeld of the Siemens-Schuckert-Werke

Statement by H. Gleichmann, Siemens-Schuckert-Werke

(*From Siemens Zeits., March,* 1928)

The Benson principle employs the critical steam condition (3200 lb. per sq. in. 706.3 deg. fahr.), at which the heat of evaporation is zero, to evaporate the water without change of volume and without the formation of steam bubbles. Therefore, no drums for the separation of steam and water and no tubes for the re-circulation of the water are needed. Re-superheating is necessary in the case of condensing operation and is accomplished either by returning the steam to a superheater in the boiler, by condensing high-pressure steam, or by using the high-pressure steam entering the unit, the temperature of which is lowered by this process.

A simplified steam-water flow diagram of the S.S.W. cable plant is shown in Fig. 12. The steam generated in boiler "a" is supplied to the high-pressure turbine "c" at a throttle pressure of 2570 lb.; the exhaust steam has a pressure of 514 lb. The 514 lb. header supplies part of the steam to the consumer "s," the remaining part to the low-pressure turbine "d." Excess steam, if present, is supplied to the Ruths accumulator "k."

The low-pressure unit has a bleeder point supplying the evaporator "g" to make up for steam used by the consumer "s_3" in which it is contaminated by acids. The vapors leaving the evaporator are mixed with the exhaust steam of the low-pressure turbine in the 78-lb. header, which supplies the consumers "s_2" and "s_3." The condensate from the consumers, excepting "s_3," the condensate of which is wasted due to contamination by acids, and from the evaporator, is collected in a tank "g" from which the high-pressure boiler feed pump "p_3" takes its suction.

The actual arrangements of the system are complicated due to difficult process steam demand conditions. A small part of the process steam is needed at 285 lb. pressure and a temperature of 464 deg. fahr., the remainder at 78 lb. and 464 deg. fahr. The temperature must be very constant to maintain a good quality of the products. About one-third of the condensate cannot be re-used due to contamination. The steam must be delivered at the required pressures and temperatures even when the turbine is not operating. These conditions complicate the system by necessitating regulators and other apparatus which are not otherwise part of the Benson system. The result is the rather complicated flow diagram shown in Fig. 13. The steam leaving the boiler "a" passes a throttle valve "n," which is wide open at full load, the throttling from 3200

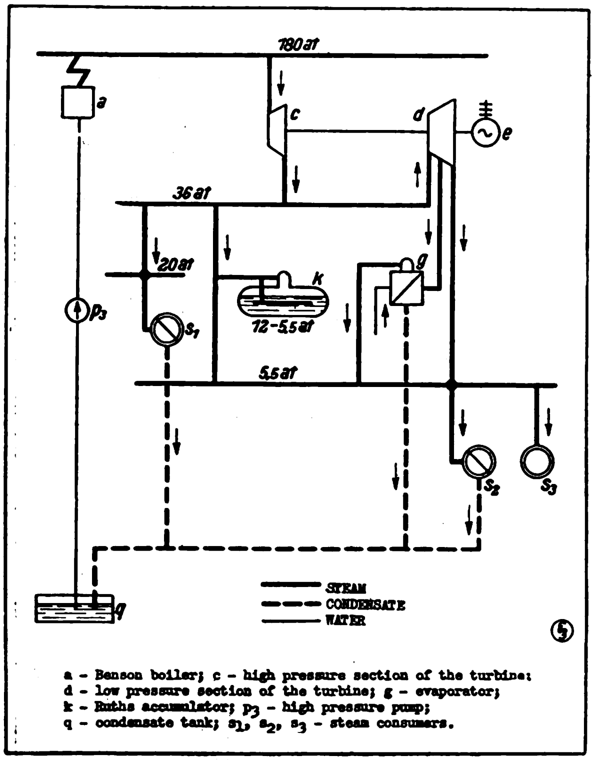
180at
a
c
d
e
36at
20at
k
12-5,5at
g
s_1
5,5at
s_2
s_3
p_3
q
STEAM
CONDENSATE
WATER
5
a - Benson boiler; c - high pressure section of the turbine;
d - low pressure section of the turbine; g - evaporator;
k - Ruths accumulator; p_3 - high pressure pump;
q - condensate tank; s_1, s_2, s_3 - steam consumers.

FIG. 12—Simplified Steam-Water Flow Diagram of the Benson Plant in the Cable Factory.

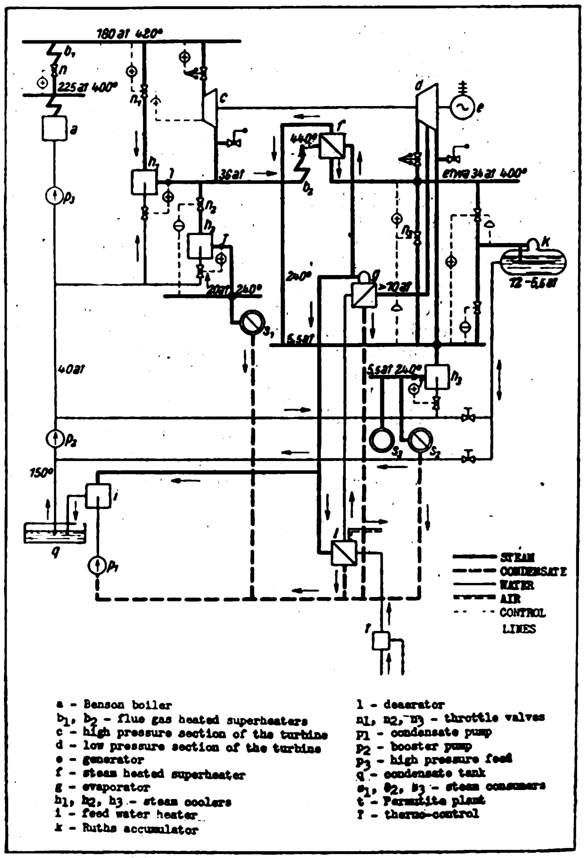
180 at 420°
b_1
n
225 at 400°
a
p_3
c
n_1
h_1
36 at
b_2
440°
f
d
e
etwa 34 at 400°
h_2
n_2
240°
s_1
g
>10 at
5,5 at
40 at
k
12-5,5 at
5,5 at 240°
h_3
n_3
s_3
s_2
p_2
150°
i
q
p_1
t
STEAM
CONDENSATE
WATER
AIR
CONTROL LINES
a - Benson boiler
b_1, b_2 - flue gas heated superheaters
c - high pressure section of the turbine
d - low pressure section of the turbine
e - generator
f - steam heated superheater
g - evaporator
h_1, h_2, h_3 - steam coolers
i - feed water heater
k - Ruths accumulator
l - deaerator
n_1, n_2, n_3 - throttle valves
p_1 - condensate pump
p_2 - booster pump
p_3 - high pressure feed
q - condensate tank
s_1, s_2, s_3 - steam consumers
t - Permutite plant
r - thermo-control

FIG. 13—Flow Diagram of the Benson Plant in the Cable Factory.

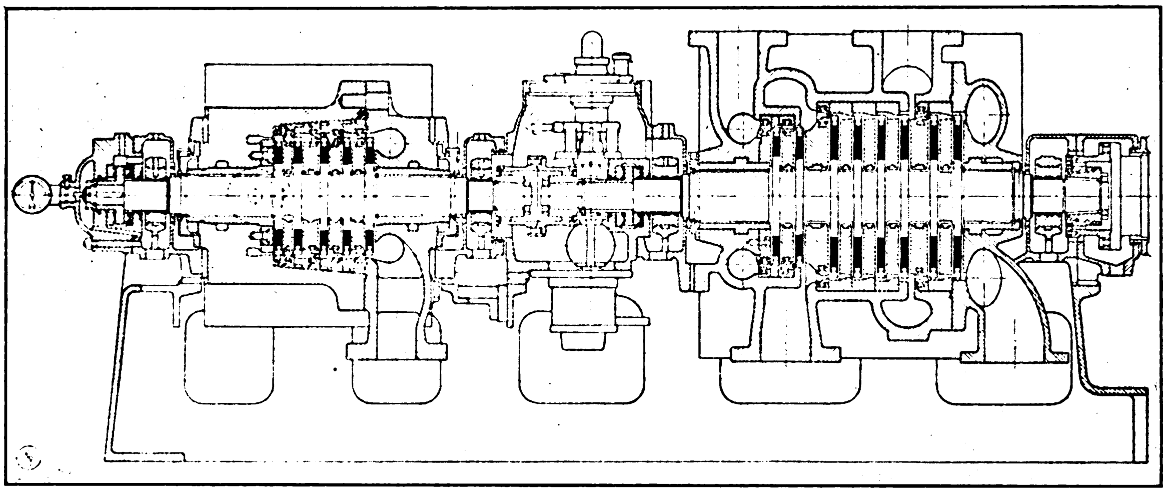

FIG. 14—HIGH-PRESSURE TURBINE AT GARTENFELD.

lb. to 2570 lb. being accomplished in the superheater "b_1." It is intended to connect this throttle valve to the turbine control in later installations. The steam is heated to 842 deg. fahr. in the superheater "b_1" and enters the high-pressure turbine, which is shown in Fig. 14, at this temperature. The turbine governor, acting as overflow regulator, admits all steam generated. The pressure is reduced from 2570 lb. to 856 lb. in the two rows of blades of a Curtis wheel. The spindle and the high-pressure glands, therefore, are exposed only to a pressure of about 856 lb. and a temperature of about 742 deg. fahr. The steam pressure is reduced to about 514 lb. in the remaining stages of the turbine.

When the turbine is not operated, the throttle valve "n_1" is used to reduce the pressure to 514 lb., the steam being cooled in the steam cooler "h_1" which is supplied with water by pump "p_2." Part of the steam taken from the 514-lb. header is reduced to 285-lb. pressure by throttle valve "n_2" and kept at 464 deg. fahr. by the steam cooler "h_2" and is supplied to the consumer "s_1." The remainder of the steam is reheated to 824 deg. fahr. in the reheater "b_2" and admitted to the steam heater "f," in which it superheats the 78 lb. in exhaust steam from the evaporator "g" to 464 deg. fahr. This process reduces the superheat of the steam to about 750 deg. fahr., at which temperature it enters the low-pressure cylinder "d" of the turbine. The exhaust steam of the turbine is admitted to the 78-lb. header. Approximately one-third of the steam entering the low-pressure cylinder is bled at a pressure of about 143 lb. to supply the evaporator. The condensate from this steam, after leaving the evaporator, is returned to the condensate tank. The 78-lb. steam generated in the evaporator is superheated to 464 deg. fahr., as shown above, and supplied to the 78-lb. header.

Since there are considerable steam demand variations in the rubber manufacturing plant, a Ruths accumulator "k" has been installed, which takes steam from the 514-lb. header when the pressure in the 78-lb. header increases, and furnishes steam to this latter header at decreasing pressure in it. Since the temperature of the 78-lb. steam might be lowered to less than 464 deg. fahr. at discharge of the accumulator, the steam leaving the turbine is kept above a temperature of 464 deg. fahr., a cooler "h_3" being normally used to reduce the temperature to that required. At discharge condition of the accumulator, the water supply to the cooler is reduced or eliminated to maintain a final temperature of 464 deg. fahr. in the header. A throttle valve connection "n_3" has been provided to supply the 78-lb. header with steam when the turbine is not operating.

The evaporator raw water is pretreated in the Permutit plant "t" and in the deaerator "l." The condensate from the heaters and consumers, excepting "s_3," is returned to the condensate tank after passing a direct contact heater "i." The steam used in the deaerator and in the heater is taken from the 78-lb. vapors leaving the evaporator. The pump "p_3" takes the condensate, which has a temperature of 300 deg. fahr., from the tank and supplies it to the high-pressure boiler feed pumps at a pressure of 571 lb. This intermediate pressure was selected to obtain a supply of water at sufficient pressure for the steam coolers "h_1" and "h_2." The high-pressure boiler feed pump is a horizontal plunger pump with six pistons and is driven by a d-c. motor for better control. A second pump has been provided for a-c. drive; this pump is a 16-stage, two-cylinder centrifugal pump.

The design of the boiler has been already shown. (See Report of the Subcommittee on Foreign Developments, July, 1928, Pub. No. 278-77). The generation of steam at critical pressure, without circulation and drums, necessitates equal distribution of the water in the parallel tubes and equal heat transmission. The heat needed for heating the water to the critical temperature and part of the superheat is transmitted in the radiation part of the furnace. The furnace, therefore, was arranged as a cylinder, vertical tubes forming the walls. In order to obtain equal resistance in the tube systems, a header has been arranged above the furnace in its vertical center lines from which the water is distributed to the eight tube systems forming the furnace walls. The steam is collected in a header and supplied to four superheater sections arranged in the second pass of the boiler. The exhaust steam of the high-pressure cylinder of the turbine is reheated in the remaining four superheater sections at a pressure of 514 lb.

The forced draft fans supply the combustion air to a circular duct on the foundation from which it passes through the hollow covers of the superheater chambers and air heaters to the inlet of the eight air heaters. After passing downward through the air heaters, in counterflow to the flue gases, it enters a circular duct formed by the air heaters and by the cast iron plates closing the furnace behind the tubes. A small part of the air is passed as primary air to the burners which are located at the top of the furnace. The larger part enters the furnace as secondary air through eight rows of nozzles.

An advantage of the Benson system is the independence from water circulation and drums. A Benson boiler, therefore, can be adapted to any type and form of furnace. In turn, it is necessary to develop furnaces which are adapted to the peculiar type of fuel and combustion selected.

An oil-fired boiler for an hourly capacity of 6600 lb. of steam has been erected in the Technical University at Charlottenburg for test purposes. Designs have been made for chain grate firing and for lignite. The German State Railroads have ordered a fast passenger train locomotive with a Benson boiler from the Maffei Co., at Munich, for test purposes. A small Benson boiler locomotive for exhaust operation is under construction in the United States. A large powdered-coal boiler for 30,000 kw. capacity will be constructed soon.

Foreign Stoker Developments

STATEMENT BY THE AMERICAN ENGINEERING COMPANY, PHILADELPHIA, PA.

The use of multiple retort underfeed stokers in Great Britain and on the Continent is increasing rapidly.

The operation of the new super power station plan in London necessitates the selection of equipment of large steam generating capacity. Chain grate stokers, so far, have been limited to a maximum continuous steam generating capacity of about 100,000 lb. per hr. and, in addition, have not been successful in the use of highly preheated air.

Multiple retort underfeed stokers are installed at the Deptford East and Deptford West plants of the London Electric Companies System. The stokers at Deptford East are typical of those of the best plants in the United States. Fig. 15 illustrates one of a number of similar units at Deptford, 37 tuyeres long and 11 retorts wide. The furnace construction is interesting because of the ingenious method of applying a long stoker, and elimination of a large refractory arch. These units have been in service for some time and have exceeded expectations, giving remarkable fuel burning rates with very low air pressures. Indications are that the fuel burning rates common in the United States can be exceeded with British coals due to their burning characteristics. These units operate with air preheated to 250 deg. fahr. There is an interesting installation in Italy —the Genoa Station of the Milan Edison Company. This station, which serves as a standby, supplementing a hydro-electric system, consists of four boilers each of 19,700 sq. ft. heating surface, fired by 15 retort 37 tuyere Taylor Stokers, as illustrated in Fig. 16. The steam pressure is 425 lb. per sq. in. with a final temperature of 750 deg. fahr. The present boilers are equipped with economizers, but it is planned to use air preheaters in future extensions. The rear wall is protected by a high-pressure waterback, shown in the illustration. Up to the present time it has been impossible to determine the capacity of these units, since the electric output of the station has not yet permitted it.

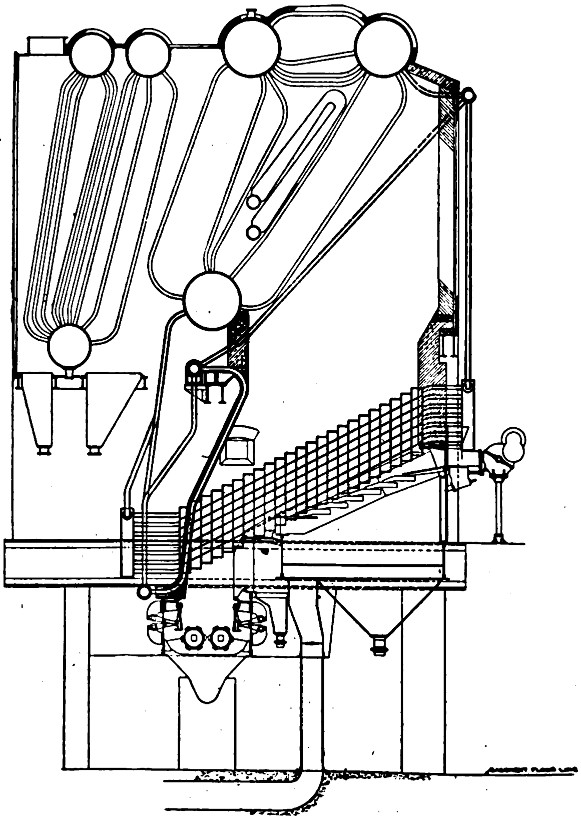

FIG. 15—STOKER AT DEPTFORD EAST STATION.

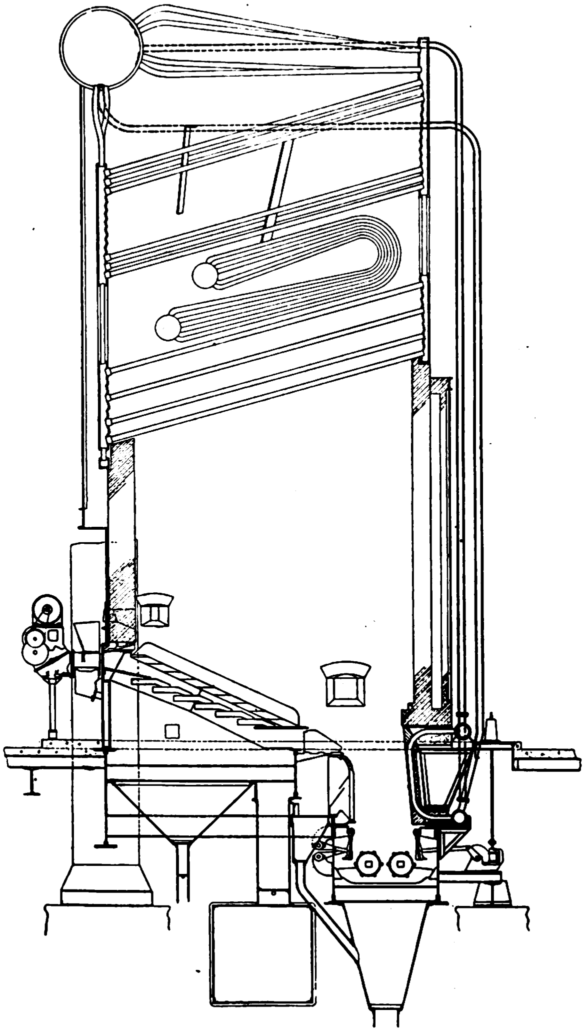

FIG. 16—TAYLOR STOKERS AT GENOA STATION.

"Bewag," in Berlin, Germany, has just placed orders for eight boilers and stokers for the West Side Station in Berlin. These boilers will be 2580 hp. Borsig boilers operating at 410 lb. per sq. in. steam pressure, 800 deg. fahr. steam temperature and feed water at 300 deg. fahr. The temperature of the air for combustion will be approximately 500 deg. fahr. The coal used will have a calorific value of from 11,000 to 14,000 B.t.u. per lb. as fired. The furnace will be cooled on both sides and rear by American Engineering Company type water walls with machined, cast iron blocks bolted to the tubes along the fire line. The stokers will be 20 retorts wide and 49 tuyeres long, giving them the largest projected area of any stokers ever built.

The London Electric Company is rebuilding an old portion of the Deptford West plant and has placed an order for two large boilers and underfeed stokers. These boilers will operate with a steam pressure of 325 lb. per sq. in. and a final steam temperature of 700 deg. fahr. and will be fired by 17 retort, 49 tuyere Taylor Stokers.

The largest steam station in Holland is the "Gurtruidenberg," which is now installing multiple retort underfeed stokers.

That there is a distinct trend toward the underfeed stoker in the large central stations of England, Germany, Holland and Italy is evinced in the above plants in which are represented the latest developments in European power plant practice.

Progress of the Ruths Steam Storage System During the Past Year

STATEMENT BY DR. E. G. RITCHIE, RUTHS STEAM STORAGE, LONDON, ENGLAND

Throughout the world rapid progress is being made in the application of the Ruths Steam Storage System to industrial and power plants. In Sweden the situation is an interesting one because the invention is of Swedish origin, and in its early development was entirely confined to that country. In Sweden almost every factory where the system is applicable now has its Ruths steam accumulator, and from a business point of view the sale of steam accumulators in that country has reached its saturation point. In Germany developments are proceeding apace, while in Great Britain the steam accumulator idea is making great progress.

A Ruths Central organization has been formed in Berlin to undertake research work connected with the subject of Steam Storage, and to act in an advisory capacity for the various Ruths Companies throughout the world.

Several noteworthy engineering developments have taken place in the past year. In Germany railway power stations are now equipped with a Ruths steam accumulator installation, while the system is being applied on a large scale to take care of the peak load in the city of Berlin. It will be recollected that the intention was to make the Klingenberg Station the peak load plant for the whole of the area, the base load being carried by a group of interconnected stations throughout the city. The Klingenberg Station is a "Lopulco" pulverized coal fired station, and represented, when it was erected, the highest development of this system of firing on the Continent. It was later decided, however, to make the Klingenberg Station a base load plant, and to install special turbines and a Ruths Steam Storage Battery at Charlottenburg to take care of the peak load. This decision was only reached after a prolonged discussion as to the best method of solving the problem, the opinions of all interested parties being secured before the matter was finally settled. The accumulator battery in this particular instance comprises 16 vertical tanks 14 ft. 9 in. in diameter by 65 ft. 0 in. high, with a pressure range from 190 lb. to 7 lb. The total weight of water impounded is approximately 5000 tons. The maximum anticipated peak load to be supplied by accumulated steam is 40,000 kw. and the total amount of energy generated during 2½ to 3 hours in the afternoon is approximately 70,000 kw-hr. The peak load turbines are of special types comprising a high-pressure pass-out stage, exhausting steam to the accumulator, which supplies steam to a low-pressure condensing stage operating with an inlet pressure which varies with the pressure in the accumulator. This stage is fitted with a special arrangement of admission nozzles which are brought into operation in succession as the pressure in the accumulator battery falls.

The Charlottenburg steam accumulator installation represents one of the most noteworthy departures in steam electric power generating practice of recent years, and the results obtained will be studied eagerly by power station engineers throughout the world.

Steam storage is a relatively new idea; its progressive development is therefore very largely a matter of education, but there are signs that in all the industrial countries the use of the system is being more and more understood and appreciated.

Electric Boilers and Steam Accumulators

STATEMENT BY C. J. WHARTON

(*From "Science Abstracts" 1276—August, 1928*
World Power, 9 pp. 256-260, May, 1928
Paper read before the Inst. Eng. Inspection)

The author considers the conditions in which it is advantageous to use electricity for generating steam for processes in industrial works, and discusses two types of electric boiler. In the Swedish type, the electrodes enter the base of the vertical cylindrical shell. Steam output and electrical input are varied by raising or lowering vertical tubes round the electrodes. The water level is kept uniform. The German system leads in the circuits at the top of the boiler to hanging electrodes, with piled insulating disks surrounding them. The output of steam is varied by raising and lowering the water level.

The makers guarantee 96 per cent efficiency under commercial conditions. The only losses are due to radiation and blow-down necessary to keep the electric resistance of the water within the required limits. With feed water at 68 deg. fahr. 1 kw-hr. will produce 2.75 lb. steam at 114 lb. gage pressure.

In one case three Lancashire boilers were required to supply a hospital. An electric boiler occupying 49 sq. ft. of floor space, including switchgear and accessories, did the same work as the three boilers. Repairs and maintenance costs are extremely small, and no pitting or scale formation occurs. Ruths steam accumulator is referred to and its use described.

Electric Steam Boilers of 147,000 Kw. Capacity at Gatineau Paper Mill, Canada

STATEMENT BY W. P. MUIR

(*From "Science Abstracts" 1271—August, 1928, Elect. News, Toronto, 37 pp. 55-57, May 15, 1928*)

The boilers are built for power at 6600 volts, 3 phase, and steam at 200 lb. per sq. in. The installation consists of three 42,000 kw. units and one 21,000 kw. Usually one unit using 60-cycle power runs continuously, and a second unit using 25-cycle power supplies the balance or variable load. They are so connected that either frequency can be used. No trouble has occurred due to gas formation in boilers.

The boilers deliver 190 lb. steam to a steam accumulator 12 ft. diameter by 60 ft. long, from which it is drawn at 125 lb. When first installed, as with other new similar plants, quite a lot of dirt was carried back to the feed tank, reducing the purity of the water and necessitating about 25 per cent bleeding. This has now righted itself. The boilers are blown down about 6 or 8 in. every four hours, and under these conditions it has been found necessary to open the boilers every two months only for cleaning. The inner insulators are renewed at the same time. These are of high-grade porcelain, but due to being wet and at high temperature they are found to develop fine cracks in about this length of time. The electrodes are estimated to last five years.

The steam is practically dry saturated, some tests showing only 0.4 per cent moisture.

The New Askania Combustion Control

STATEMENT BY DR. TH. STEIN, A. E. G. BERLIN

On account of the small boiler units used in Europe, the introduction of combustion control demands as cheap and simple equipment as possible. Some useful constructive elements developed for other purposes, were already at hand. The far-reaching use of the Ruths Accumulator in Europe has led to many great improvements in steam regulators. Furthermore, mechanical CO_2 recorders have been so well developed that they could take the place of the more expensive airflow-steamflow recorders for the regulation of boilers. Through theoretical research work on the regulation of combustion processes,* it was possible to decide from the many possible arrangements which was the best. These studies, corroborated by practical tests in 1926, have resulted in the installation of A. E. G.-Askania Combustion Regulators on 79 boilers.

At first it was found that the large dashpots between the regulator and the servomotor as used in numerous hydraulic constructions could be replaced by a small spring attached to the regulator. The spring acts in the same way as the dashpot by producing an opposing force on the regulator, when the regulator leaves its central position, which means when the servomotor is in motion. After all, the dashpot does not do more than produce such an opposing force on the regulator.

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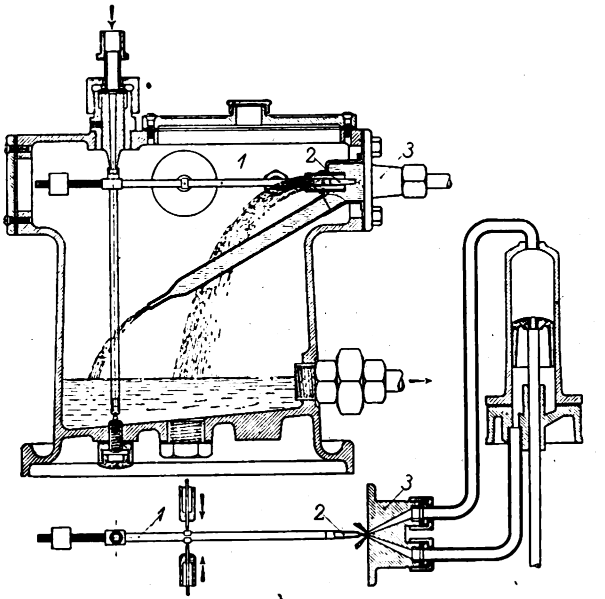
* Th. Stein, Regelung und Ausgleich in Dampfanlagen, Berlin, 1926, Julius Springer.

The regulation was divided into three separate processes to avoid incomplete combustion occurring in consequence of quick changes of load before the CO_2 recorder which works with time lag, gets into action. Each process works successively. The load regulator acts only on the speed of the coal feeders by means of a slow-running servomotor. The speed of the coal feeders acts by means of a second regulator with quick-running servomotors on the damper, and supplies an amount of air proportional to its speed. The lack of proportion between the feeder speed and the quantity and changing quality of coal is not so great that incomplete combustion can occur. It has to be specially noted that through its slow-running servomotor the changes of the speed of the feeders are slower than the changes in the consumption of steam. The accumulator capacity of the boiler is utilized through temporary changes of pressure to provide the quantity of steam needed. Therefore, the CO_2 recorder has time to correct the remaining faults every two minutes.

The Jetpipe Combustion Regulator
(See Fig. 17)

The oil enters the bore of the jetpipe at "1," the end "2" of which is movable sideways. Diaphragms act on both sides of the jetpipe, as shown by arrows. A small motion is sufficient to send the oil through the end "2" to the one or the other opening of the distributor "3" whereby the servomotor "4" is moved in either direction.

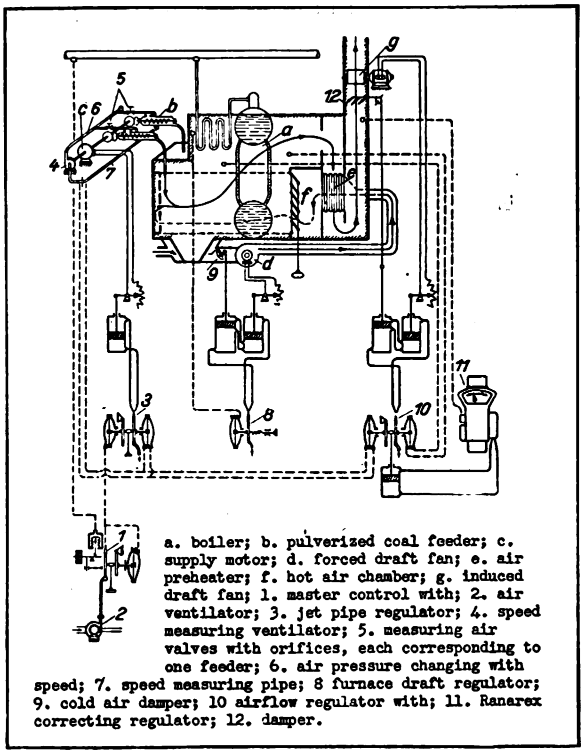


1. jetpipe; 2. end throwing the oil against the, 3. distributor; 4. servomotor.

FIG. 17—JETPIPE REGULATOR.

Regulation of the Speed of Feeders
(See Fig. 18)

The steam pressure acts on the master control "1," where it is balanced against an air-pressure produced by a fan "2." The air-pressure acts on the combustion regulator "3" and moves the resistance of the feeder-motor "c" until the proper speed is reached. The motor "c" drives several feeders at the same speed. The speed is measured by a fan "4." This fan produces an air pressure in the pipe "6" which changes with the speed. Furthermore, the quantity of air flowing through the measuring pipe "7" is in proportion to the number of open valves "5," which are put on and off simultaneously with corresponding feeders. Very small gold orifices are placed in front of these valves. By measuring the airflow in the pipe "7" one records the speed multiplied by the number of the feeders in action as a measure for the quantity of coal fed.



a. boiler; b. pulverized coal feeder; c. supply motor; d. forced draft fan; e. air preheater; f. hot air chamber; g. induced draft fan; 1. master control with; 2. air ventilator; 3. jet pipe regulator; 4. speed measuring ventilator; 5. measuring air valves with orifices, each corresponding to one feeder; 6. air pressure changing with speed; 7. speed measuring pipe; 8 furnace draft regulator; 9. cold air damper; 10 airflow regulator with; 11. Ranarex correcting regulator; 12. damper.

FIG. 18—COMBUSTION CONTROL A. E. G. ASKANIA AT A PULVERIZED COAL BOILER.

Preliminary Regulation of Air

This same measuring air is also transferred to the regulator "10," which acts through the servomotors on the induced draft fan "g" at high loads, and on the damper "12" at low load. At increasing speed of the feeders the airflow increases in the measuring pipe "7," which acts on the left diaphragm, and the servomotors increase the flow of flue gases until the right diaphragm on which the flue gases act is balanced with the left diaphragm, so that the flow of flue gases corresponds to the speed of the feeders. Contrary to the servomotor of the regulator "3," the servomotors of the regulator "10" work very quickly. The oil pipes are connected in special order so that the damper is opened first at low load, and only when its servomotor is at the highest position does it open the oil pipe leading to air damper "9" at low load and the resistance of the forced draft motor at high load.

Correcting Regulation by Ranarex-Recorder

The indicator needle of the Ranarex CO_2 Recorder "11" is connected with a jetpipe which by means of its servomotor gives a correcting impulse on the regulator "10" every two minutes. This changes the proportion between the coal quantity (left) and the flue gas quantity (right). If the Ranarex shows instead of 14 per cent normal CO_2 content only 12.6 per cent it means that about 1.4 ÷ 14 or 10 per cent too much air is furnished by the preliminary regulator "10." The regulator functions in such a way that the proportion of coal and air quantities is changed by 10 per cent. In this way only one single regulation period of two

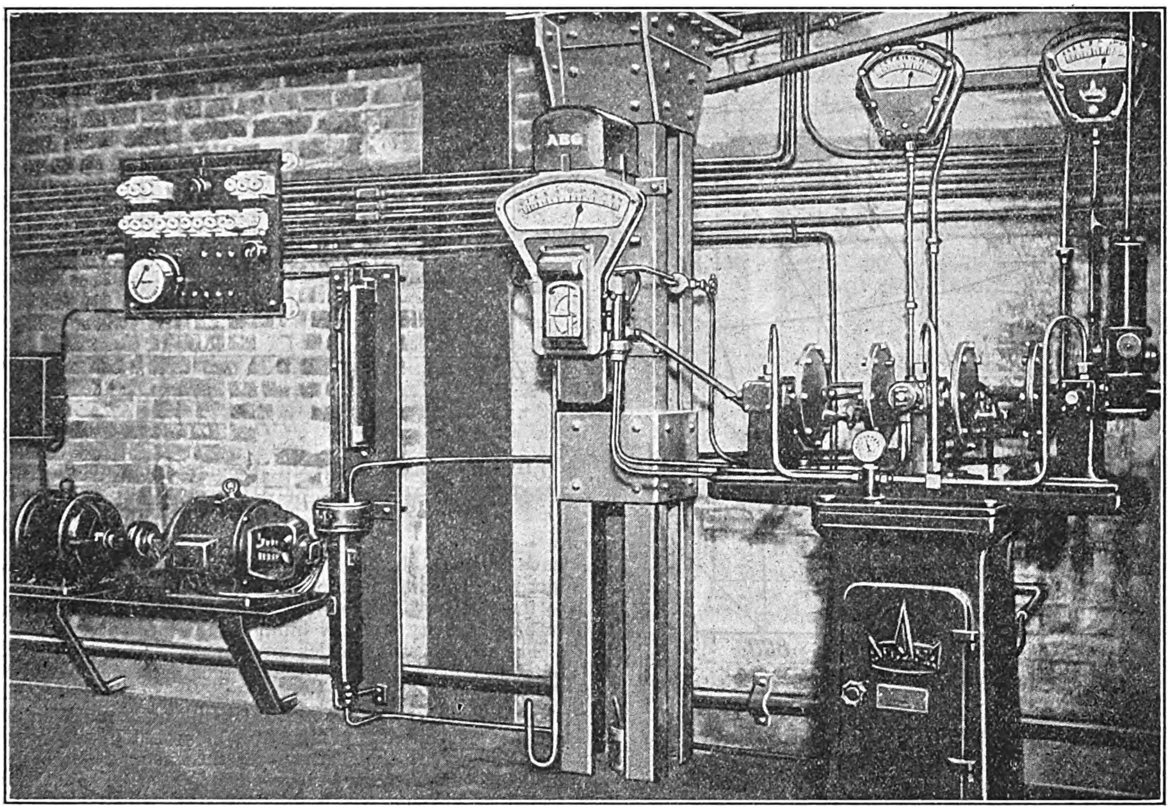


FIG. 19—INSTALLATION OF THE A. E. G. ASKANIA REGULATOR.

minutes in all cases is sufficient for correcting a variation of the CO_2 content.

Fig. 19 shows the whole regulator in a Stettin central station. On the right hand is a box containing the oil pump. The three regulators are installed on top of this box. In the middle of Fig. 19 the Ranarex-Recorder is shown and on the left a Ward-Leonard dynamo with its resistance control by means of which the speed of the feeder motor is regulated.

In the case of boilers with chain grates, the regulation by Ranarex-Recorders is not generally employed, as the speed of the driving motor is a sufficiently good measure for the coal quantity. Also when using boilers without induced draft the grate is enclosed and provided with a regulated damper in order to avoid the discharge of gases from the furnace into the boiler room.

The regulators are so simple, reliable and standardized that they can be adapted to other equipments in power stations. It is therefore proposed to use this standardized apparatus for the regulation of complete steam plants with boilers, Ruths accumulators and turbines.

Efficiencies of High Pressure Turbines

STATEMENT BY DR.-ING. MELAN. SIEMENS-SCHUCKERT-WERKE

(*Siemens Zeit., March,* 1928)

Turbine efficiencies decrease with increasing pressures, due mainly to increase of the leakage and other losses.

Recent investigations made by the S. S. W. showed that the efficiency of a turbine depends on two factors. One of them is the Parson factor:

$$q = \frac{\Sigma u^2}{H_0}$$

i. e., the total of the squares of the peripheral velocities divided by the adiabatic heat drop. The other factor is the "mean steam volume" as expressed by the formula

$$\xi = \frac{P_1 - P_2}{D \times H_0} = \frac{\text{pressure difference}}{\text{Amount of steam} \times \text{adiabatic heat drop}} = \frac{\text{constant}}{\text{Mean volume}}$$

The thermodynamic efficiencies depending on two factors can be shown in a space diagram (Fig. 20). The diagram is correct for complete turbine expansion. Bleeder turbines and "two-pressure turbines" discharging or receiving respectively steam at an intermediate stage must be considered in separate sections according to the varying amounts of steam.

The factor ξ in diagram Fig. 20 increases with higher initial pressure p_1 and decreases with increasing amount of steam D. Turbines with large mean volume are close to the zero point on the ξ axis, turbines with small mean volume farther away. The Parsons factor q is the second axis of the diagram. The ξ formula indicates that the mean volume is determined mainly by pressure drop, amount of steam and adiabatic heat drop and, therefore, can be calculated according to the operating conditions in any individual case.

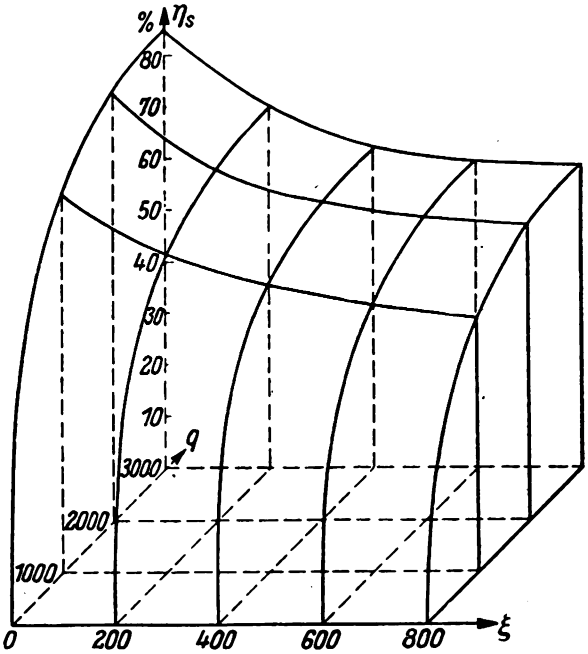
The efficiencies shown in Fig. 20 refer to saturated steam. Correction factors must be used to obtain the actual efficiencies, these factors being larger than 1 for superheated steam and smaller than 1 for wet steam.

The correction factor "f_1" for superheated steam, at a mean superheat "t_m", is

$$f_1 = 1 + \frac{t_m}{1650}$$

The correction factor for wet steam, at a steam quality factor "x_0", is

$$f_2 = \frac{1 + x_0}{2}$$



$$\xi = \frac{p_1 - p_2}{D \cdot H_0} \ldots \; x_1 \approx \text{axis}$$

$$\varphi = \frac{\Sigma u^2}{H_0} \ldots\ldots \; x_2 \approx \text{axis}$$

FIG. 20—SPACE DIAGRAM OF EFFICIENCIES CALCULATED TO SATURATED STEAM.

Recent investigations have shown these factors, which were determined some time ago, are more or less correct.

Numerous test results indicate that the change of efficiency within the range of high pressures, depends on the factors q and ξ. Table III shows the results of a number of tests at different steam pressures and turbine sizes. (The factors q and ξ in the table, as well as other data, are recalculated to the foot-pound Fahrenheit system.) The test results indicate that size of unit does not decide the efficiency; the factor ξ is far more important. The influence of the factor q on the efficiency is approximately identical for the range of from 0 to 800. For comparing calculations, therefore, the efficiency can be reduced to equal q as it has been done for the curve shown in Fig. 21. Table III indicates, for instance, that two entirely different turbines, Nos. 3 and 5, have approximately equal mean volumes ξ though one is operating at a pressure of approximately 200 lb. per sq. in., the other at 728 lb. per sq. in. The efficiencies, therefore, reduced to identical conditions, must be approximately equal, as they actually are. For small ranges of ξ, the efficiencies, calculated to equal conditions, can be shown by the equation

$$\eta = \alpha \beta \xi$$

For small differences ξ, α and β can be considered to be constant. The change of these factors seems to become smaller at high pressures. Further, an upper limit is set to increasing the pressure by the resulting short length of the blades.

Tests made by the S. S. W., together with Escher, Wyss & Co., on a 1400-lb. test turbine in the Nonnendamm Station are very interesting. The turbine received its steam from a Benson boiler, the pressure being throttled from 3200 lb. to the operating pressure. The amount of steam was about 19,600 lb. per hr. The factor ξ was considerably larger than all such figures known before. Accordingly, the thermodynamic efficiency, which was determined to be approximately 62 per cent at ¾ load, was low. These tests have further shown the influence of short blades which increases the influence of the walls on the steam flow, due to the small available cross-section areas. It seems that this turbine capacity is a low limit for this pressure.

The use of still smaller amounts of steam at 1400 lb. or of equal amounts of steam at higher pressures would lower the efficiency still more. An increase of the amount of steam, at otherwise identical conditions, results in larger cross-section areas for the steam flow and in a corresponding decrease of the wall effect; the factor ξ decreases and the efficiency increases correspondingly. This fact is illustrated by turbine No. 6 in Table III, which has been designed for a ten times larger amount of steam than the 1400-lb. unit. The efficiency, at equal conditions, has been increased to 74.2 per cent. Fig. 22 shows the steam rates

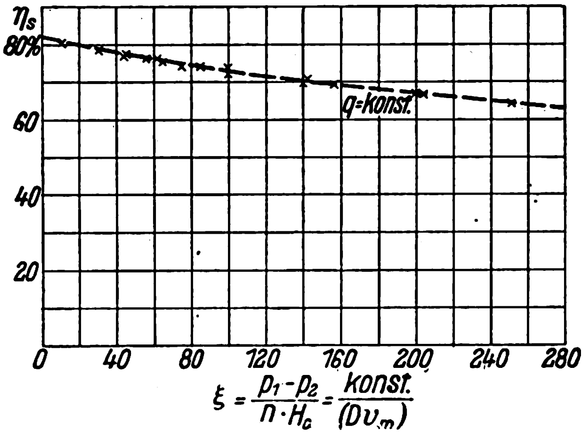


FIG. 21—THERMODYNAMIC EFFICIENCY, CALCULATED TO SATURATED STEAM, IN RELATION TO THE "MEAN STEAM VOLUME" FOR CONSTANT Q.

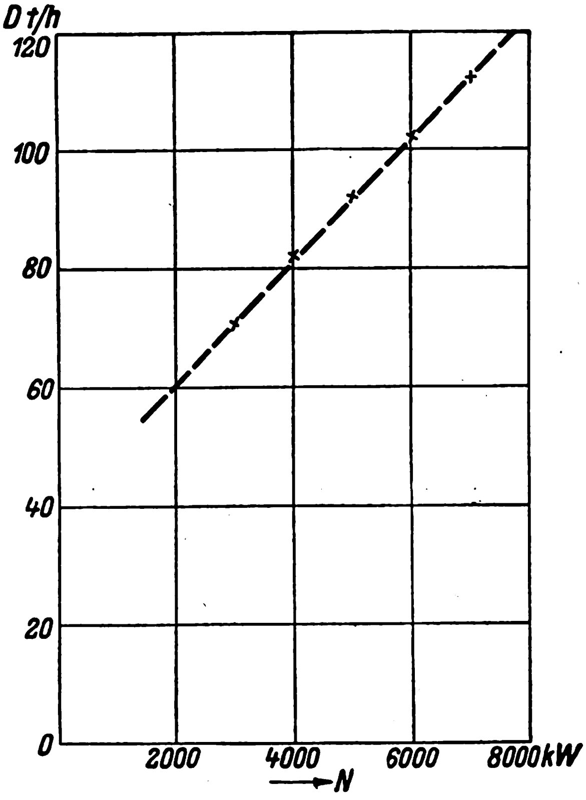


FIG. 22—STEAM RATE CURVE OF THE LAKESIDE TURBINE.

TABLE III

THERMODYNAMIC EFFICIENCIES

	1	2	3	4	5	6
Full load, h.p.	2,800	2,800	900	3,400	2,450	10,000
Throttle pressure, lb. per sq. in. abs.	189.8	190.0	199.8	473.8	728	1,245
Throttle temperature, °F.	613	566	572	727	824	716
Back pressure, lb. per sq. in. abs.	48.7	47.4	21.4	184.5	313.9	308
Exhaust temperature, °F.	373	323	266	530	651	430
Amount of steam, lb. per hr.	64,200	68,800	18,380	101,300	79,300	238,200
Adiabatic heat drop, H° B.t.u.	301.6	285.7	424.5	236.0	226.2	301.7
Factor ξ	73.5	72.5	229	121	232	140
Factor q	5,236	5,412	3,662	6,891	4,612	6,375
Efficiency, as determined	81.3	80.0	67.5	78.5	75.5	77.7
Saturated steam efficiency, calculated to q=5426	77	77.1	69.8	75.0	70.8	74.2
Tests reported by	SSW and Boiler Testing Assoc.	SSW and Boiler Testing Assoc.	SSW and Boiler Testing Assoc.	Impartial Experts	VDI, Vol. 70, Page 711	NELA Serial Report 1926-27 (Lakeside unit)

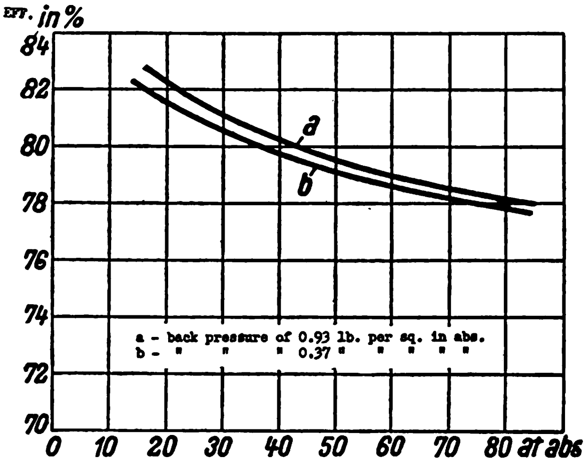


FIG. 23—EFFICIENCIES AT VARYING THROTTLE PRESSURES AND CONSTANT THROTTLE TEMPERATURE OF 748 DEG. FAHR. ACCORDING TO LAW AND CHITTENDEN.

at partial loads, according to a report of the Prime Movers Committee. As shown, the steam rate curve is, also, a straight line for high pressure.

The design and construction of the blades is very important at high pressure. The length has a certain influence as mentioned above. All surfaces which are in contact with the steam flow should be machined to decrease friction losses; the ratio of the distance between blades to the width of the blades should be selected to produce the most favorable hydraulic conditions. The steam velocity should be small at high pressures in order to decrease friction losses and to allow more favorable blade dimensions. With large amounts of steam, the simpler reaction blading should be considered in place of the impulse blading.

The graphic method used above makes it possible to compare the available test data on high-pressure turbines on a fair base. Fig. 23 shows the efficiency curves of a condensing turbine for varying throttle pressures at constant throttle temperature (748 deg. fahr.) and at two different

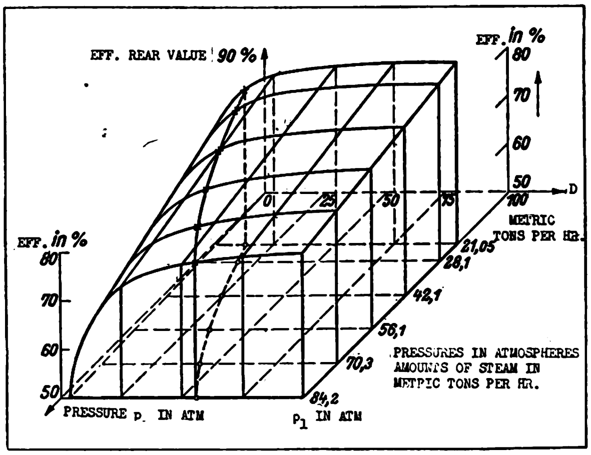


FIG. 24—EFFICIENCIES OF CONDENSING HIGH-PRESSURE TURBINES, NO REHEATING, Q = 5426, THROTTLE TEMPERATURE 748 DEG. FAHR., VARYING THROTTLE PRESSURES P_1 AND AMOUNTS OF STEAM D.

TABLE IV

THERMODYNAMIC EFFICIENCIES ACCORDING TO LAW AND CHITTENDEN, FOR CONDENSING TURBINES AT DIFFERENT THROTTLE PRESSURES, CONSTANT THROTTLE TEMPERATURE OF 748 DEG. FAHR. AND A VACUUM OF 93.5 PER CENT. (*Engineering,* Vol. 124, Page 610).

Pressure, lb. per sq. in. abs.	300	400	600	800	1,000	1,200
Superheat, °F.	329	302	259	227	200	180
Steam condition at exhaust, quality	0.924	0.915	0.896	0.88	0.867	0.854
Correction factor	1.086	1.077	1.057	1.040	1.028	1.016
Adiabatic heat drop	994	1,024	1,067	1,091	1,108	1,121
Thermodynamic efficiency, per cent.	82	81.15	80	79.12	78.51	78
Thermodynamic efficiency, calculated to saturated steam, per cent.	75.5	75.5	75.6	76.0	76.5	76.7
Amount of steam from Fig. 5, lb. per hr.	28,600	37,620	54,560	72,600	94,600	123,200
Factor ξ	105.5	103.7	102.9	101.2	95.5	92.2

vacua, according to A. H. Law and S. P. Chittenden, *Engineering,* Vol. 124, p. 610. Curve "a" shows the efficiencies at a vacuum of 93.5 per cent, curve "b" of 97.4 per cent.

The thermodynamic efficiencies are shown for pressures up to 1200 lb. per sq. in. They are correct for uninterrupted expansion, i.e., without reheating and bleeding. As shown, the efficiency goes down from 85 per cent at a pressure of 300 lb. to 78 per cent at 1200 lb.

Table IV shows the efficiency values as calculated to equal conditions; Fig. 24 is a space diagram of the efficiency values in a slightly changed form. The application of the efficiency values taken from Fig. 23 to this space diagram shows the corresponding amounts of steam. Therefore, the understanding that a definite amount of steam belongs to any of the efficiency values.

The result of this investigation is the conclusion that the turbine efficiency at high pressures depends on a certain factor in addition to the Parsons factor. This new factor is determined mainly by the mean steam volume.

Efficiency values based on this conclusion make it possible to determine the efficiency curves for different throttle pressures and amounts of steam as shown in Fig. 25 for amounts of about 55,000 and 165,000 lb. per hr. It is assumed that the throttle temperature is increased with increasing pressure up to a limit of about 800 deg. fahr. The back pressure is assumed to be about 57 lb. per sq. in. abs. The diagram shows that the efficiency decreases at a greater rate at small amounts of steam than at larger amounts. This method can be used to determine the maximum permissible throttle pressure for a turbine at a given amount of steam, and may serve to aid the selection of the steam pressure in designing power plants.

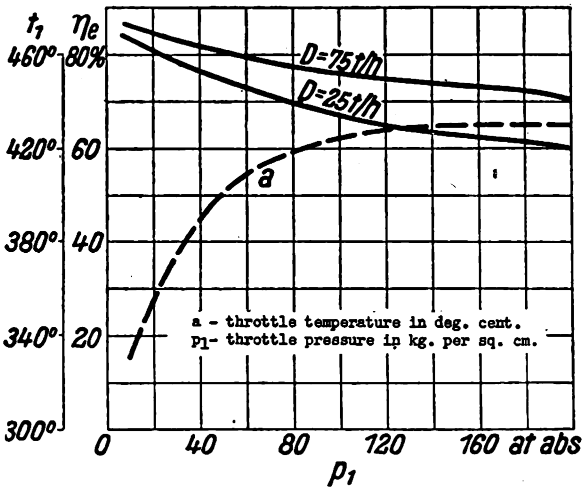


FIG. 25—THERMODYNAMIC EFFICIENCIES IN RELATION TO THROTTLE PRESSURES P_1 AND AMOUNTS OF STEAM D, AT A BACK PRESSURE OF 57 LB. PER SQ. IN. ABS.

Ljungstrom Steam Turbines

STATEMENT BY S. T. A. L. FINSPONG, SWEDEN

"We have an order from the City Electricity Works of Stockholm at Vartan, for a 27,000 kw. Ljungstrom turbine to be delivered in the summer of 1929. We have also obtained an order from the Government Power service for a 50,000-kw. Ljungstrom turbine at 1500 r.p.m. Its best heat consumption is 11,200 B.t.u. per kw-hr. with initial pressure 242 lb., temperature 750 deg. fahr. and 1.16 in. of mercury exhaust pressure. Details of these units will be available for next year's report.

"Tests were made in November, 1928, on a 13,500-kw. Ljungstrom turbo-generator set installed at the Hamburg Electricity Works, Germany, with the results shown in Table V. These were official acceptance tests of one hour each. In accordance with our practice, the steam leaking from the turbine glands is not included in the turbine water rate."

TABLE V

TESTS OF 13,500-KW. LJUNGSTROM TURBINE AT HAMBURG, GERMANY

Test No.	1	2	3	4
Output, kw.	4,358	8,450	11,931	14,436
Steam pressure before throttle, lb. per sq. in. abs.	230.0	220	217.5	216
Steam temperature before throttle, °F.	624.0	644.0	676.0	653.0
Exhaust pressure, in. of mercury abs.	0.64	0.9	1.2	1.54
Total steam consumption, lb. per hr.	46,710	84,420	114,320	145,630
Steam used by air ejectors and glands, lb. per hr.	1,060	1,370	1,720	2,030
Net steam used by turbine, lb. per hr.	45,650	83,050	112,600	143,600
Net steam per kw-hr., lb.	10.47	9.82	9.44	9.55
Engine efficiency, per cent. (without gland steam)	71.7	78.5	82.8	82.1

New Stal Double-Rotation Back-Pressure Turbine

(From "Science Abstracts" 4—January, 1928 *A. S. E. A. J.* 4 *pp.* 98-101, *August,* 1927*)*

This article describes and illustrates a back-pressure turbine, Type DM, of particularly high thermodynamic efficiency and simplicity of construction recently brought out by the STAL Company. It is of the radial double-rotation construction. The blade system contains a smaller number of rings than for condensing turbines, and the outer ring has a smaller diameter.

On account of the comparatively high pressure of the steam in the last state (15 to 150 lb. per sq. in.) a special steel inner housing is placed inside the usual turbine case. The heat insulation is very effective, and also the inlet valve is of ample size for the steam required to be passed. In addition to speed-regulating governors, back-pressure regulators of STAL design are fitted, so that when in parallel with other machines the regulator gives constant back pressure, and the speed governing is put out of action. When the turbine runs alone the speed is governed and the back-pressure regulator thrown out.

Some test results are as follows:

Pressure, inlet lb. sq. in. (abs.)	170.8	202.1	243	256.1
Back pressure, inlet lb. sq. in. (abs.)	59.9	54.6	57	57
Temperature, inlet deg. fahr.	513	524	553	562
Output, kw.	774	1047	1440	1815
Total quantity of steam lb. per hour	33,058	38,094	45,699	57,358
Thermodynamic efficiency, per cent	83.2	85.0	85.2	82.3

The normal output of the turbine is 7500 kw.

Heat Insulation with Aluminum Foil

(From "Science Abstracts" 6*—January,* 1928 *V. D. I.* 71 *pp.* 1395-1400, *October,* 1927*)*

Owing to the very low thermal conductivity of air, the efficiency of a heat insulator depends largely on its porosity and the entrapped air. The porosity also reduces the volume weight of the insulator. The size of the voids is limited, however, by the effect of convection of the air within the cells. The author discusses the influence of the thickness of the air layer on the convection effect and the total heat transmission, and describes experiments carried out to investigate it. The effect of radiation is also considered.

Non-metallic bodies all have radiation coefficients approaching that of "black" bodies. Oxidized metallic surfaces have rather lower values, but polished metallic surfaces have very much lower coefficients, especially in the case of aluminum, for which the figure is about 0.07. This fact is utilized in a form of aluminum foil heat insulation, which is described. The thickness of the foil is less than 0.002 in. and concentric layers are fixed round the pipe to be insulated, separated from one another by rings of insulating material, which also determine the thickness of the air spaces, between 0.4 and 0.8 in. The outer layer may be protected by a sheet-iron casing.

The volume weight of a typical insulation of this kind may be less than 2.5 lb. per cu. ft., i.e., between 5 and 10 per cent of the weight of other insulators. The insulating properties of the new insulation compare favorably with those of the best materials previously used, and various other advantages are described.

The Utilization of Diesel Engines in German Power Houses

STATEMENT BY DR. M. GERCKE, CHIEF ENGINEER, MASCHINENFABRIK AUGSBURG-NURNBERG, A. G.

Small and medium-size Diesel engines, principally of the single-acting four-stroke type, are utilized in thousands of units for driving the electric generators of many power houses all over the world. The high thermal efficiency of the Diesel engine and its high standard of mechanical perfection were responsible for the speedy introduction of this internal-combustion engine in the electric installations where formerly only steam and gas engines were operated.

For small and medium-size engines the single-acting four-cycle type, with airless fuel injection, is holding the field; single-acting two-cycle engines began to compete seriously some time ago with the four-cycle type by lower initial prices, though the fuel consumption of the four-cycle type is somewhat lower than that of the two-cycle type.

For electric power house service two different types of Diesel engines must be considered:

(1) For continuous operation—the total load, base load and peak load together being covered by the same engines;
(2) For peak load service and for stand-by purposes exclusively, i.e., for short-time operation, the base load being borne by steam or water power plants.

For purpose (1) high thermal efficiency and long life are essential, besides, of course, continuity of operation. As a rule heavy and expensive engines with low and medium speeds are supplied for this service, mainly single-acting four-stroke and single and double-acting two-stroke engines of different types.

For purpose (2) Diesel engines of another special design had to be constructed which are characterized by the following features: (a) Low first cost; (b) perfect safety of operation; (c) simple operation with quick starting and loading. High thermal efficiency and long life are not the predominant considerations.

These requirements lead to light construction and the application of extra high quality materials, high rotative speed, high mean effective pressures and high piston speed.

For outputs between 1000 and 2000 kw., mainly high-speed, single-acting, four-stroke engines with airless fuel injection are used, and their superiority is unchallenged. For medium-size units up to something like 3000 kw. single- and double-acting two-stroke engines are in keen competition regarding first cost, fuel consumption and floor space; if high-powered units are wanted, only double-acting, two-stroke engines with speeds between 200 and 300 r.p.m. are successfully employed. The high-powered Diesel engines up to 10,000 kw. and over are exclusively double-acting, two-stroke engines; single-acting units being only constructed occasionally for a maximum capacity of more than 3000 kw. Examples of Diesel engines, classified according to this scheme, are shown in the illustrations, viz:

Fig. 26—Plant of a chemical concern for practically continuous full-load service, with 7 single-acting, four-stroke engines of 1000 kw. each, and one double-acting, two-stroke engine of 3800 kw., all of them running at slow speed.

Fig. 27—A high-speed, single-acting, four-stroke engine of 1000 kw. with airless fuel injection, installed in the peak-load and standby station of the municipal power house of Kottbus, which is operated as a substation fed by the Berlin Municipal Electric Works (BEWAG).

Fig. 28—A high-speed, double-acting, two-stroke Diesel engine of 7500 kw. net with airless fuel injection on the test bed; two units of this capacity are employed for the peak-load and standby installation of the substation Hennigsdorf near Berlin, owned by the Maerkisches Elektrizitatswerke A. G.

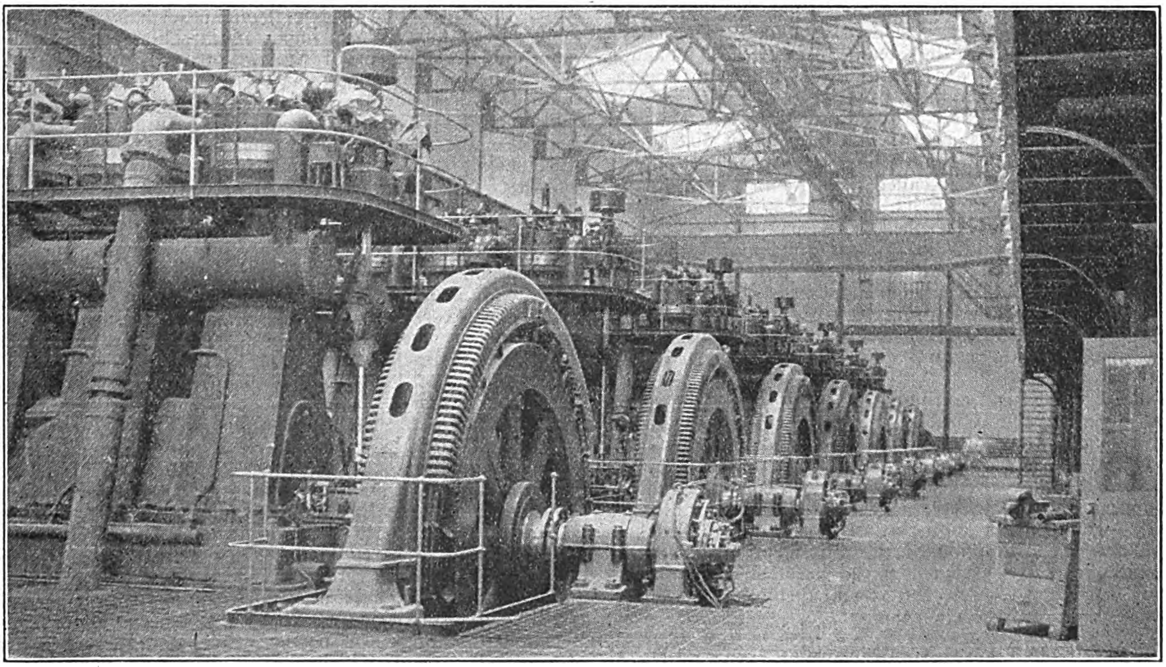


FIG. 26—PLANT OF A CHEMICAL CONCERN FOR PRACTICALLY CONTINUOUS FULL LOAD SERVICE.

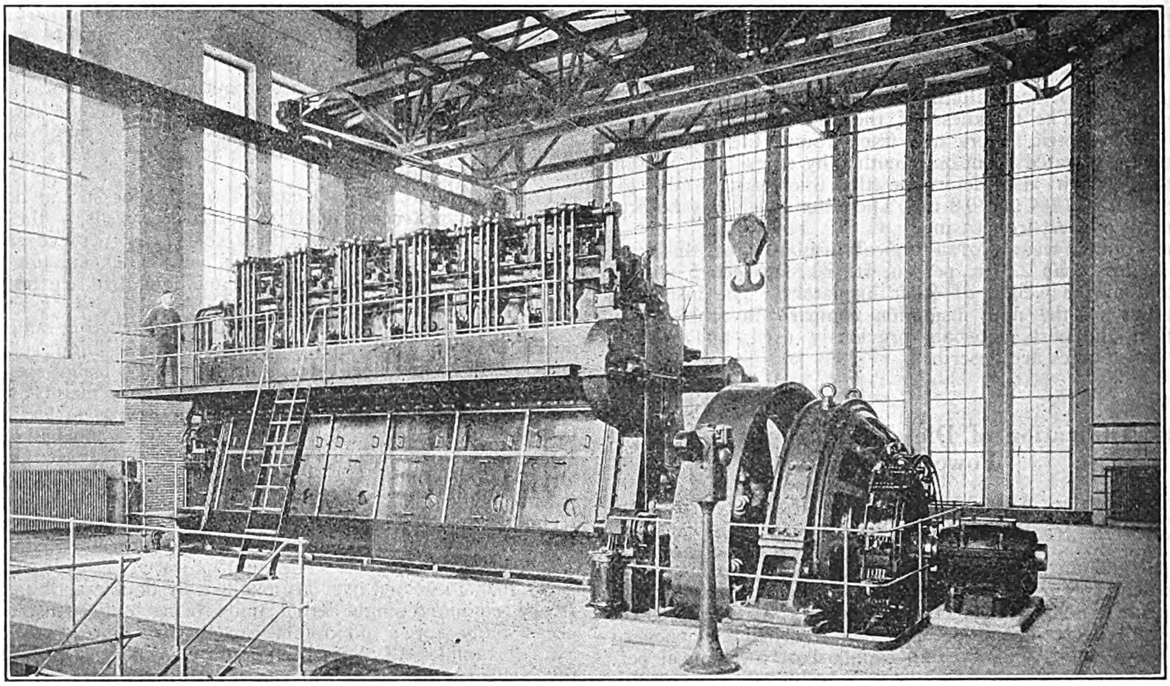


FIG. 27—A HIGH-SPEED SINGLE-ACTING FOUR-STROKE ENGINE OF 1000 KW. WITH AIRLESS FUEL INJECTION.

Fig. 29—The largest Diesel engine in the world, a double-acting, two-cycle engine of 10,000 kw., installed in the Neuhof power house of the Hamburg Electric Works, as a peak-load and standby unit.

The engines, Fig. 26 to 28, were constructed by the Maschinenfabrik Augsburg-Nurnberg A. G. Augsburg Works (M. A. N.), and engine, Fig. 29, by the Hamburg shipyard of Blohm & Voss on the basis of the patents and with the cooperation of the M. A. N.

Comparing the technical and economical features of the Diesel engines with steam installations of the same capacity and the same operating conditions, the following facts may be emphasized.

Regarding safety of operation and reliability, both types of prime movers may be considered as equal. The Diesel engines are superior to the steam installations, including boilers, condensers and accessories, in simplicity of operation, in constant consumption of fuel per kw-hr. and in floor space occupied—this last point, at least, for a total capacity of the power house of less than about 30,000 kw.

The economical comparison of both types of prime movers must be based upon the so-called time factor of the maximum demand or load factor, i.e., on the ratio of utilization which can be practically reached per year. It is clear that a high load factor results in a great influence of the fuel account upon the total expenses of the power production, the capital costs being of minor importance. On the other hand, peak-load and standby service cause a very small load factor; therefore, the influence of the fuel consumption cost is small, but the capital costs must be reduced to a minimum.

Calculating the heat consumption of a high-class steam turbine plant with favorable circumstances of operation (high pressure, high superheat and good vacuum), an average of 4200 k. cal. per kw-hr. (16,700 B.t.u. per kw-hr.) may be considered as a conservative figure, compared with a consumption of 2600 k. cal. per kw-hr. (10,350 B.t.u. per kw-hr.), secured by a high-class Diesel engine, all losses and the power consumption of the auxiliaries included. If the initial costs are assumed to be practically equal, the ratio of equal fuel costs for steam turbines and Diesel engines results from the comparison:

$$\frac{4{,}200}{7{,}200} \times \text{price of coal per kw.} = \frac{2{,}600}{10{,}000} \times \text{price of Diesel oil per kg.}$$

with coal of 7200 k. cal. per kg. (13,000 B.t.u. per lb.) and Diesel oil of 10,000 k. cal. per kg. (18,000 B.t.u. per lb.). These are compared to find the same fuel costs per kw-hr. From this formula results the ratio:

$$\frac{\text{price of coal}}{\text{price of Diesel oil}} = \frac{2{,}600 \times 7{,}200}{4{,}200 \times 10{,}000} = \frac{1}{2.24}$$

This means that the economy of the Diesel engine is equivalent to the economy of the steam turbine, calculated for full load and without waste heat utilization, if the price of 1 ton of Diesel oil is not higher than the price of 2.24 tons of coal. As a matter of fact in Germany imported Diesel oil is now 4.5 to 5.5 times dearer than coal; on the other hand, the production of Diesel oil in Germany is very small and only of limited local importance. This fact is handicapping the development of the stationary high-powered Diesel engine for continuous service in German electricity plants with good load factors. For smaller outputs up to a couple of hundred kilowatts, conditions are naturally different. In this case the Diesel engine competes not against the steam turbine but against the steam engine and other power generators. If little exhaust steam is required for heating purposes, then the Diesel engine gets the preference in Germany. Also for large outputs there are special cases where the high fuel charges of the Diesel engines are balanced by unfavorable water supply for the boilers and condensers of the steam installations, or by bad transport conditions for coal. In these cases the Diesel engine is superior to the steam plants, even if the fuel is much more expensive.

The more or less perfect utilization of the waste heat, in the form of low-pressure steam, hot water or hot air, may furthermore change the economical balance between the two types of prime movers in individual cases.

For peak load purposes the situation is different, as the Diesel engine has the advantage of quick starting, i.e., of carrying load within a few minutes without previous fuel consumption, preheating or other preliminaries.

In case of necessity, the peak load Diesel engines can also be used to carry load besides that required for peak load purposes, because they are independent of the base load units—a big advantage in comparison with such secondary peak load installations as Ruths steam accumulators, water accumulator tanks for power water storage and batteries for direct current, which are all dependent upon the base load installations and the power transmission system, and

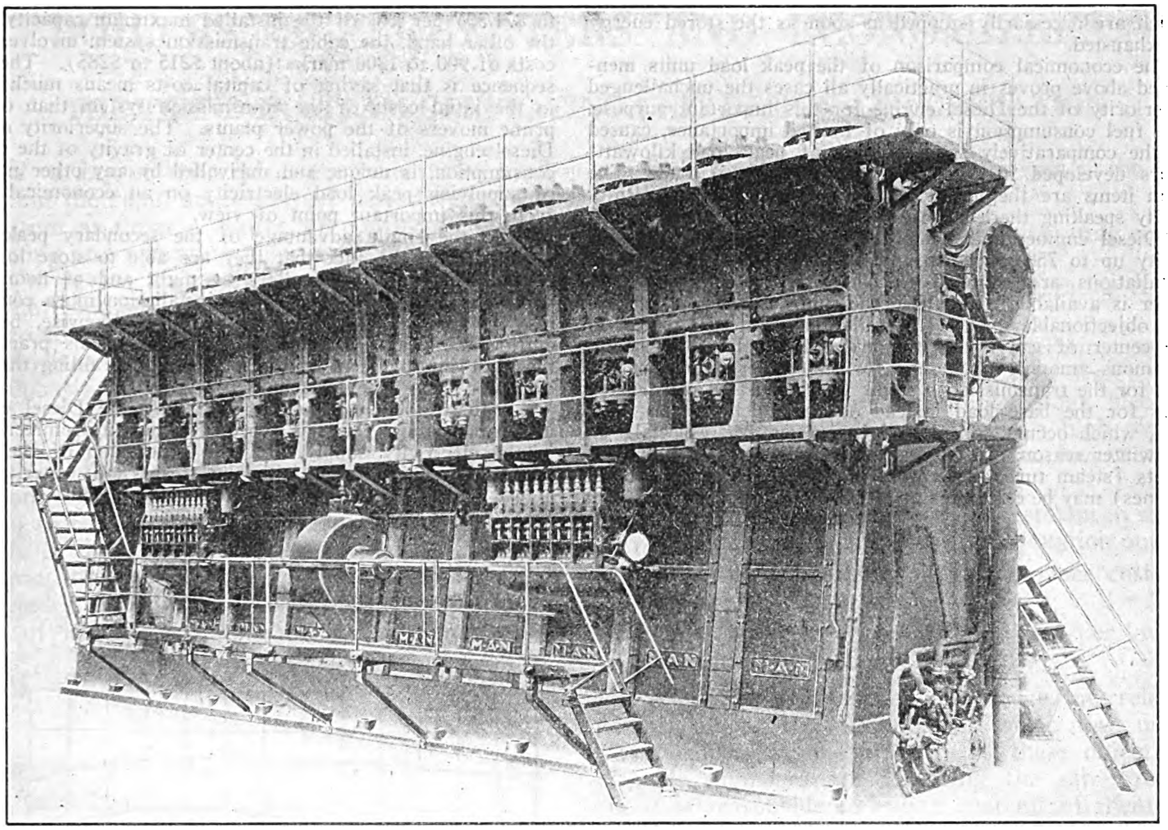


FIG. 28—A HIGH-SPEED DOUBLE-ACTING TWO-STROKE DIESEL ENGINE OF 7500-KW. NET WITH AIRLESS FUEL INJECTION ON THE TEST BED.

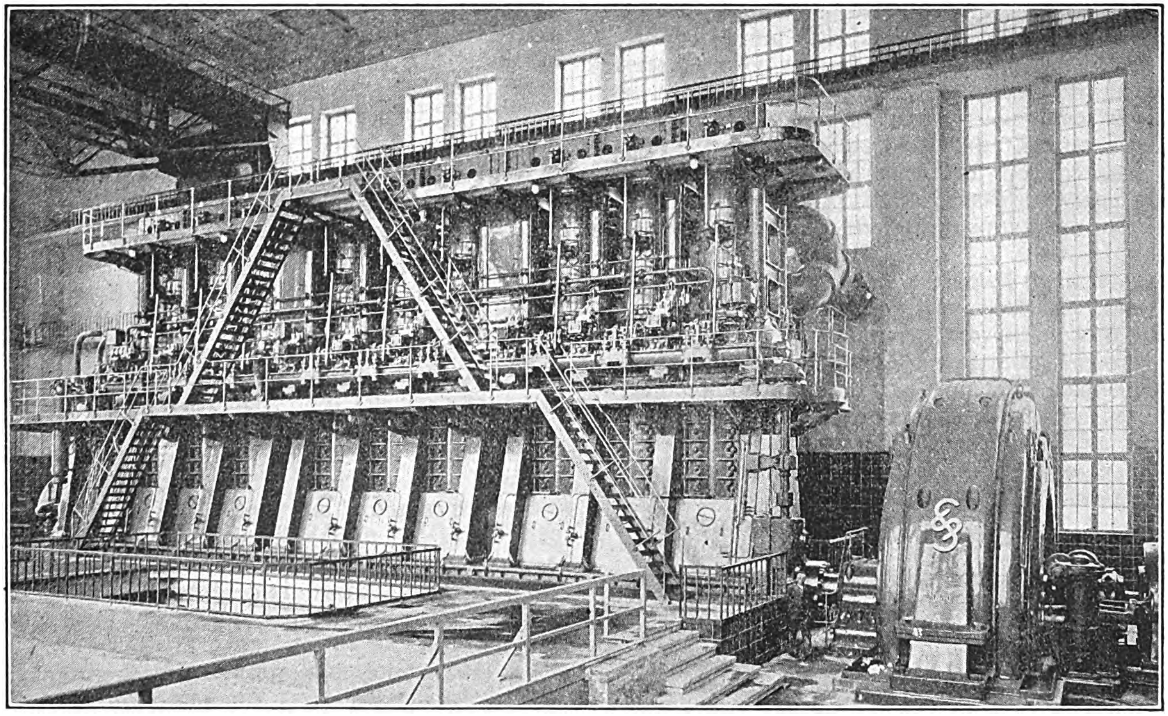


FIG. 29—THE LARGEST DIESEL ENGINE IN THE WORLD. 10,500 KW.

which are necessarily stopped as soon as the stored energy is exhausted.

The economical comparison of the peak load units mentioned above proves in practically all cases the unchallenged superiority of the Diesel engine for this important purpose. The fuel consumption is only of limited importance, caused by the comparatively small amount of peak load kilowatt-hours developed in comparison with the base load. The main items are the initial costs and fixed charges. Practically speaking there is no difference between the first cost of Diesel engines and steam turbo-generators of equal capacity up to 7500 kw. per unit or thereabouts. But steam installations are confined to places where much cooling water is available, and where the flue gases and ashes are not objectionable. Diesel installations can be erected in the center of gravity of the area of supply, thus saving enormous amounts of money for the cables, transformers, etc., for the transmission systems which must be constructed only for the base load instead of the much heavier peak load, which occurs only 2 to 3 hours per day, especially in the winter season. In Germany the first cost of heat power plants (steam turbo generators with boilers, etc., or Diesel engines) may be calculated at 200 to 300 marks (about $47.50 to $71.50) per kw. of the installed maximum capacity. On the other hand, the cable transmission system involves first costs of 900 to 1200 marks (about $215 to $285). The consequence is that saving of capital costs means much more in the intial costs of the transmission system than of the prime movers of the power plants. The superiority of the Diesel engine, installed in the center of gravity of the power consumption, is unique and unrivalled by any other method of supplying peak load electricity on an economical scale from this important point of view.

Even the single advantage of the secondary peak load suppliers, i.e., the fact that they are able to store lost energy during the load valleys at night and at noon, and make the load of the base load installation more constant, may be claimed for the Diesel engines likewise, because cutting the peaks of the load diagrams means practically the same improvement of the load factor as filling the load valleys of the base load units.

All these facts together explain why the Diesel engine in German power plants is expected to play a prominent rôle in the electricity supply, viz., the production of the peak load kw-hr. in parallel with the steam and water power plants, which supply the base load kw-hr. in bulk.

BOILERS, SUPERHEATERS AND ECONOMIZERS

THE TREND IN STEAM GENERATING UNIT DESIGN AND OPERATION

The variety of boiler plant equipment now available and the rapid succession of new developments constitute at times a source of confusion, both to designing and operating engineers. It seems worth while to review and evaluate some of the most recent developments and to attempt to relate important trends of design where possible, to certain definite objectives.

Emphasis of much of the work done by designing and operating engineers during the interval from 1918 to 1925 was placed on improvement in the overall efficiency of the steam generating unit. Publication in January, 1925, of the results of tests made on one of the four 30,600-sq. ft. pulverized fuel fired boilers in the Lake Shore Station of the Cleveland Electric Illuminating Co. served as a milepost of progress in boiler plant design. These tests, the results of which are shown in Fig. 1, demonstrated the feasibility of transfer of heat from coal to water and steam, with a total loss varying from 8 to 10 per cent of the total heat in fuel, for an operating range from 65,000 to 250,000 lb. of steam output per hour. One 22-hr. test, with a total evaporation of 131,400 lb. per hour, showed an overall efficiency of 92.9 per cent. Operation during these tests, resulting in these extremely high efficiencies and in the reduction of the temperature of flue gases to values ranging from 174 to 318 deg. fahr. left a negligible margin for future improvement. While it was realized that the delivery of water to the economizer at temperatures ranging from 125 to 157 deg. fahr. during these tests was a contributing factor which made possible the high overall efficiencies, this fact did little to minimize the value of the achievement.

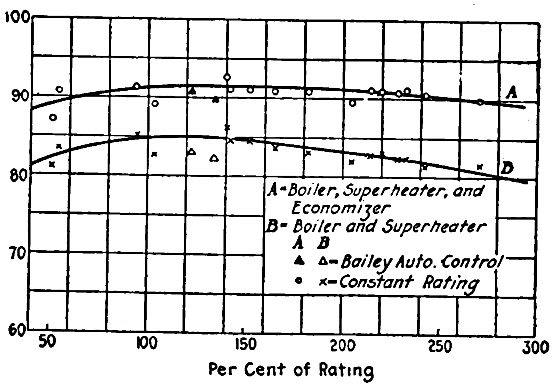


FIG. 1—BOILER TESTS, LAKE SHORE STATION. CLEVELAND ELECTRIC ILLUMINATING CO. (JOHN WOLFF, MECH. ENG., JAN., 1925).

During the last four years, a major portion of the work done by designing and operating engineers has been dominated by a desire to reach the following objectives:

1. Successful operation of steam generating equipment with higher pressures.
2. Successful operation of steam generating equipment with higher temperatures.
3. The modification of steam generating equipment so as to allow heating feed water to a relatively high temperature by stage bleeding and still permit of maintaining a high overall efficiency of transfer of heat from fuel to steam and water.
4. To effect a reduction in the investment in steam generating equipment per kw. of station output.
5. To effect a reduction in maintenance cost per kw-hr. of station output.
6. To effect a reduction in labor cost per kw-hr. of station output.

These six objectives are very much interrelated. Almost all of the development work now under way is aimed at one or more of these objectives. Not all engineers are following the same roads, but it is reasonable to expect that all of them are dominated by a desire to reach the same reasonable objectives.

High Steam Pressures

Operating pressures have been pushed higher and higher during recent years. Two trends have developed. A number of engineers have been willing to do pioneering work and to go to the use of higher pressures even though this might mean the use of generating equipment quite special in its character. Much of the steam generating equipment designed for pressures in excess of 450 lb. has been special. Engineers of a second school of thought have been willing to go to only those pressures which permit the use of steam generating equipment of fairly standard characteristics.

As manufacturers have perfected their shop processes and tools, and as better materials have been made available for their use, they have been able to increase the upper limit of operating pressure for which equipment of fairly standard characteristics can be designed. For example, there have been successive increases from 385 to 425, to 450, to 488, and more recently to approximately 600 lb., in the maximum operating pressure for straight-tube cross-drum boilers of fairly conventional design, using 4-in. tubes. Not many years ago the maximum pressure for which Stirling boilers or other bent tube boilers of similar type having tubes 3¼ in. in diameter could be purchased, was of the order of 410-lb. gage. At the present time bent tube boilers having riveted drums and of fairly conventional design can be purchased for an operating pressure of 450-lb. gage.

Publication No. 289-75 Serial Report, Prime Movers Committee.

Independent analyses made by a number of engineers have demonstrated that an increase in pressure, as long as it is accompanied by no marked change in the characteristics of the equipment or the size of the steam generating units and the turbine-generators, produces two results:

1. A reduction in fuel consumption per kw-hr. of station send-out.
2. A reduction in the investment per kw. of station send-out.

There has accordingly been a very definite trend in connection with much of the recent steam station construction to use the highest pressure for which steam generating equipment of fairly standard characteristics could be purchased at the time of design.

It is coming to be well recognized that the tendency toward caustic embrittlement of boiler drums is very much more marked as the operating pressure and the temperature of the water are raised. Accelerated embrittlement tests made in the laboratory have shown that for standardized conditions flange steel has cracked in 720 hr. for 100-lb. steam pressure, in 30 hr. for 500-lb. pressure, and in 10 hr. for 1000-lb. pressure. This greater tendency toward embrittlement incidental to higher operating pressures has introduced a problem in many stations which, with relatively good water conditions and lower operating pressures, would have never needed consideration as an important operating problem. Two solutions present themselves:

1. The use of effective inhibitors. The maintaining of a proper ratio of sulphates to carbonates by the injection of sulphuric acid into the feed water is a satisfactory solution, but the increasing amount of sulphates which must be added to the feed water for higher pressures makes this solution far from desirable. Laboratory research work has indicated that relatively small amounts of phosphate will serve effectively to inhibit embrittlement. It is hoped that actual operating experience will prove the effectiveness of the phosphate treatment.
2. The use of forged or hammer-welded boiler drums rather than riveted drums probably offers a solution for the problem of caustic embrittlement. In general, it has been the practice to use forged drums for operating pressures in excess of 700 lb. One company has, however, fairly definitely standardized on the use of forged or hammer-welded drums for pressures in excess of 450 lb. One of the operating companies has ordered during the last two years a number of boilers having hammer-welded drums. Presumably the thought lying back of the use of welded construction is elimination of the possibility of concentration of solids in the seams and the corresponding hazard of embrittlement.

In connection with riveted drums, the practice of inside caulking of seams has been adopted almost universally. The limitation in operating pressure for which bent tube boilers having riveted drums can be designed has mainly existed in connection with the drums and, as pointed out earlier, has served to limit the maximum pressure for a time to 410-lb. and more recently to 450-lb. gage. In connection with straight-tube cross-drum boilers, the limit in pressure has been in connection with the headers. The practice has been adopted in a great many cases of designing the drums for a somewhat higher pressure than the headers and the tubes, in order to allow for an appreciable amount of pitting in the drum without the necessity of derating the operating pressure of the boiler.

The rather general adoption of operating pressures in excess of 400 lb. has involved the almost universal discarding of round gage glasses and the use of high-pressure gage glasses having flat glass windows. The problem of satisfactorily illuminating the flat glass windows has not been satisfactorily solved for the majority of installations. It is hoped that development work now under way will lead to a satisfactory solution of this problem.

A most valuable development has been the use of a standard recording flow meter, calibrated to record the head of water in the water column and so serving as an accessory to the high pressure gage glass recording the level of water in the boiler drum.

Higher Steam Temperatures

There has been a very general trend toward the use of higher steam temperatures. A survey of operating practice in the United States, as outlined later in this report, shows that the average operating temperature for the stations considered is 640 deg. fahr., and that in normal operation a temperature of 750 deg. fahr. is seldom exceeded. This is perhaps accounted for by the fact that one of the leading manufacturers has taken the stand that a steam temperature of 750 deg. should not be exceeded, unless superheater tubes of very special and quite expensive alloy metal are used. A second manufacturer, however, in a statement submitted to this Committee in 1926, stated that he is willing to offer superheaters designed for a steam temperature of 800 deg. using plain steel tubes.

There is a definite desire on the part of operating and designing engineers to go to the use of still higher temperatures. There are three incentives justifying such use:

1. An increase in temperature will result in a material reduction in fuel consumption. If the increase in steam temperature can be effected without the adoption of radical changes in design, it is one of the easiest ways of effecting an appreciable fuel saving.
2. Independent studies made by a number of engineers have shown that higher temperatures will result in a reduction in the investment, assuming that no marked change in the construction of the steam generating unit is involved. (The use of special and expensive alloy metal in the superheaters or the use of a single stage of reheating with steam returned to the boiler house, this being the equivalent of increase in

steam temperature at the turbine throttle, may be classified as marked changes.)

3. An increase in temperature at the turbine throttle with the corresponding reduction in moisture in the lower stages of the turbine, results in very material reduction in the amount of erosion in the lower stages of the turbine, reducing the cost of one of the largest single items of turbine maintenance and increasing the number of hours per year that turbines are available for service.

The expressed willingness of two of the manufacturers to build straight-tube cross-drum boilers with tubes 4 in. in diameter, and in other respects of fairly standard construction for operating pressures in the neighborhood of 600 lb., has increased the importance of considering higher steam temperatures. With 600 lb., 800 deg. fahr. steam delivered to the turbine throttle, the percentage of moisture in the steam passing through the last row of turbine blades and expanding to a 29-in. vacuum would be no higher than with 375 lb., 700 deg. fahr. steam delivered to the turbine throttle, and also expanded to 29-in. vacuum.

The fact that the use of temperatures ranging from 800 to 850 deg. holds promise of a reduction in fuel cost, a reduction in investment and corresponding fixed charges, and a reduction in maintenance, serves as a very definite incentive for intensive development of equipment for operation at these higher temperatures.

It appears that the most serious obstacle standing in the way of the general adoption of higher temperatures is the fear that there will be a rapid deterioration in the superheater elements. Two problems present themselves in connection with the superheater elements:

1. Due to the transfer of heat through the wall of the superheater element, the metal temperature is appreciably higher than the steam temperature, and it is the temperature of the metal which determines the rate of deterioration.
2. Due to the transfer of heat through the wall of the superheater element, the outer skin is at a higher temperature than the inner portion of the wall, resulting in the setting up of temperature stresses which, under certain extreme conditions, may be of the same magnitude as the stresses from the steam pressure.

The solutions for these two problems lie along several different lines. Anything that can be done to reduce the differential between maximum steam temperature and the maximum temperature of the metal will be beneficial. In this connection the problem of superheater design as it now stands, closely parallels the design of electrical machinery, the aim being the same in both cases to limit hot spot temperatures as much as possible. A decrease in the average rate of heat transfer and particularly in the rate of heat transfer at the outlet end of the superheater; an increase in the steam velocities through the elements; a reduction in the mean internal hydraulic radius of the superheater elements; the introduction of saturated steam into the portion of the superheater in contact with the hottest gases; the maintaining of high steam velocities in the elements and low steam velocities in the headers, so as to insure uniform distribution of steam between all elements in parallel; the elimination of laning of the gases through the superheater; and the elimination of secondary combustion in the superheater pass, are all effective in the reduction of the differential between the highest metal temperature and the steam temperature at the superheater outlet. A reduction in the maximum rate of heat transfer for any portion of the superheater, and particularly for the area adjacent to the superheater outlet, will serve as the most effective means of reducing temperature stresses.

The success which has been attained in the operation of radiant superheaters over a period of three or four years, with rates of heat absorption in the neighborhood of 45,000 B.t.u. per hr. per sq. ft. (at final temperatures of from 700 to 750 deg. fahr.) seems to point the way to the design of superheaters for operation with steam temperatures from 800 to 850 deg. fahr. The rather successful operation of these radiant heat superheaters must be viewed in the light of their high rates of heat transfer, the fact that the elements are of plain forged steel, and that the elements have a wall thickness of approximately ¾ in. Conditions of operation are such as to result in relatively high metal temperatures and also in relatively high temperature stresses. In contrast, the use of convection type superheaters, shielded from the furnace by ten rows of boiler tubes and designed with very liberal areas, will permit of delivering steam at a temperature of 800 deg. fahr. or higher, and a maximum heat transfer rate of approximately 5000 B.t.u. per hr. per sq. ft. of surface.

It would appear that it is possible, in connection with a very liberally designed convection type superheater, using tubes having a wall thickness of No. 10 B. W. G. (0.134 in.) and delivering steam at a temperature of 800 deg. fahr., to limit both the maximum metal temperature and the temperature stresses to lower values than exist in connection with installations of radiant heat superheaters, which are now in successful operation, delivering steam at a temperature from 700 to 750 deg. fahr.

It is not generally realized either by designing or operating engineers that, in the interests of good design and safe operation, a high-pressure drop through the superheater must be accepted. This is particularly true in connection with the superheaters of boilers which must operate successfully through a wide range of load. In connection with an installation of this type, a pressure drop of 40 lb. through the superheater at maximum load is not unreasonable. To insure proper steam distribution, safe design indicates that not more than 15 per cent of the pressure drop should be in the headers.

It must be recognized that the acceptance of a convection type superheater having low rates of heat transfer involves a greater variation in steam temperature from low load to maximum evaporation than will be the case for interdeck superheaters, or for the combination of a convection type superheater in series with a radiant type superheater. The steam temperature characteristic can be flattened out to some extent by the use of very high steam velocities through the superheater elements at maximum load. It seems probable that the assurance of freedom from trouble which we may reasonably expect from a convection type superheater designed along the lines outlined above, the ability to go to higher temperatures, the possibility of the use of steam pressures of the order of 600 lb. without the need for reheat, and the simplification in design of the boiler unit itself, may serve as such powerful incentives that they will offset the greater variation in steam temperature from low to maximum load.

Maintenance of High Overall Efficiency with Increased Temperature of Feed Water Delivered to the Steam Generating Unit

The desire on the part of designing and operating engineers to avail themselves of economies incident to the use of the regenerative cycle has led very generally to an increase in the temperature of feed water delivered to the steam generating unit. This condition has in many cases made necessary radical changes in the design of the steam generating unit in order that the overall efficiency might be maintained with feed water temperatures ranging from 350 to 425 deg. fahr. In most cases the result has been the installation of an air heater or the combination of an air heater and economizer. Until five years ago there were many new installations of boiler units without either air heaters or economizers. For the larger stations, engineers were fairly evenly divided into two groups: Those who favored the use of high boilers or their equivalent and no economizers; and those who favored the use of fairly low boilers with economizers. The simultaneous introduction of the regenerative cycle and the use of air heaters, together with the desire in most cases to effect a reduction in coal consumption, has divided boiler installations into three classes:

1. A comparatively low boiler or its equivalent, and an economizer.
2. A comparatively high boiler or its equivalent and an air heater.
3. A comparatively low boiler or its equivalent, followed by an economizer and an air heater.

A related matter which has affected the choice and the proportioning of the air heater has been the air temperature which operating engineers have found desirable in connection with different types of fuel burning equipment.

Of the fifteen new power stations which have recently gone into operation, or are now in the course of construction, there are only two in which neither air heaters nor economizers are installed. In one of these two stations plans are made for the future installation of air heaters and economizers.

Reduction of Investment in Steam Generating Equipment Per Kw. of Station Output

This subject may be divided into two phases:

1. The reduction in investment per unit of installed capacity.
2. The reduction in the amount of spare capacity.

Advances in the design of fuel burning equipment have been such as to permit of burning a greatly increased amount of fuel in a single boiler unit. The development of fuel burning equipment was brought to a point five years ago so that it no longer served as a limitation to boiler output, the real limitation being in the ability of furnace refractories to stand punishment. The air cooling of furnace walls provided some relief. The use of water-cooled furnace walls served, however, as the real solution for the problem and definitely eliminated refractories as a limitation to boiler output.

The introduction of water-cooled furnace walls was surrounded with a certain amount of misunderstanding. It was claimed by some engineers that the use of water-cooled furnace walls would result in an increase in the overall efficiency of the boiler unit as a result of the absorption of a larger percentage of the total heat by radiation. Other engineers claimed that the extensive use of water-cooled furnace walls would decrease furnace temperatures to such a degree as to interfere with complete combustion, and that this would result in increased losses and smoke. Other engineers claimed that the cheapest way of obtaining increased boiler capacity was by the installation of water-cooled furnace walls, which, by reason of seeing the fire, absorb heat at extremely high rates as compared to those portions of the boiler which do not see the fire. An evaluation of very extensive operating experience during the last four years has shown that water-cooled furnace walls do effectively accomplish the following aims which are listed in the order of their importance:

1. By either the entire elimination of refractories or the effective cooling of them by closely adjacent boiler tubes, it has been possible to eliminate refractory troubles and to increase very materially the rates at which fuel can be burned.
2. By materially increasing the amount of water-cooled surface which sees the fire, it has been possible to decrease appreciably the maximum rates of heat transfer and correspondingly to decrease the danger of burning tubes incident to the collection of a very small amount of scale. The possibility of failure of tubes incident to the temperature stresses resulting from high rates of heat transfer has also been minimized. This latter effect is particularly important in connection with the use of thick wall tubes which are necessary for higher pressures. Indicative of the trend toward lower average unit rates of heat transfer for the surface which sees the fire, in many boilers installed ten or fifteen years ago and fired by means of short underfeed stokers, rates of heat

transfer in the bottom half of the lower row of tubes were found by several investigators to be in the neighborhood of 100,000 B.t.u. per sq. ft. of surface per hr., corresponding to maximum load at 250 per cent (8.4 k-B.t.u. per sq. ft. per hr.) rating. In contrast there are boiler units being installed and in operation today for use at maximum evaporation which would correspond to 1200 per cent (40 k-B.t.u. per sq. ft. per hr.) rating. Boiler rating is based on the area of the boiler alone, but as the furnace walls are water-cooled, the maximum rate of heat transfer for the bottom row of boiler tubes, or for any portion of the water-cooled surface which sees the fire, has been rarely found to exceed 70,000 B.t.u. per sq. ft. per hr. Here again the trend of design of the steam generating unit parallels the design of electrical machinery and has for its purpose the limiting of hot spot metal temperatures in the pressure parts. This problem of limiting the maximum unit rates of heat transfer for the radiant heat absorbing surface requires skillful design not only of the boiler and the superheater but also of the furnace and the fuel burning equipment. The laning of the gases in the furnace, blow torch action impinging on the heat absorbing surface, lack of uniformity in the fuel beds, and penetration of the slag screen by the flame from vertically fired pulverized fuel burners, all result in high rates of heat absorption in localized areas, and result in high local hot spot temperatures.

3. Except for very low rates of evaporation, the effect of water-cooled furnace walls on unburned fuel losses, smoking and the overall efficiency of the boiler unit has been very slight.
4. The use of water-cooled furnace walls has very materially reduced the cost of boiler maintenance, and has increased the number of hours per year that each boiler unit is available for service.
5. The use of water-cooled furnace walls has apparently minimized the collection of slag on the tubes at the inlet to the first pass of the boiler.

The improvements in fuel burning equipment and the use of water-cooled furnace walls have, as indicated above, made it possible to carry very much higher rates of evaporation. Additional factors have entered in, however, to make it possible to increase the total amount of steam produced by a single boiler unit. Longer boiler tubes are being used both in connection with straight-tube cross-drum boilers and also for bent tube boilers. The total width of boilers is being increased incident to the ability of manufacturers to fabricate longer drums. Straight-tube cross-drum boilers for a width of 35 ft. between furnace walls are now available. Due to the increase in the length of tubes and also to an increase in number of rows deep for bent tube boilers and number of rows high for straight-tube cross-drum boilers, it is possible to increase materially the amount of heat absorbing surface per foot of furnace width.

The two trends, one toward the increase in the average rate of evaporation per square foot of boiler surface (this, by virtue of the water-cooled furnace walls, being accompanied by a decrease in the maximum unit rate of heat absorption for the surface which sees the fire) and the increase in the total amount of heat absorbing surface, have resulted in material increases in the maximum capacity of individual boiler units.

Nine years ago there were only a few boiler units in this country supplying steam under normal conditions of operation for a total generation of 10,000 kw., all of these boilers being installed in the stations of the Detroit Edison Co. Today there are at least twenty-four boiler units, either in operation or in the course of construction in this country, each unit to supply steam for a total of 35,000 to 40,000 kw., and three of these units will be capable each of supplying the steam required for 75,000 kw.

The combined effect of the work referred to above has been to decrease the investment per unit of installed boiler plant capacity.

The increase in the capacity of the individual boiler units has very much simplified the design of the boiler plant. In many cases the boilers are being arranged in a single row parallel to the turbine room, resulting in but one firing aisle and a maximum of light and accessibility to equipment.

The elimination of refractories, the decreasing of the maximum unit rates of heat transfer for the heat absorbing surfaces, the proper control of feed water treatment, and the improvement in details of design of the boiler unit proper, its fuel burning equipment and its accessories, are all tending toward an increase in the number of hours per year that the steam generating unit is available for service; this results in a reduction of the amount of spare boiler plant capacity. It seems probable, in light of our present knowledge, that for any station in which the use of a 60,000-kw. turbine is justified, it is equally possible to justify the use of a 60,000-kw. boiler, this by reason of the indication, yet to be verified in its entirety, that a large, well-designed steam generating unit at least equals in reliability and sustained availability for service a turbine-generator of equal capacity.

The development of high rates of evaporation from a single steam generating unit and the extensive use of water-cooled furnace walls has made a careful consideration of the problems of circulation for each steam generating unit of increasing importance. That the problems incident to the provision for proper circulation are not too difficult of solution is evidenced by the moderate amount of trouble experienced in the large number of installations made during the last four years. The problem of circulation is worthy, however, of careful study. Two worth-while reviews of this subject are included in a later section of this report.

One of the most difficult problems incident to the operation of large steam generating units at high rates of evaporation is the proper control of feed water delivered to the boiler. The statements from certain of the operating companies serve to define this problem, and statements from certain of the manufacturers outline the development work which they are doing. A trend is indicated toward the use of more water storage capacity in the boiler and a combination of water level and differential pressure control either in connection with the feed pumps or the individual boilers.

Increases in the maximum rate of evaporation and in the maximum steam production from a single unit make it correspondingly difficult to limit the amount of moisture carried over from the boiler to the superheater. Much development work done during the last two years on this problem is now bearing fruit. It appears that we may reasonably expect equipment which is now available to limit the moisture carryover from the boiler drum to the superheater to one-half of 1 per cent, corresponding to the maximum rate of evaporation.

The collection of slag at the inlet to the first pass of the boiler, particularly when burning low-grade coal, has served in a great many instances to limit the capacity of the steam generating unit. Complete correction of these difficulties involves a study of combustion conditions, as well as the development of proper slag screens to reduce the extent of slag collection. Unless the combustion of the fuel is completed in the furnace, one cannot obtain the full benefit of slag screens designed to decrease the amount of slag collection on the tubes.

It is practically impossible for most installations to develop the proper economic value from a steam generating unit without the use of induced draft fans.

The use of considerable amounts of power for driving the induced draft fans must accompany the development of high rates of evaporation. It is not unreasonable in connection with a steam generating unit evaporating 500,000 lb. per hr. to use as much as 1000 h.p. for the drive of the induced draft fans. It seems entirely reasonable in connection with the very large steam generating units which are being installed today, to install two induced draft fans in order that trouble in connection with one of these fans will result in a decrease of not more than 30 per cent in the steaming capacity of the unit.

As indicated earlier, one of the combinations offering a possibility of excellent station economy with moderate investment is that involving the use of a pressure of the order of 600 lb. and a temperature of the order of 800 deg. fahr. with no reheat.

Cost of Maintenance

The most important factor in reducing the cost of maintenance in the boiler house has been the elimination of refractories incident to the use of water-cooled furnace walls. Improved methods of feed water treatment have also been effective.

There seems to be a trend away from the use of steam soot blowers in connection with underfeed stoker-fired boiler units. A factor in connection with this trend has been the high cost of maintaining the blowers. In a number of cases appreciable losses of boiler tubes resulted from impingement of steam from blower nozzles. In contrast, however, the trend seems to be toward a continued use of steam soot blowers for pulverized fuel fired boilers and their superheaters; for the cleaning of economizers in connection with both stoker-fired and pulverized-fuel-fired boilers; and for the cleaning of superheaters in connection with stoker-fired boilers.

For certain installations burning low-grade coal, soot blowers have proved ineffective for the cleaning of economizers and water washing is being resorted to. Water washing has also proved quite effective in a number of cases for the removal of scale from the external surfaces of boiler tubes, the water washing being done while the boiler is out of service.

It would appear that in the interest of reduced maintenance cost and improved reliability, more careful routine inspection of the boiler and superheater tubes and the use of methods that will eliminate faulty tubes are justified. At least some work along this line is now in progress.

There is a rather general adoption of the use of protective coatings for the internal surfaces of boiler drums, boiler and economizer tubes. There is also a rather widespread adoption of the practice of removing mill scale from the internal surfaces of tubes and drums of new equipment in order to permit the application of protective coatings before initial commercial operation.

Aside from obtaining an adequate solution of the problem of steam distribution in the superheaters, it appears that we must, from the standpoint of safety of operation and reduction of maintenance, insist on the simplification of headers and the elimination of baffles and ferrules in new designs.

Reduction in Operating Labor

The reduction in the number of boiler units, the simplification of boiler plant design, and the use of combustion control equipment have all been effective in reducing the cost of operating labor in the boiler house.

In practically each case the statements which follow constitute detailed descriptions of the different phases of steam generating unit design, the general trends of which have been outlined above. The subcommittee has asked the manufacturers to prepare their statements so as to indicate the way in which they have been relating their development work to the accomplishment of the reasonable objectives which were outlined earlier in this statement. We believe the manufacturers have complied admirably.

Probably the most worth-while piece of work which has been undertaken in recent years relative to the development of boiler plant design and operation is the study being conducted by C. F. Hirshfeld of the Detroit Edison Company covering the extent and cause of outages in connection with steam generating units. Operating records of most of the representative stations of the country are being compiled covering the period of operation from Aug. 1, 1928. to Aug. 1, 1929. The analysis of these operating records by the engineers who compile them and the analysis and comparison which will be made by Mr.

Hirshfeld should do much to focus the attention of operating engineers on improved methods of operation and maintenance which will decrease the percentage of outage hours, and to center the attention of the designing engineers on the improvement of details which will result in a reduction in outage hours. The overall results of this analysis, which are to be presented in a paper before the annual meeting of the American Society of Mechanical Engineers in December, 1929, are awaited with interest.

The important problems of reducing the investment per unit of installed capacity in the boiler house and of maintaining each piece of steam generating equipment available for service the maximum possible number of hours per year deserve the best thought of operating and designing engineers.

SURVEY OF OPERATING STEAM TEMPERATURES

The use of increasingly high superheated steam temperatures in central station practice has made it desirable to make a survey of operating practice. Definite information has been received relative to the temperatures obtaining in 81 representative stations. The results of the survey are shown in Fig. 2 and Table I on the next page.

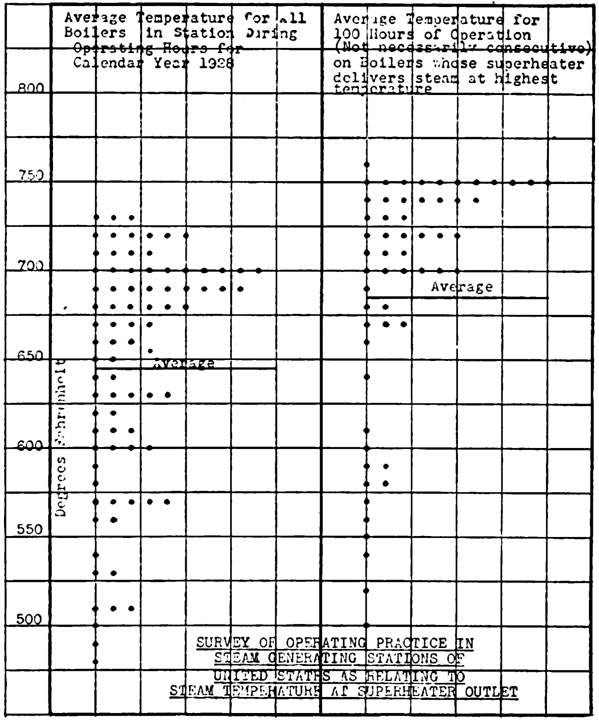


FIG. 2—SURVEY OF OPERATING STEAM TEMPERATURES.

MISCELLANEOUS STATEMENTS

Circulation in Water-Cooled Furnace Wall Circuits

STATEMENT BY GEORGE A. ORROK AND N. ARTSAY, 52 VANDERBILT AVE., NEW YORK, N. Y.

In the earlier years of boiler construction and operation when fire tube and shell boilers were standard, it was appropriate to consider the bubbles of steam apart from hot and cold water and their effect on the circulatory system. Later when water tube boilers and steam pressures up to 300 lb. were the rule, ideas on circulation became highly individual and many boiler models were evolved, most of which, through troubles, were soon eliminated. Quite naturally, designers still thought in terms of bubbles, and the idea of the "free path for the bubbles of steam" may be still seen here and there in boiler literature and designs.

With the present high pressures, high rates of heat absorption, and the extension of radiant heat surface, it is time to consider the close mixture of water and suspended steam bubbles which in its action resembles an emulsion or perhaps a colloid. In modern steam generators, satisfactory circulation in the "boiler" part is taken for granted, since for some time most of the unsatisfactory types have been eliminated. The connection between the "furnace walls" and the main circulation and the effect of this connection on the whole circulatory system is still a matter of conjecture, with the usual natural consequences. As to circulation in the water wall circuits proper, very little has been published, although many plants have run tests to ascertain the state of water or its mixture with steam behind the surfaces exposed to the radiant heat. The variety of engineering opinion as to what happens in these furnace

TABLE I

COMPARISON OF STEAM TEMPERATURES IN VARIOUS PLANTS OF THE UNITED STATES

Company and Station	Avg. Steam Temp. at Superhtr. Outlet During Operating Hr.	Max. Steam Temp. at Superhtr. Outlet for 100 Hr. Operation (Not Necessarily Consecutive) on One Boiler
Alabama Power Co.,		
Gorgas	570*	591*
American Light & Traction Co.,		
Comal	729	752
Associated Gas & Elec. System,		
Seward	574	610
Staten Island	614	670
Solvay Process Co.,		
Syracuse	716	748
Barstow, W. S. & Co., Inc.,		
Middletown	703	...
Parr, S. C	673	...
Binghamton, N. Y	707	...
Benson Springs, Fla	692	...
Avon Park, Fla	693	...
Brooklyn Edison Co., Inc.,		
Hudson Avenue 280 lb	599	...
Hudson Avenue 400 lb	703	720
Byllesby Eng. & Mgmt. Corp.,		
Horseshoe Lake, Harrah, Okla	655	700
Riverbank Station, Muskogee	625	...
Buffalo General Electric Co.,		
Charles R. Huntley	630	749
Cleveland Electric Illuminating Co.,		
Avon	708	757
Lake Shore	675	715
Commonwealth Edison Co.,		
Fiske Street	577	...
Northwest	601	...
Calumet	640	...
Crawford Avenue	705	...
Connecticut Light & Power Co.,		
Devon	665	705
Consumers Power Co.,		
Saginaw River	720	765
Day & Zimmermann Eng. & Constr. Co.,		
Saxton	675†	700†
Vienna	680†	750†
Detroit Edison Co.,		
Connors Creek	630	...
Marysville	660	685
Trenton Channel	695	....
Duke Power Co.,		
Buck	698	720
Duquesne Light Co.,		
Colfax: Stoker boilers	573	...
Pulv. fuel boilers	650	740
Brunot Island: Stoker boilers	490	...
Pulv. fuel boilers	514	...
Edison Electric Illuminating Co. of Boston,		
Edgar	703*	...
L Street Extension	604*	...
Gulf States Utilities Co.,		
Neches	685	725
Hartford Electric Light Co.,		
South Meadow	680	750
Illinois Electric Power Co.,		
East Peoria	669	700
Indiana Electric Corp.,		
Dresser	645	675
Louisville Gas & Electric Co.,		
Waterside	560	677
Los Angeles Gas & Electric Corp.,		
Seal Beach	671	737
Luzerne Co. Gas & Electric Corp.,		
Hunlock	718	747
Milwaukee Electric Railway & Light Co.,		
Lakeside	729 708‡	750 750‡
Montaup Electric Co.,		
Somerset	694	740
New York Edison Co.,		
East River	713	719
Northern States Power Co.		
Riverside	513	575
High Bridge	660	695
Ohio Edison Co.,		
Mad River	690	724
Ohio Power Co.,		
Windsor	611*	...
Philo	720*–730‡	...
Twin Branch	696*–709‡	...
Stanton	728*–718‡	...
Pennsylvania-Ohio Power & Light Co.,		
Toronto	693	750
Pennsylvania Power & Light Co.,		
Hauto	535	575
Pine Grove: Stoker boilers	585	600
Pulv. fuel boilers	697	750
Pennsylvania Water & Power Co.,		
Holtwood	555	570
Peoples Power Co.,		
Riverside	676*	....
Philadelphia Electric Co.,		
Schuylkill No. 2	497	558
Delaware	641	697
Chester	600	662
Richmond	668	697
Barbados Island	617	673
Potomac Edison Co.,		
Williamsport	684	715
Public Service Co. of Colorado,		
Valmont	630	680
Public Service Co. of No. Illinois,		
Waukegan: Units 1 and 2	690	710
Unit 3	725	735
Joilet: Unit 3	685	705
Public Service Electric & Gas Co.,		
Essex	560	640
Kearny	698	750
Rochester Gas & Electric Corp.,		
Station No. 3	480	500
Station No. 8	530	535
Station No. 9	510	515
Southern California Edison Co.,		
Long Beach No. 2	633*	...
Long Beach No. 3	689*	740*
Texas Power & Light Co.,		
Trinidad	697	738
Union Electric Light & Power Co.,		
Cahokia	715	740
Ashley Street	525	545
Union Gas & Electric Co.,		
Columbia	722	751
West End	573	636
United Electric Light & Power Co.,		
Hell Gate	625	732
Virginia Electric & Power Co.,		
Reeves Avenue	720	740
West Penn Electric Co.,		
Springdale: Original boilers	615	...
1924 boilers	703	752

*Indicates temperature at throttle. †Indicates reheat temperature. ‡Indicates at 400% rating (13.4 k-B.t.u. per sq. ft. per hr.)

wall tubes makes a theoretical investigation in a first approximation desirable, and the present article will deal with a simple furnace wall circuit beginning and ending in the boiler drum. Fig. 3 shows the circuit. Let us denote:

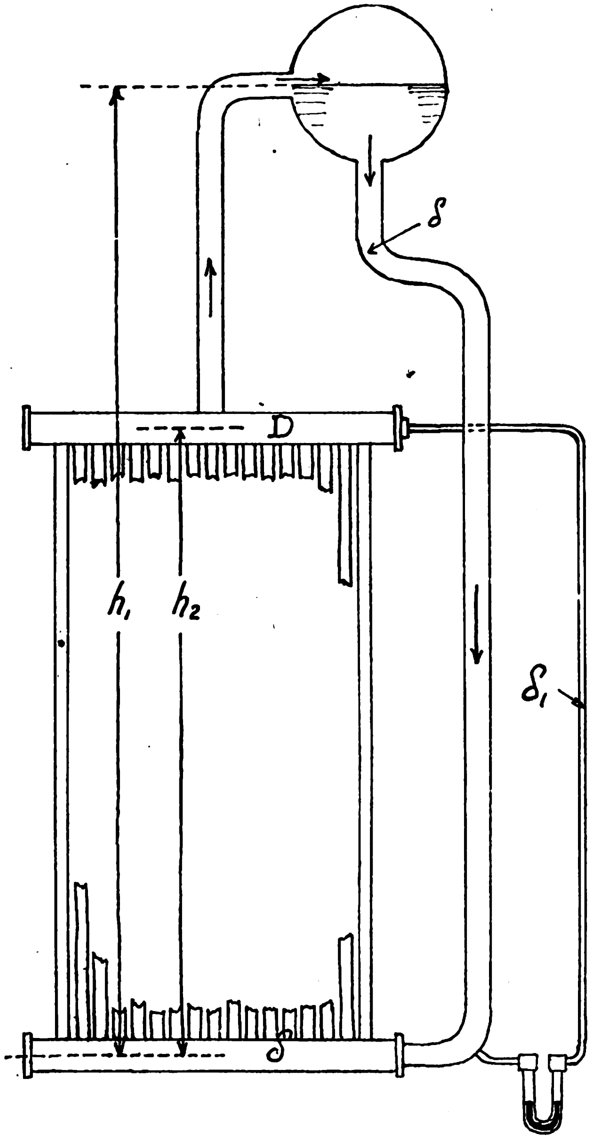


FIG. 3—Typical Water-Cooled Furnace Wall Circuit Considered in Calculating Circulation. Orrok and Artsay.

H = Total heat absorption in the circuit, B.t.u. per second.
p = Circulation of water, pounds per second.
λ = Latent heat of evaporation, B.t.u. per pound.
h_1, h_2 = Heads in feet as shown in Fig. 3.
δ = Density of water at saturation temperature.
Δ = Density of dry steam at drum pressure.
D = Density of the mixture entering the drum. All densities in pounds per cubic foot.
S = Orifice of the circuit into the drum, square feet.
αp^2 = Hydraulic resistances in feet solid water column in different portions of the circuit.

In the first approximation to the actual conditions, that is, neglecting the variation of boiling point along the vertical direction of the circuit, we can write:

$$D=\frac{\delta}{1+\frac{H}{\lambda p}\left(\frac{\delta}{\Delta}-1\right)} \qquad \text{(1)}$$

$$\text{or from (1)} \quad H=\frac{\lambda p\left(\frac{\delta}{D}-1\right)}{\left(\frac{\delta}{\Delta}-1\right)} \qquad \text{(2)}$$

By taking the outlet end of the circuit:

$$h_1\delta-h_2\times\frac{\delta+D}{2}-(h_1\text{-}h_2)D=\delta\left(\Sigma\alpha+\Sigma\alpha\frac{\delta}{D}\right)p^2+\frac{D}{2g}\left(\frac{p}{DS}\right)^2$$

which reduces to:

$$\left(h_1-\frac{h_2}{2}\right)(\delta-D)=\delta\left(\Sigma\alpha+\Sigma\alpha\frac{\delta}{D}+\frac{1}{2g\delta DS^2}\right)p^2 \qquad \text{(3)}$$

The most convenient way of using the equations is to choose a set of values for D and calculate p's from (3), plotting them against H calculated from (2). The resistance factors $\Sigma\alpha$ for the stretches where water moves in a solid column change to $\Sigma\alpha\,\frac{\delta}{D}$ and where the density of hot water is decreased by the presence of steam bubbles. The increase in the factor for the mixture of steam and water is due to the higher velocity of the less dense fluid and the second power of the velocity element. The resistance factors refer to the flow in pounds per second and can be derived from any suitable formula of hydraulic resistance corrected for the temperature of the water. Let us take now a numerical example. Let the circuit contain 300 sq. ft. of projected heating surface 20 ft. high (h_2), the bottom header of which is 30 ft. (h_1) below the level of water in the drum. The inlet and outlet pipes are 8-in. diameter inside, and the resistance of the circuit is equivalent to an 8-in. pipe, 240 ft. long, of which length 140 ft. will be in the region of solid water, while 100 ft. are in the region of the steam water mixture. The evaluation of resistance gives $\alpha=\frac{89}{\delta}\times10^{-6}$ ft. per foot circuit length of the 8-in. pipe per lb. per second of circulation; δ is the pounds of hot water per cubic foot.

Calculations were made for 150, 300, 600 and 1500-lb. steam pressures, and the results are represented in Fig. 4 and 5 plotted against heat absorption in B.t.u. per hr. per sq. ft. of projected water wall surface. First we notice that the circulation is quite intense already at moderate rates of heat absorption. With the increase of bubble content, the resistance in the mixture part of the circuit begins to be felt and reduces the amount of water circulating per second. This is clearly seen on Fig. 4 from the curves of inlet solid water

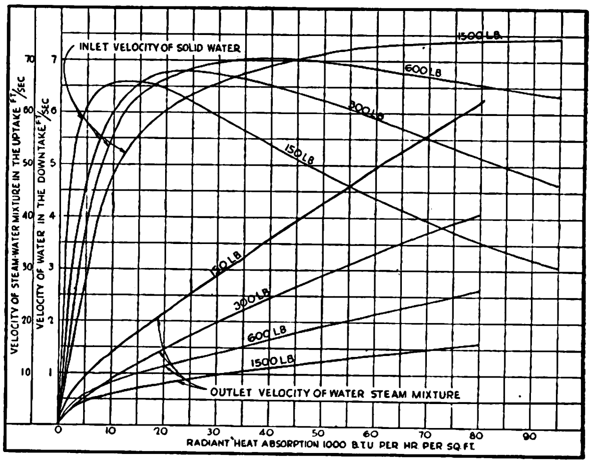


FIG. 4—Water-Cooled Furnace Wall Inlet and Outlet Velocities. Orrok and Artsay.

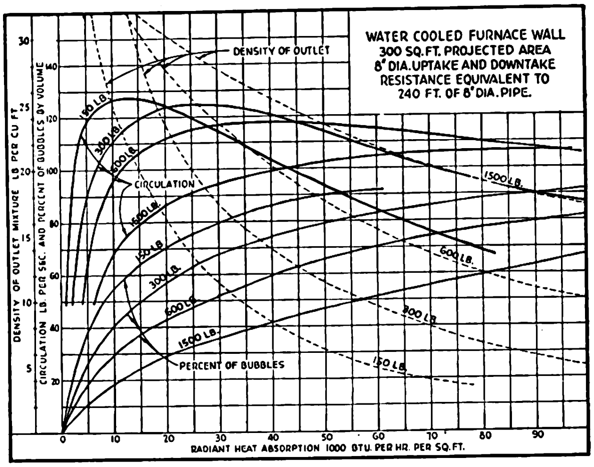


FIG. 5—CIRCULATION CHARACTERISTICS, WATER-COOLED FURNACE WALLS. ORROK AND ARTSAY.

velocity. Next we notice the beneficial effect of higher pressure on the mean density of the fluid in the circuit. This fact is reflected in the steadier water level at variable steam demand observed in the high-pressure boilers. The percentage of bubbles shown on the curves of Fig. 5 gives the indication of the actual state of the steam-water mixture in the tubes. At high ratings, one might say, the tubes are blowing out very wet steam, and in this they approach the flash type of evaporating coils.

Suppose now that we connect a closed mercury U-tube with the upper and lower headers as shown on Fig. 3, the connecting tubes being filled with solid columns of water. The indications of such a device need an interpretation even in the first approximation. If we denote by δ the lb. per cu. ft. of cold water in the small connecting tubes of the device, by v the velocity in the lower header, and by m the reading of the mercury U-tube in inches, then

$$m = \frac{12}{13.6}\left[h_1\left(1-\frac{D}{\delta}\right)-h_2\left(\frac{\delta 1}{\delta}-\frac{D}{\delta}\right)+\frac{v^2}{2g}\left(\frac{\delta}{D}-1\right)-\alpha_2\frac{\delta}{D}p^2\right]\frac{\delta}{62} \quad . \; . \; . \; . \; . \; (4)$$

where α_2 is factor of resistance in the uptake.

It is quite tempting to neglect the resistance and the velocity heads and to consider the U-tube readings as reflecting the densities only. In such a case:

$$m = \frac{12}{13.6}\left[h_1\left(1-\frac{D}{\delta}\right)-h_2\left(\frac{\delta 1}{\delta}-\frac{D}{\delta}\right)\right]\frac{\delta}{62} \quad . \; . \; . \; . \; . \; (5)$$

but the value of the neglected terms is so large that the positive reading m, according to (5), must be negative, according to (4), due to the cold column of water in the connecting tube, as can be easily ascertained by using data in Fig. 4 and 5. This effect of velocity and resistance must be always kept in mind in setting up a test device.

Several secondary phenomenæ occur in circuits such as the one here described.

1. The inlet velocity into the circuit at average ratings is of the order of 6.5 ft. per second, involving a pressure drop of about ¼ lb. per sq. in. or boiling point drop of about 0.1 deg. fahr. However small is this drop of temperature, it involves a partial evaporation which will reduce the density in the top of the downtake by about 6 per cent, which will be equivalent to a restriction of the passage and hence should be considered as an additional resistance. This effect is greater at lower steam pressures.
2. The height of water column above the center of the heating surface is considerable, 20 ft. for this case and more in many instances. The involved rise of the boiling point varies from 3.8 deg. fahr. (150 lb. pressure) to 0.5 deg. fahr. (1500 lb. pressure), and the superheating of water is equivalent to a retardation in the evaporation. It is possible to estimate the order of this effect. The average circulation is 120 to 100 lb. per second (150 to 1500 lb. pressure). Hence the percentage of latent heat involved in superheating of water is 0.52 per cent to 0.09 per cent. At 45,000 B.t.u. per hr. per sq. ft. heat absorption rate (= 3750 Bt.u. per second in the circuit), the percentage of the circulating heat capacity involved in the absorption is 3.9 to 6.75 per cent and the shift upward of the center of evaporation will be 2.67 ft. and 0.27 ft. at 150 and 1500 lb. per sq. in. pressures. The effective heads h_1, h_2 of the circuit must be correspondingly reduced, but the correction is slight.

The elementary calculations shown here permit us to estimate the effect of connecting a furnace wall circuit to the boiler circulation. Many surprising effects can be anticipated, but in this connection every case will be an individual one, where the dimensions and pipe connections play the most important role, and it is impossible to deal with these cases in an article of general character.

Steam Generating Capacity of the Water Tube Boiler

STATEMENT BY E. B. POWELL, CONSULTING ENGINEER, STONE & WEBSTER ENGINEERING CORP., BOSTON, MASS.

In the past it has been customary to regard the potential capacity of the modern water tube boiler as limited only by the increase in moisture carry-over with the steam. It was felt that, while undoubtedly there was a theoretical limit to the rate of circulation which could be attained, given clean heating surfaces, the circulation would be adequate to meet safely the maximum commercial requirement. Meanwhile, however, the introduction of the boiler separator has removed the problem of moisture carry-over as a factor in steam boiler capacity, and within the past few years the greatly increased rates of steam generation have in a number of instances been found to overtax the circulation capacity of the individual boiler. Similar experiences have been encountered with many types of furnace water walls.

The boiler circulation is, of course, merely a problem of heat absorption on the one hand and of hydraulics on the other. We now have very dependable heat transmission formulas, and one might expect that suitable hydraulic formulas would be equally available. Unfortunately, however, there are very large gaps in our data on both aspects of the problem. The work of Broido, Orrok, Wohlenberg, Haslam and Hottel, supplemented by the field investigations of Kreisinger and of Sherman, have accomplished much toward clearing our understanding of the factors influencing the temperatures in different parts of the boiler furnace, but we are still unable to predict with assurance, for untried conditions, the temperatures which will obtain in the path of the combustion gases at any short distance beyond the boundaries of the furnace. Dependable values for such temperatures are, of course, essential as a basis for the application of our heat transmission formulas. Consideration of the hydraulic aspect of the problem has suggested some very creditable theories, but there are extremely few data of definite value on the properties of mixed fluids such as obtain in the boiler circulating system.

It is true that, with our present information, limitations of boiler circulation can be estimated as rough approximations. However, the question of maximum dependable boiler capacity is of such increasing importance that further research appears highly desirable. The problem is suggested for the attention of our recently formed Special Research Committee. In the meanwhile it would seem advisable, because of the absence of data required for definite determinations that estimates of steam boiler capacities and of water wall circulation requirements include a conservative factor of safety.

Thermal Stresses

STATEMENT BY GEORGE A. ORROK AND N. ARTSAY,
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The minuteness of the effects of thermal expansion in metals and the same order of magnitude for the elastic deformations, in the majority of cases being invisible to the naked eye, has without doubt been the cause of the widespread neglect of these most important stresses produced by inequalities of temperature even in continuous pieces of metal.

The condition of very long metallic members in a structure (pipes, rails), or very small clearances (steam turbines), very limited total deformation before breakdown (cast iron, glass) and very large temperature differences (welding, shrinkage stresses at cooling of castings), represent the phenomena of thermal stresses with obvious visible results. Practically every piece of metal anywhere is subject to these stresses; for instance, the millions of frying pans in daily use. In the great majority of cases these stresses pass unnoticed because they do not inflict any permanent harm. This high percentage of harmless effects has detracted from the attention due to the small residual where danger occurs.

Thermal stresses are usually superimposed on mechanical stresses, and hence the case of thermal engines deserves a closer attention from this viewpoint than is given at the present moment, and power station engineers must be on the continuous lookout for trouble which may be caused by them.

Let us take open-hearth steel with a 40,000 lb. per sq. in. elastic limit, 30×10^6 lb. per sq. in. Young's modulus and a 6.3×10^{-6} coefficient of thermal expansion per deg. fahr. These figures mean that a temperature difference of 215 deg. fahr. across a closed contour or in a system with restricted expansion will produce stresses equal to the elastic limit. If the steel is under stress already, then lesser inequalities of temperature may produce residual deformations. If the thermal conditions are fluctuating around some such values, fatigue will set in with the course of time. If the metal is already strained in the same main directions as the running thermal stresses, the fatigue limit will be reached with smaller temperature differences.

For instance, very often the feed water is 100 to 150 deg. fahr. below the temperature of saturated steam in boiler drums; the streamlets of the colder feed which have not yet mixed thoroughly with the hotter boiler water may reach the drum walls and thus cause the fatigue in spots where the sum of thermal and mechanical stresses is above the fatigue limit. Such spots may be numerous in a boiler drum, the most common ones are under the rivet heads and in the curved drum heads. The continuous agitation of water in the drum will produce the necessary number of stress changes and minute fatigue cracks will appear which will be further worn out by the chemical action of the boiler water and its impurities. This may be the explanation of the so-called caustic embrittlement of boiler plate.

Let us take a boiler tube 0.4 in. thick, exposed to radiant heat and let, additionally, a flame play on it. The total heat transfer in such conditions may easily reach 150,000 B.t.u. per hr. per sq. ft. The heat conductance of open-hearth steel is approximately 300 B.t.u. per hr. per sq. ft. per deg. fahr. per in. thickness. Thus in the tube 0.4 in. thick transmitting 150,000 B.t.u. per hr. per sq. ft. there will be a temperature difference of 200 deg fahr. between the outer and inner surfaces. A complete analysis of such a case (see paper on "High-Pressure Boilers," A. S. M. E. Trans., 1928) will show that the outer fibers of the tube will be not only relieved of tension due to pressure but also compressed to a serious extent. The inner fibers, consequently, have to bear a very much increased stress of tension. The "creep limit" will be passed and the metal will begin to thin out locally, with a blister as the result. Many other points of large thermal stresses may be found in any boiler.

Let us take now a turbine blade. In the wet zones of steam expansion a droplet of moisture separated from the steam may strike the blade with a high velocity. A shock at 700 ft. per sec. relative velocity will heat up the droplet instantly, raising its temperature and of the nearest thin layer of the metal about 10 deg. fahr. In the wet zones of steam expansion the turbine blading has the temperature of the under-cooled steam. Stodola's investigations,[1] permit us to consider the 3.5 ratio of under-cooling, meaning that the actual temperature of steam below the saturation line on the Mollier chart corresponds to a pressure equal to

$$\frac{1}{3.5} = 0.286$$

of the actual value. We may thus expect in the lower pressure stages of a turbine an under-cooling of 50 to 60 deg. fahr. Whenever a droplet of moisture strikes the metal it is flattened immediately, with consequent breaking of the unstable state of under-cooling. Thus, the mean temperature of the spot hit by a droplet will be about 65 deg. fahr. higher than the temperature of the surrounding metal. The thermal stress involved locally on a polished blade surface will be about 14,000 lb. per sq. in. for nickel steel and 19,000 lb. per sq. in. for brass. To this must be added the very indefinite stress due to the kinetic energy of the shock. The metal of the blade is well stressed already by centrifugal force, vibration and steam impulse, hence the addition of recurrent thermal stresses of this value will produce fatigue and the microscopic cracks so often reported. Once the latter set in, the shearing stresses parallel to the surface, evolved by the thermal conditions, will begin to act and will scale off minute portions of metal. We may go even deeper: in the crystalline structure of the blade alloy the steep temperature gradients (due to the smallness of droplets and space affected) and the uneven heat conductance and thermal expansion between the crystals may produce a loosening of the structure and hence more marked and serious erosion.

A blade already slightly corroded, will present a very uneven surface layer and to the surface stresses of compression and tension must be added stresses due to bending moments; it is obvious that the rate of erosion will increase quickly. The actual behavior of blade metals in service strongly supports this idea. Moreover, a study of steam conditions across a blade shows that the maximum erosion occurs in places in the curved steam path where the pressure of steam falls off and under-cooling and temperature differences are greater.

One well-organized turbine and boiler concern in Europe has promulgated a rule in its design departments to write all the stress calculations in hot metals in red pencil while calculations for cold metals are written in black. This is being done to call continuous attention to the change of resistance in materials at high temperatures as well as to the possibility of thermal stresses.

With proper attention paid to the thermal stresses on the part of operating engineers who have the opportunity to observe the different manifestations of these forces and on the part of designing engineers who have the means of analysis, some common troubles with metals may be well reduced if not avoided entirely by judicious criticism of present constructions.

It is most desirable to collect in one place information on all the troubles in power plants which may be attributed to thermal stresses and to arrange a periodic survey of the general conditions producing these troubles. The Prime Movers Committee of the N. E. L. A. seems to be the proper place for this work.

Embrittlement in Steam Boilers

STATEMENT BY FREDERICK G. STRAUB, ENGINEERING EXPERIMENT STATION, UNIVERSITY OF ILLINOIS, URBANA, ILL.

[This article is an elaboration of part of the material that has appeared in Bulletins 155 and 177 of the Engineering Experiment Station of the University of Illinois. The publication of this article has been authorized by Dean Ketchum, Director of the Engineering Experiment Station.]

The subject of embrittlement of steam boilers has received much consideration in the reports dealing with feed water treatment. Operating engineers frequently find it necessary to consider whether or not their boilers, or proposed boilers, will be subject to this distress. They call in their chemical staff and ask for data, and the chemist turns to the reports and finds that he must work to a so-called sulphate to alkalinity ratio. This, in turn, is dependent on the boiler pressure. To determine this ratio he refers to the A. S. M. E. Boiler Code, which recommends ratios up to 250 lb. per sq. in. pressure. If the boilers under consideration operate above 250 lb., he is at a loss to know what to recommend. If he finally decides upon a desired ratio, he must then determine how much effort must be spent in maintaining this ratio. Shall it be a lower limit, an average or a value to be reached once in a while? Furthermore, what alkalinities must be considered in maintaining these ratios?

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[1] A. Stodola, Dampf und Gas Turbinen, 6th edition, par. 41, page 96; par. 178, page 853.

Much effort has been expended in attempting to clear up the uncertainties connected with the subject of embrittlement. To date there is much unknown about this cracking of boiler plate which occurs very rapidly and with practically no warning. On the other hand, much definite knowledge is available, and a brief résumé of this is as follows:

1. The cracking is the result of using a water having too much sodium carbonate in respect to the sodium sulphate content.
2. The workmanship in the boiler is not necessarily the primary cause.
3. The quality of steel does not influence the cracking to any marked extent.
4. The cracks will occur at almost any period after about one year's operation.

If a water has sufficient sulphate, no cracking occurs. The A. S. M. E. Boiler Code has given ratios of sulphate to alkalinity for pressures up to 250 lb. This will undoubtedly be modified shortly to include pressures up to 600 lb. For increase in pressure the sulphate ratio should be raised. Thus, at 400 lb., 5 seems to be advisable, and at 600 lb. it should be about 7. These ratios are of sodium sulphate to total alkalinity expressed as sodium carbonate in the actual boiler water. They are not determined by the composition of the feed water.

Plant experience in the past has indicated that these ratios are minimum values that must be maintained at all times. One-half the ratio is no better than none.

Some engineers ask whether the undecomposed sodium carbonate in the boiler water could be considered as an inhibitant and be added to the sulphate. This is undesirable since the ratios are based upon actual plant data, which in turn allow for the various rates of decomposition at various pressures. The total alkalinity in the boiler water should be calculated as sodium carbonate, and this value compared to the sodium sulphate content in order to obtain the desired ratio.

If the boilers have been operating at intervals below the recommended ratios, it would be well to start a thoroughly systematic inspection of all seams in order to ascertain whether or not cracking has started.

Structural Stability of the Steam Boiler

STATEMENT BY E. B. POWELL, CONSULTING ENGINEER, STONE & WEBSTER ENGINEERING CORP., BOSTON, MASS.

In the last half dozen years, and particularly since the first 1200-lb. boiler unit was placed in operation at the Edgar Station in 1925, there has been frequent questioning as to the hazard involved in the operation of the new higher pressure equipment as compared with that for the lower pressures regarded as standard a short time before. A report rendered after the investigation of one of the instances of caustic embrittlement which came to attention in 1928 describes the failure of a cross-drum boiler in which the drum shell pulled apart perhaps ½ in. and, although the boiler was under full operating pressure of 400 lb., the escape of water and steam merely put out the fire and, beyond the boiler itself, caused practically no damage. The account of this experience, reinforced by the experience of tube failures under much higher pressures at the Edgar Station and at the Lakeside Station, Milwaukee, suggested that the pressure zone of maximum hazard from a steam boiler of present-day construction might lie below 425 lb. It appeared that the greater thickness of metal employed with the high pressures might give such stiffness that, notwithstanding the same factors of safety were applied for all pressures, there would be greater stability of shape under rupture in the higher pressure boiler.

A study of stresses in plates of thickness corresponding approximately to those used in the standard 54-in. cross-drum developed the following relations:

Length of plate element which, considered as a cantilever beam, will withstand drum pressure without exceeding elastic limit stress (27,500 lb. per sq. in. for the plates of the 150 and 450-lb. drums, and 37,500 lb. per sq. in. for the 1400-lb. drum forging):

Drum Pressure, Lb. per Sq. In.	Plate Thickness, In.	Element Length, In.	Length Ratio
150	0.60	4.7	1.0 (Base)
450	1.65	7.4	1.6
1,400	4.00	12.0	2.6

Relative deflection obtained under drum pressure in plate element considered as a cantilever beam of fixed length, so selected that stress will not exceed elastic limit:

Drum Pressure, Lb. per Sq. In.	Plate Thickness, In.	Deflection Inverse Ratio
150	0.60	1 (Base)
450	1.65	7
1,400	4.00	32

The deflection ratios shown in the second table would seem to afford the closer measure for the relative stability of the different drums. While these values cannot, of course, be regarded as demonstrating immunity from destructive explosion, even for the 48-in. drum of the 1400-lb. boiler, they do point toward a decrease in operating hazard for the higher pressures where suitable materials and modern construction are employed.

Operation of High-Pressure Cross Cracking Stills

Relative to the maximum availability of large boiler units which is reasonable of attainment, the Committee has considered it worth while to obtain from one of the large oil refining companies a statement for the calendar year of 1928 for operation of their sixteen high-pressure Cross cracking stills. The operating problems for the oil heaters are not unlike those encountered in the operation of high-pressure boilers and are in many respects more difficult.

Oil at a temperature of approximately 150 deg. fahr. is delivered to the suction of the reciprocating steam-driven feed pumps. The feed pumps deliver the oil to the inlet of the oil heater at a pressure of 800 lb. The oil heaters which are fired with still gas are arranged for series flow of oil, and there is no provision for storage of oil in the heater or for recirculation. Straight tubes are used in the oil heaters, and in general the construction is similar to that used in a high-pressure water economizer. The oil is heated to a temperature of 890 deg. fahr. The pressure drop through the heater averages 150 lb., but is appreciably higher than this near the end of the run, as a result of the heavy accumulation of coke in the tubes at the hot end. The oil is delivered at a temperature of 890 deg. fahr. and a pressure of 650 lb. into a forged steel drum, closely resembling the boiler drum for the 1400-lb. boilers in the Edgar Station in Boston, in which the liquid phase cracking takes place. The product is bled out of the reaction drum through a needle valve and delivered to a fractional distilling tower.

Each of the Cross cracking stills is made up of an oil heater with its feed pump, a reaction drum and a fractional distilling tower. The feed pumps of each pair of stills are interconnected so that one feed pump can supply oil to two heaters in parallel.

The flow through each of ten oil heaters is 52 g.p.m.; for each of three oil heaters, 117 g.p.m., and for the remaining three oil heaters, 140 g.p.m.

The operating records for each of the sixteen stills are shown in Table II. The sixteen stills were on stream (in effective operation) during 1928 an average of 92.63 per cent of the hours in the year. They were down cold for an average of 214 hr. for each still. The work performed during a periodic cleaning is: Cleaning coke out of tubes, cleaning coke out of reaction drum, taking down high-pressure piping for cleaning and inspection, and cleaning of fractional distilling towers. The tubes in the oil heaters are inspected for defects during each periodic cleaning and changed when necessary.

Table II

Outage Schedule, Oil Refinery

Number of Still	Time on Stream, Hr.	Times Down for Periodic Cleaning	Average Time Required for Periodic Cleaning, Hr.
1	8,213	32	18
2	8,147	31	20.5
3	8,177	33	18.5
4	8,182	32	18.75
5	8,142	34	19
6	8,204	32	18
7	8,016	33	23
8	8,249	32	16.5
9	8,275	31	16.5
10	8,266	31	16.5
11	8,101	30	22.5
12	8,089	29	24
13	7,840	31	30.5
14	8,135	23	28
15	7,913	27	32
16	8,221	29	19

This same company is installing four additional Cross cracking stills, each to have a capacity of 400 g.p.m. A single turbine-driven centrifugal feed pump will supply oil to each oil heater, with no cross connections. Oil will be delivered to the feed pump suction at a temperature of 650 deg. fahr. and to the inlet of the oil heater at a pressure of 1500 lb.

Statement by the American Uniform Boiler-Law Society, 253 Broadway, New York, N. Y.

During the past two years the activities of the Chairman and Administrative Council of the American Uniform Boiler-Law Society have been directed toward bringing into accord the Massachusetts Boiler Rules and the A. S. M. E. Boiler Code. It has been rather a long and tedious struggle covering some years, but practically all minor differences have been eliminated and only one or two major differences remain to be adjusted.

During the coming season of the convening state legislatures it is intended to take up the question of code legislation, if advisable, in Virginia, Illinois, Colorado, Florida, Georgia and possibly others, if upon investigation it is deemed advisable to introduce code legislation. Sometimes, under certain local conditions, it does more harm to advocate code legislation during a session than to wait until a later date when conditions have become more favorable. There are two or three of the states named in which the possibilities of code legislation being enacted are good, such as Colorado and Florida. The Florida Engineering Society has gone on record unanimously in favor of A. S. M. E. Code legislation, and has appointed a legislative committee to work with this Society.

A number of bills were introduced during the above period in several code states that were inimical to the best interests of this society as well as its members, and it was necessary to use a great deal of time and effort in order to insure the non-passage of these bills. In one instance it was necessary to appeal to the governor of the state.

The Society has been, and is at the present time, spending as much time, labor and expense in keeping the present code states in line, in order not to disrupt the uniform practice of administering the code, as in introducing new code legislation. At times it has been found difficult to convince some of the administrative powers that a change in their law to meet local conditions, if followed by other code states would entirely disrupt the uniformity which took much effort to bring into being and to maintain.

A part of the work that may not be generally known consists of acting as advisors to the several boiler inspection departments on matters pertaining to the Boiler Code, inspection rules and administration. From time to time it has been possible to adjust differences that have arisen between Society members and the inspection departments. A few of our contributors, not knowing these conditions, have been under the impression that since eighteen states have adopted the Code, others would be added to the list without any work on the part of the Society. This is far from being the case. The work of the Society includes:

Keeping in constant touch with the administrative authorities and legislatures in the eighteen states which have adopted the Code,

Acting as a clearing house for matters vital to the administration of the A. S. M. E. Uniform Boiler Code,

Watching bills that are inimical to the Society's interests.

STATEMENTS BY OPERATING COMPANIES

Statement by the Alabama Power Company, Birmingham, Ala.

New Boilers at Gorgas Steam Plant

Two new boilers of 30,315 sq. ft. each for supplying steam to a 60,000-kw. unit known as Gorgas No. 4, will be ready for operation in April, 1929. These boilers are designed for 475 lb. drum pressure with superheater outlet conditions of 462 lb. and 725 deg. fahr. at 350,000 lb. per hr. normal output. The maximum rating on each boiler is 450,000 lb. per hr., at which the corresponding pressure and temperature are 453 lb. and 740 deg. fahr. The drums are 72 in. dia., 34 ft. 2¾ in. long, and are said to be the largest size built for 475 lb. pressure. Interdeck superheaters are located above the first deck of 7 boiler tubes.

Three sides of the furnace are water-cooled with fin tube water walls having a total surface of 3505 sq. ft.—900 sq. ft. in each side wall, 1180 in the rear wall and 525 in the hearth screen. The furnace volume is 24,000 cu. ft., which at normal ratings will give a heat liberation in the furnace of 18,000 B.t.u. per cu. ft. per hr.

Each boiler is equipped with a C. E. Corp. plate type air preheater with a total heating surface of 30,600 sq. ft. The preheated air will range in temperature as follows:

Rating, lb. per hr.	Air Temp. Leaving Heater, deg. fahr.
160,000	372
300,000	422
350,000	445
450,000	492

Fig. 6 shows the calculated performances expected from this unit at various ratings.

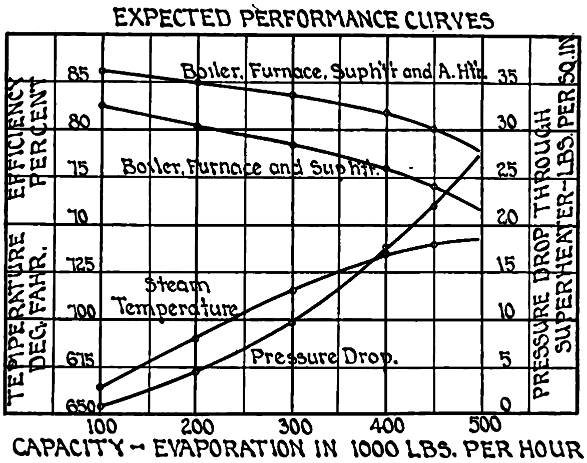


FIG. 6—Calculated Performance Data, Gorgas Steam Plant. Alabama Power Co.

Statement by W. S. Barstow & Company, Inc., Reading, Pa.

Boiler Units in the Holland Station

In considering the steam generating units for the Holland Station, it appeared that the building of each steam generator with its reheater as one unit would facilitate operation, simplify regulation and would cripple the plant less if one steam generator went out of service.

The first arrangement considered consisted of a bent tube boiler with an interdeck convection superheater, combined with one of the radiant type, and a reheater consisting of radiant type apparatus located in the side walls of the setting. This proposed arrangement of equipment was not entirely satisfactory.

After carefully considering all of the possible arrangements of water walls, boiler, superheater, reheater, economizer and air preheater, taking into consideration the cost of the various equipment, it appeared that the best arrangement was a first stage steam reheater and a second stage gas reheater with a convection type superheater, an economizer and an air preheater. The distribution of surfaces is as follows:

	Sq. Ft.
Boiler	7,928
Water walls and screens[1]	2,194
Superheater, approximately	4,600
Steam reheater	1,508
Gas reheater	11,450
Economizer	11,880
Air preheater	32,450

[1] No. 1 boiler with fin tubes on rear and front walls —2194 sq. ft.

No. 2 boiler with plain tubes on rear and front walls —1866 sq. ft.

Steam from the boiler flows to the convection superheater and thence to the high-pressure section of the turbine, which exhausts to the steam reheater operated in series with a flue gas reheater. It is then returned to the low-pressure section of the turbine. Saturated steam from the boiler is used for heat supply in the steam reheater, constant reheat temperature being obtained by thermostatic regulation of the steam. The proportions of the two reheaters are so arranged that at full loads the steam reheater is nearly cut out, the flue gas reheater furnishing all the heat required.

Comparisons between bent tube and straight tube boilers favored the adoption of the straight tube type for this case, there being four major considerations: (1) in high-pressure boilers, drums constitute the greatest expense, and the straight tube boiler with one drum had an advantage in cost; (2) the straight tube boiler allowed a more satisfactory arrangement for the gas reheater, it being difficult to place this between the first and second passes of the bent tube boiler; (3) the straight tube boiler allows all of the high

Table III

Brooklyn Edison Co., Check on Boiler No. 54, Hudson Ave. Station

Test No.	3		1		2	
Feed water temperature entering economizer, °F	235.2		244.0		266.4	
Feed water temperature leaving economizer, °F	320.2		331.3		351.3	
Flue gas temperature leaving economizer, °F	312		338		342	
Steam temperature leaving superheater, °F	703.1		712.7		708.5	
Actual evaporation, lb. per hr	194,310		231,560		327,700	
Factor of evaporation	1.106		1.099		1.075	
Equivalent evaporation, lb. per hr	214,840		254,470		352,290	
Boiler horsepower developed, h.p	6,227		7,376		10,211	
Boiler rating, %	262.2		310.4		429.9	
Heat absorbed in boiler, superheater, water walls, and economizer, B.t.u. per hr.x10^{-6}	225.3		267.6		370.5	
Combined efficiency of boiler, superheater, water walls, and economizer, %	86.78		84.88		83.63	
Efficiency of boiler, superheater and water walls, %	80.29		78.32		77.17	
Efficiency of economizer, %	80.65		77.81		75.60	
Gain in efficiency due to economizer, %	6.49		6.56		6.46	
Heat Balance (Dry Coal Basis)	B.t.u.	%	B.t.u.	%	B.t.u.	%
Heat absorbed by boiler, superheater, water walls, and economizer	12,470	86.78	12,019	84.88	12,017	83.63
Heat loss due to moisture in coal	44	0.31	40	0.28	45	0.31
Heat loss due to combustion of hydrogen	481	3.35	466	3.29	498	3.47
Heat loss due to dry chimney gases	864	6.01	896	6.33	903	6.28
Heat loss due to unburned carbon in refuse	117	0.81	108	0.76	124	0.86
Heat loss due to incomplete combustion (CO)	0	0.00	0	0.00	0	0.00
Heat loss due to carbon in flue gas (est.)	0	0.00	0	0.00	491	3.42
Heat loss due to radiation and unaccounted for	394	2.74	631	4.46	292	2.03
Heat value per lb. dry coal	14,370	100.00	14,160	100.00	14,370	100.00

priced boiler surface to be located in the highest temperature zone with the reheater immediately above, and makes the most economical general arrangement of all the heating surface; (4) the straight tube boiler construction lent itself more economically to space considerations with the desired method of pulverized fuel firing.

Each boiler is to be built for a maximum capacity of 250,000 lb. of steam per hr. at a pressure of 1400 lb. per sq. in. The boiler section will consist of one forged-steel steam and water drum, 52 in. inside diameter by 4 in. thick, 46 ft. 0 in. long, connected by circulating tubes to 45 sections, each section consisting of 8 tubes, 3¼ in. o. d., 20 ft. 0 in. long, expanded at each end into headers sufficiently long to accommodate 13 tubes. The tubes are so arranged in each section that, counting from the bottom, the second, fourth and sixth spaces on the headers are to be left blank to form a slag screen, and the twelfth and thirteenth spaces are to be left blank, so that additional tubes may be added later.

The connections from the sections to the steam drum will be provided by a row of horizontal circulating tubes, curved at one end to enter the top of the corresponding uptake header. These tubes will enter the steam drum in two horizontal rows. The downtake end of the sections will be connected to the steam drum by one row of circulating tubes. Each section will be connected at the bottom to a wrought steel mud drum by nipples.

STATEMENT BY THE BROOKLYN EDISON COMPANY, INC., BROOKLYN, N. Y.

Operation of No. 5 Unit, Hudson Ave. Station

A statement covering a description of the No. 5 unit installation at Hudson Avenue Station was given in the 1928 Report of the Boilers, Superheaters and Economizers Subcommittee (N. E. L. A. Publication No. 278-65). These boilers have been in operation since September, 1928, and have given very good performance from the start. The superheat was slightly high at first, and in order to limit the maximum steam temperature from 730 to 740 deg. fahr. at the superheater outlet, a total of 102 tubes were removed from the three passes of the interdeck superheater.

The superheater performance curve as obtained from checks on the superheater of No. 52 boiler is not flat, as the steam temperature is 40 deg. below the expected temperature of 670 deg. fahr. at 80,000 lb. per hr. steam flow; it checks the expected temperature of 700 deg. at 140,000 lb. per hr. steam flow; and is 17 deg. higher than the expected 708 deg. temperature at 220,000 lb. per hr. steam flow.

Feed water regulation by means of the Copes regulators is satisfactory and approaches very closely the results secured on boilers without water walls. There has been no evidence of priming on this installation.

The performance of the No. 5 unit boilers for the last three months of 1928 has been 84.4 per cent overall efficiency of boiler, superheater, economizer and water walls, with an average steam flow of 191,000 lb. of steam per hr., corresponding to 256.5 per cent (8.6 k-B.t.u. per sq. ft. per hr.) boiler rating.

An efficiency and capacity check run on boiler No. 54 to determine operating performance gave an overall efficiency of 84.9 per cent at 254,500 lb. of steam per hr. equivalent evaporation, and 78.3 per cent without the economizer. This run was of 27 hr. duration, made in accordance with the A. S. M. E. Code. Capacity runs were made for 6 hr. at 352,300 lb. per hr. equivalent steam flow (430 per cent rating) and for 3 hr. at 405,800 lb. per hr. (495 per cent rating). No trouble was experienced in obtaining the high ratings. Table III gives the results of these runs.

A check of the effect of various percentages of excess air upon the degree of superheat for the different types of furnace walls at Hudson Ave. Station is tabulated below.

EFFECT OF PERCENTAGE OF EXCESS AIR ON SUPERHEAT WITH BARE AND COVERED FURNACE WATER WALLS AT HUDSON AVE. STATION

Boiler number	11-34	41-44	51-54
Size, sq. ft.	19,650	22,920	23,760
Furnace construction	Refractory walls	Bare water walls	Bailey water walls
Superheater	Single pass	Single pass	3 pass
Location of superheater	Interdeck	Interdeck	Interdeck
Steam temperature increase per 10% change in excess air, °F.	3.0	7.0	1.5

Check on Boiler No. 54:

Boiler	B. & W. cross drum, 23,764 sq. ft.
Superheater	B. & W. 3 pass interdeck, 3037 sq. ft.
Water Walls	Fuller Lehigh, 1326 sq. ft.
Economizer	B. & W. return bend, 14,975 sq. ft.
Stoker	Westinghouse underfeed, 15 retort, 33 tuyere

STATEMENT BY THE CLEVELAND ELECTRIC ILLUMINATING COMPANY, CLEVELAND, OHIO

Cross-Baffling in Stirling Boilers

Fig. 7 shows a cross baffle installed by the Engineer Company of New York in one of our Class "P" 13-26, 14,460 sq. ft. Stirling boilers. Comparing the operation of this boiler with a similar one having four-pass baffling usually recommended by the B. & W. Co., we find the following:

With the same grade of coal and as nearly as possible the same percentage of excess air, there is no difference in the final temperature of the gases. It has been found possible to increase the capacity some 23 per cent of normal rating to a limit of roughly 300 per cent (10 k-B.t.u. per sq. ft. per hr.) rating. With a cross baffle the water level is not as stable as with the regular baffles.

STATEMENT BY THE CONSOLIDATED GAS, ELECTRIC LIGHT & POWER COMPANY OF BALTIMORE, BALTIMORE, MD.

Radiant Heat Superheaters, Westport Generating Station

In the Westport Generating Station, a total of eight Foster Wheeler radiant heat superheaters are installed in connection with the 10,470 sq. ft. boilers. The first of these, an experimental installation in No. 24 boiler made in January, 1924, marked the first use of a radiant heat superheater in a stoker-fired furnace for central station service. Following two years of experimenting with the first installation, the second superheater was placed in operation in boiler No. 30, January, 1926. This second installation incorporated several changes in design, the major change being the use of forged steel instead of cast steel elements.

The radiant heat superheaters operate in series with convection type superheaters installed above the first boiler pass. Based on the satisfactory performance of the radiant heat superheater installed in boiler No. 30, and further, because the expected increase in the average temperature would effect economies to justify the expense, six additional boilers were so equipped, the latest installation being placed in service in March, 1927.

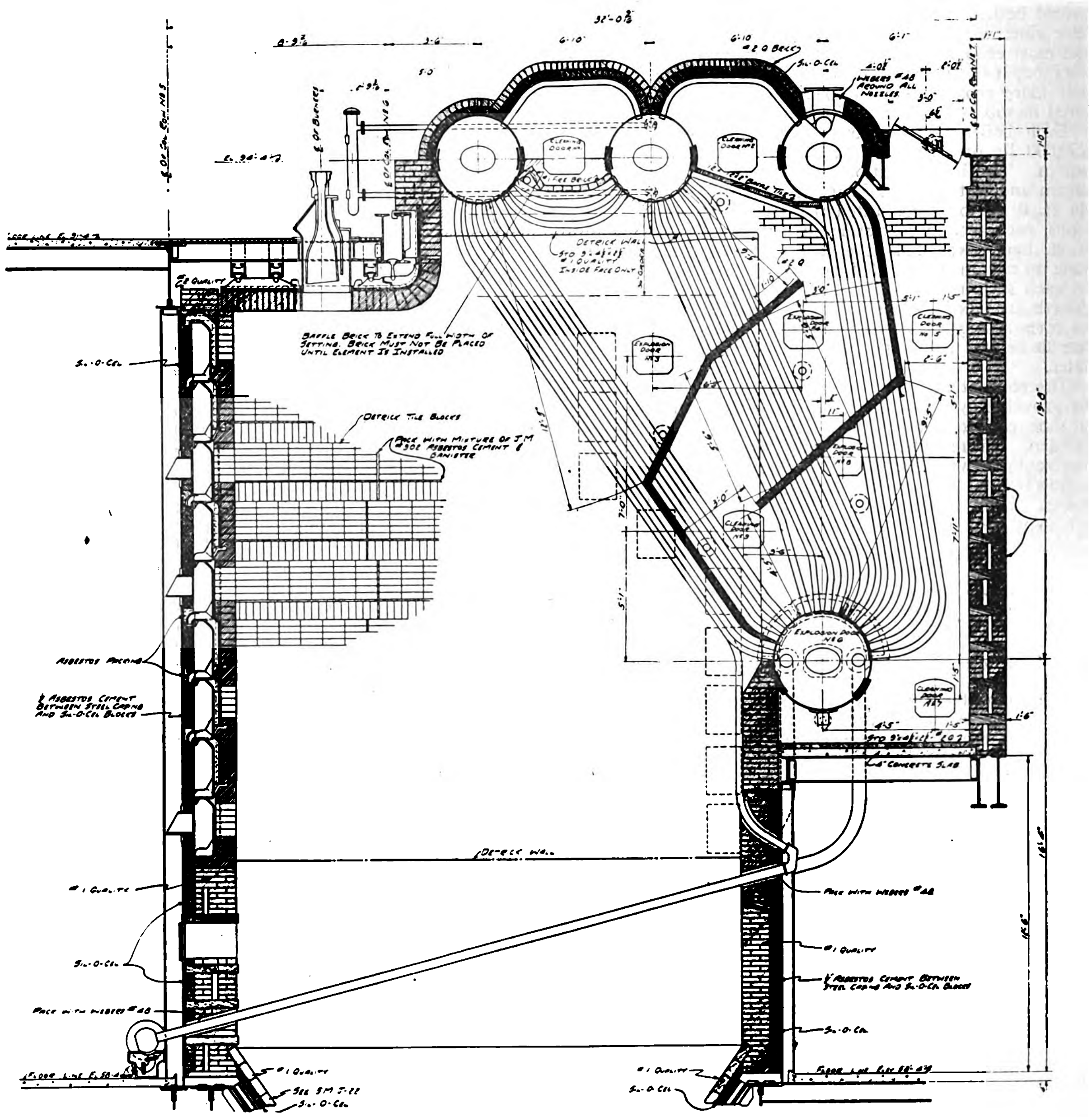

32'-0½"
Baffle Brick To Extend Full Width Of Setting. Brick Must Not Be Placed Until Element Is Installed
Detrick Wall
Std 9" #1 Quality Inside Face Only
Explosion Door No 3
Explosion Door No 6
Cleaning Door No 5
Detrick Tile Blocks
Pack With Mixture Of J M #302 Asbestos Cement & Banister
Asbestos Packing
½ Asbestos Cement Between Steel Casing And Sil-O-Cel Blocks
Sil-O-Cel
#1 Quality
Pack With Wibeco #48
Detrick Wall
4" Concrete Slab
Floor Line Elev 58'-6¾"
19'-0"
18'-6"

FIG. 7—14,460 Sq. Ft. Stirling Boiler Showing Cross Baffling. The Cleveland Electric Illuminating Co.

Each superheater is made up of 48 elements of rectangular cross-section, each 5 ft. 4 in. long by 4 in. wide, installed in a vertical position in the furnace bridge wall. Each superheater has a heating surface of 84.5 sq. ft. Steam enters one end of a divided top header, flows vertically down through 24 elements into a common bottom header, thence vertically up through the remaining 24 elements and out the opposite end of the divided top header. Both headers are 10 in. in diameter with walls 9/16 in. thick and are slightly flattened on two opposite sides to allow the entrance of 2 in. No. 9 gage (0.148 in.) nipples connecting the headers to the elements, and for the 2 in. handholes which are necessary for rolling the nipples into the elements and headers. The nipples connecting the headers and elements are about 30 in. long. Both top and bottom headers are supported on spring hangers.

All of the superheaters have forged steel elements with ends forge-welded in, the cast steel elements on the first installation having been replaced by forged steel elements after about two years of unsatisfactory operation. The elements have a wall thickness of about ¾ in., but at the point where the nipples are rolled in, the wall thickness was increased to about 1¾ in. to allow a suitable tube seat for rolling. The tube seat is fitted with two grooves, ¼ in. wide and 1/16 in. deep, of the "Lufkin" type. Each element has a 4 in. x 4 in. x ⅜ in. angle iron welded to the back of the element and midway its length, for resting on cast iron plates built into the bridge wall so as to transfer the weight of the elements from the nipples to the bridge wall.

Between every second nipple at the bottom and every third nipple at the top a box is formed by a section of 8 in. cast iron I-beam, having a ⅛ in. sheet iron plate front and back. This box is filled with long fiber asbestos packing and allows movement of the nipples due to warping of the elements.

Fig. 8 and 9 show the construction at the front and back of the superheaters.

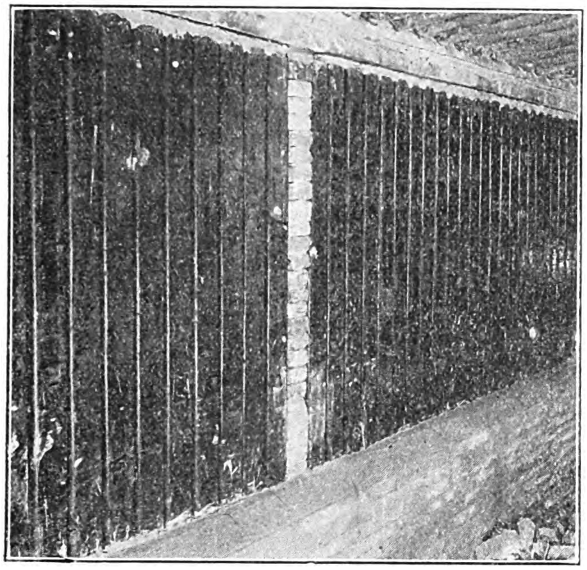


FIG. 8—RADIANT SUPERHEATER, FRONT VIEW, WESTPORT STATION. CONSOLIDATED GAS, ELECTRIC LIGHT & POWER CO. OF BALTIMORE.

Operating Troubles

The troubles which have been experienced with these radiant heat superheaters were, in the main, confined to the initial experimental installation. The cast steel elements used in the first installation were subject to excessive warping. When hot they took a shape convex toward the fire, and when cold, concave toward the fire. The headers were arranged on roller supports in such a manner as to provide for longitudinal expansion, but with no allowance for vertical movement. When the elements warped, it was either necessary that the nipples take up the movement or that the headers move vertically. The nipples proved rigid, with the result that the rolled joint where the nipple entered the element was placed under severe stress, and in several instances actually parted, creating a very troublesome operating condition until the boiler could be taken off the line. A change to spring supports for the headers and an increase in the width of tube seat, where the nipples are rolled into the element, together with the provision of grooves in this tube seat, served to remedy the trouble. The increase in the bearing surface for rolling of the nipples into the elements was very successful, as it had been very difficult to keep these joints tight because of the movement of the elements and the inability to inspect carefully the rolling. The excessive warpage of the cast steel elements was still unsatisfactory and, coupled with the successive appearance of leaks caused by sand holes, finally made it necessary to replace the cast steel elements with others of forged steel.

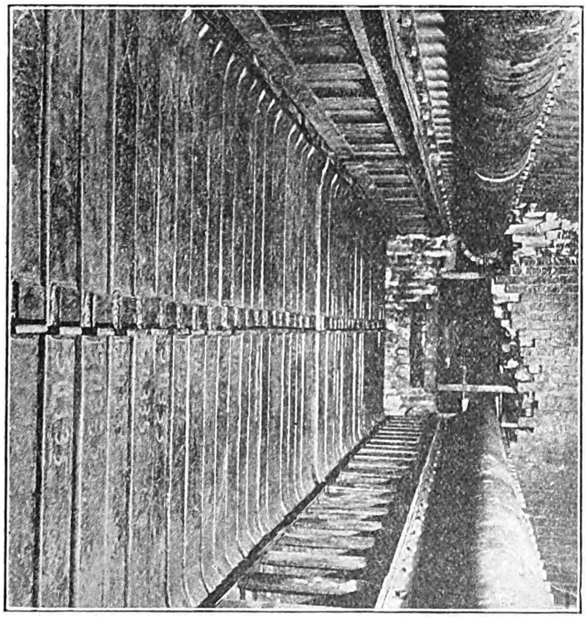


FIG. 9—RADIANT SUPERHEATER, REAR VIEW, WESTPORT STATION, CONSOLIDATED GAS, ELECTRIC LIGHT & POWER CO. OF BALTIMORE.

The illustration of the back of the superheater shows very clearly the individual angle iron supports welded to the back of each element. In the first installation two continuous angles were used, each being rigidly bolted to and supporting 24 elements. This method of support interfered with individual movement of the elements, due to warping, and it was found necessary to change to individual supports for each element in order to allow free movement.

The cleaning of the exterior surface of the superheater presented quite a problem. It was found very important to keep the superheater surfaces clean, as tests definitely showed that there is as much as a 40 per cent reduction in steam temperature rise when comparing a dirty with a clean superheater.

The first installation was provided with what was termed "rosette" type steam soot blowers. The nozzles were installed on the front of and directly attached to the superheater elements, steam being fed to the nozzles through cored holes in the cast steel elements. There were six nozzles or heads, one located at the center of every eighth element, which directed steam in all directions along the surface of the superheater. This type of soot blower proved unsatisfactory due to stoppage of the holes in the nozzles and its inability to remove slag.

A wall type of steam soot blower, consisting of stationary nozzles located at each side of the superheater, was also tried and proved unsuccessful. In addition to the soot blowers, steam lances were also tried but did not prove satisfactory. All efforts to use steam for cleaning the superheater failed. Sand-blasting was tried, with very satisfactory results, and is now being used on all of these superheaters. There has been no evidence of harmful effect on the elements because of the sand-blast. A period of about 8 min. with two men is required for cleaning.

As previously mentioned, the troubles which have been experienced were practically limited to the initial experimental installation. All of the radiant heat superheaters installed are now operating with very little trouble and require a minimum of attention from the operating forces.

STATEMENT BY THE DETROIT EDISON COMPANY, DETROIT, MICH.

Boiler Units at Delray Power House No. 3

The initial installation in the new Delray Power House No. 3 comprises 5 boiler units, each consisting of a screen boiler, a main boiler, a superheater, an economizer and an air preheater. This equipment is now being installed and will not be completed until the latter part of 1929.

These boiler units will be operated in conjunction with single end underfeed stokers, each capable of burning efficiently 34,000 lb. of coal per hr.

Screen Boiler

The screen boiler, Fig. 10, consists principally of a 54 in. o. d. steam and water drum 33 ft. 10 in. long, built from 2-in. plate, with complete water screening for all fire faces of the furnace walls and a slag screen for the exit gas passage. All pressure parts are built for 470 lb. operating pressure.

Each side wall is an independent unit, designed for recirculation between the top and bottom headers. Water flows from the screen drum to the lower headers through

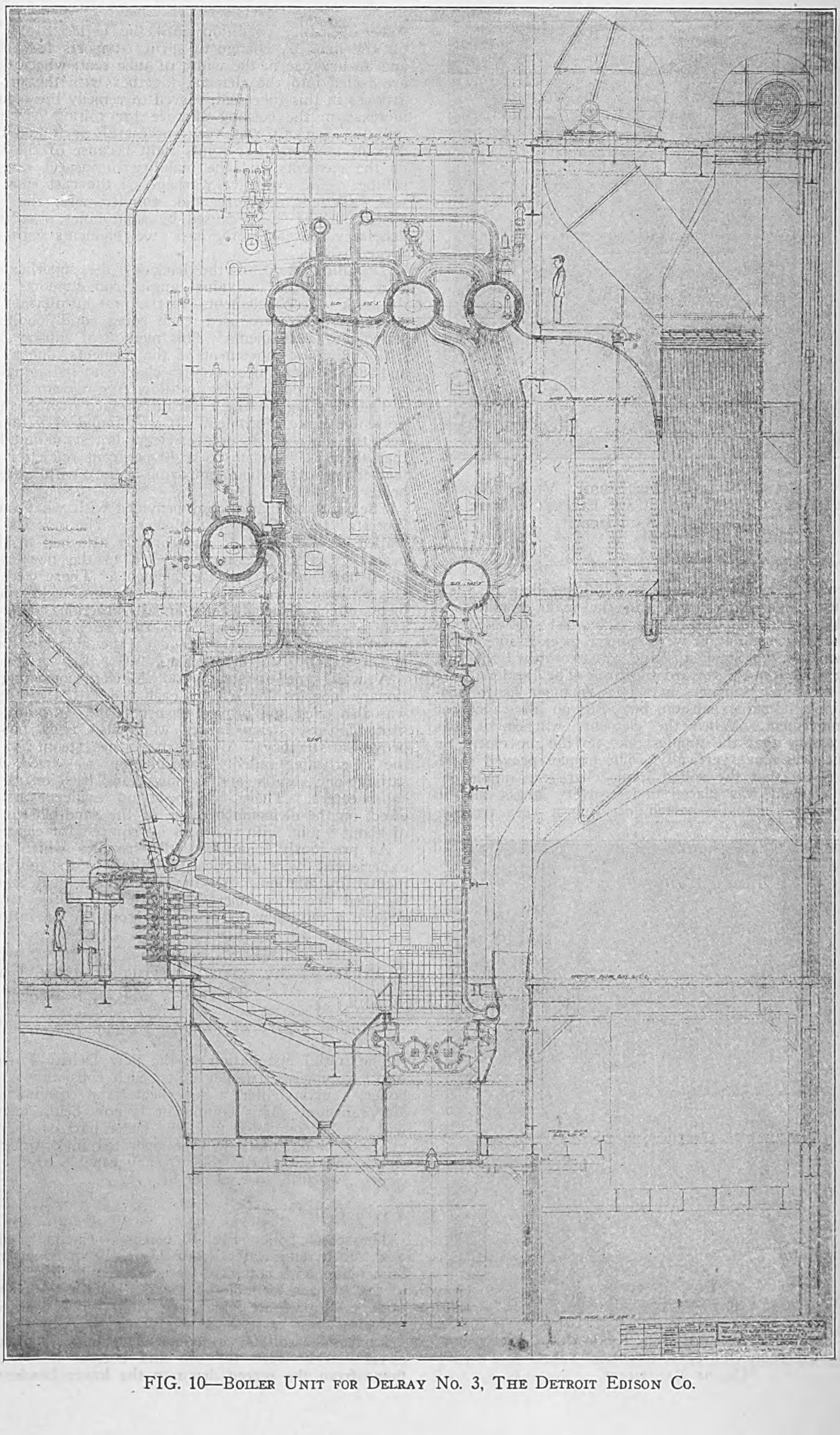


FIG. 10—BOILER UNIT FOR DELRAY NO. 3, THE DETROIT EDISON CO.

four 4 in. o. d. make-up tubes of No. 6 B.W.G. (0.203 in. thick), and steam is taken off the upper header through six 4 in. o.d. riser-tubes of No. 6 B. W. G. (0.203 in. thick) and delivered to the screen drum. Each side wall has forty-five 3¼ in o. d. wall tubes of No. 5 B. W. G. (0.220 in.) and eighteen 3¼ in. o. d. recirculating tubes of No. 5 B. W. G. (0.220 in.). Both upper and lower headers are 11¾ in. o. d. forged steel drums of 1⅜ in. thickness. All tubes within the furnace are on 6 in. centers.

The front wall is continuous with a combustion arch terminating in the screen drum. The water flows directly from the screen drum to the front wall header through twenty-four 3¼ in. o. d. tubes of No. 6 B. W. G. (0.203 in.). The wall has fifty-two 3¼ in o. d. wall tubes of No. 6 B. W. G. (0.203 in.). The header is a 11¾ in. o. d. forged steel drum of 1⅜ in. thickness.

The rear wall is continuous and in series with the slag screen which crosses the gas outlet and terminates in the steam drum. The rear wall lower header receives its water from the screen drum through two 12 in. o. d. outside pipes (one on each side of the screen boiler) bolted to the flanged ends of the header. The rear wall tubes terminate in an upper header accommodating the slag screen tubes thereby completing the circuit. The wall has fifty-two 3¼ in. o. d. wall tubes of No. 6 B. W. G. (0.203 in.), and the slag screen has the same number of tubes of the same thickness. The lower header is a 13⅜ in. o. d. forged steel drum of 1 in. thickness; the upper header is a 11¾ in. o. d. forging of ⅞ in. thickness.

The lower portion of the side walls, the lower portion of the rear wall and the entire front wall and arch will be covered with Bailey blocks, the exposed Bailey furnace wall surface being distributed as follows: Two side walls approximately 330 sq. ft., front wall approximately 808 sq. ft., rear wall approximately 312 sq. ft. The bare tube surface in the furnace is distributed as follows: Two side walls approximately 640 sq. ft., rear wall approximately 364 sq. ft. and the slag screen approximately 1040 sq. ft. Where the Bailey furnace wall construction terminates in the side walls and the rear wall, a refractory wall continues and completes the wall construction. The tiles are in close contact with half of the wall tubes, leaving the bare portion of the tubes facing the furnace.

The screen boiler is a complete self-contained unit, having its own feed water supply and a water circulation system entirely independent of the main boiler. This boiler delivers its steam through two 8 in. pipes to a superimposed 11¾ in. o. d. header located above the main boiler. From this header the steam is distributed to the rear drum through twenty-six 3¼ in. o. d. tubes of No. 7 B. W. G. (0.180 in.). The screen drum is provided with two blow-off connections, one in each end of the drum.

Main Boiler

The main boiler is a 4-drum, Stirling type water tube boiler, 53 tubes wide, having one front steam drum 42 in. diameter, 28 ft. long, built from 1 15/16 in. plate, one middle steam drum and one rear steam drum, both 48 in. diameter, 28 ft. long, built from 2 3/16 in. plate, and one mud drum of the same dimensions as the middle and rear steam drums. All tubes are 3¼ in. o. d. No. 7 B. W. G. 0.180 in.).

The boiler has approximately 23,900 sq. ft. of effective heating surface and is designed for 455 lb. working pressure.

Saturated steam from the screen boiler is introduced into the rear drum where it mixes with the steam from the main boiler. Steam is taken off the top of the rear drum and introduced into the superheater inlet header through forty-three 3¼ in. o. d. tubes, No. 7 B. W. G. (0.180 in.). The mud drum is provided with one 2½ in blow-off connection at each end.

Superheater

The superheater is of the multiple loop type and has approximately 4900 sq. ft. of heating surface arranged as shown in Fig. 10. It is designed for 455 lb. working pressure, 725 deg. fahr. Both inlet and outlet headers are 28 ft. long. The inlet header is 11¾ in. o. d., the outlet header is 13⅜ in. o. d. There are fifty-two 2 in. o. d., No. 8 B. W. G. (0.165 in.) tubes connecting the headers, the continuous one-piece length being obtained through the medium of resistance electric welding. The steam is taken off the superheater through two 12 in. steam pipes bolted to the flanged ends of the superheater outlet header. The design of the superheater does not permit of draining.

Economizer

The economizer is of the horizontal bare tube, return bend type having approximately 6032 sq. ft. of heating surface designed for a safe working pressure of 555 lb. The inlet and outlet headers are 7 in. square flanged at one end for 8 in. inlet and outlet connections. The economizer is 24 tubes wide by 20 tubes high by 24 ft. exposed length, tubes being 2 in. o. d., No. 6 gage (0.203 in.).

The amount of surface in the economizer is of sufficient size to absorb enough heat so that, with an exit gas temperature of 350 deg. fahr. at the maximum coal burning rate, the temperature of the air leaving the preheater will not exceed 350 deg. fahr.

Air Preheater

The air preheater is of the vertical tube type having approximately 30,200 sq. ft. of heating surface. It has 30 rows of 64 tubes, 23 ft. 8½ in. long, 2½ in. o. d., No. 11 gage (0.120 in.). Gas from the boiler enters at the bottom and leaves at the top. The air enters at the top, and after passing crosswise of the bank of tubes twice, leaves at the bottom. The preheater is designed to preheat the air for combustion to a maximum temperature of 350 deg. fahr. at the maximum coal burning rate.

STATEMENT BY THE DUKE POWER COMPANY, CHARLOTTE, N. C.

Buck Steam Station

The equipment in the Buck Steam Station consists of two 35,000 kw. turbines and four 26,600 sq. ft. pulverized coal-fired boilers. Steam is delivered from these boilers at 425 lb., 700 deg. fahr. In the first twelve months 429,370,000 kw-hr. were generated, which is an indication of the reliability of the plant, including the boilers. In normal operation three of the boilers carry full 70,000 kw. load, one boiler being out for routine inspection and maintenance. The plant has not yet been in operation a sufficiently long time to determine whether the availability of the boilers is equal to that of the turbine or not.

The boilers have at times evaporated as high as 340,000 lb. of steam per hr. The superheater delivers steam varying in temperature with rating from 670 to 730 deg. fahr. The feed to the boiler is controlled by thermostatic type feed water regulators with individual excess pressure valves in each boiler feed line. This combination is entirely satisfactory under normal load changes, but in the case of total loss of load, water disappears from the gage glass, and if the boiler is immediately brought back to rating, there is a decided tendency to prime. When the plant was originally started, some slight trouble was had with burning of superheater tubes, which was attributed to the poor arrangement of baffling in the superheater drums, coupled with the tendency of the boilers to prime at sudden increases of rating, although a concentration of but 5 to 7 grains per gallon (85.75 to 119.85 p.p.m.) total solids was being maintained in the water. The baffling in both the boiler drums and superheaters was changed, eliminating the tendency to prime at high rates of evaporation and completely stopping trouble with the superheater.

STATEMENT BY THE EDISON ELECTRIC ILLUMINATING CO. OF BOSTON, BOSTON, MASS.

Edgar Station

One of the main defects in the design of many stations is the ratio of the kilowatt capacity of the steam generating units as compared with the capacity of the turbine-generator units. The capacity of the boiler units has always lagged behind the capacity of the turbine-generator units and has resulted in a much higher cost for the boiler plant. We should strive to approach as nearly as possible the ideal arrangement, where the capacity of the steam generating unit matches the capacity of the turbine-generator unit. The trend of design is in this direction.

In the past, boilers have been operated far below the ratings that would result in the highest commercial economy. Much data have been obtained during the past few years on the maximum capacity of boiler sections of various designs, but the data are not complete and every effort should be made to obtain this information so that the most economical steam generating unit can be designed.

In the design of the steam generating unit an attempt should be made to distribute the heat-absorbing surface between the boiler, superheater, reheater, economizer, air heater and water-cooled furnace walls, so as to obtain the lowest first cost and the overall efficiency that is justified by the operating conditions. This balance has been obtained very seldom in the past.

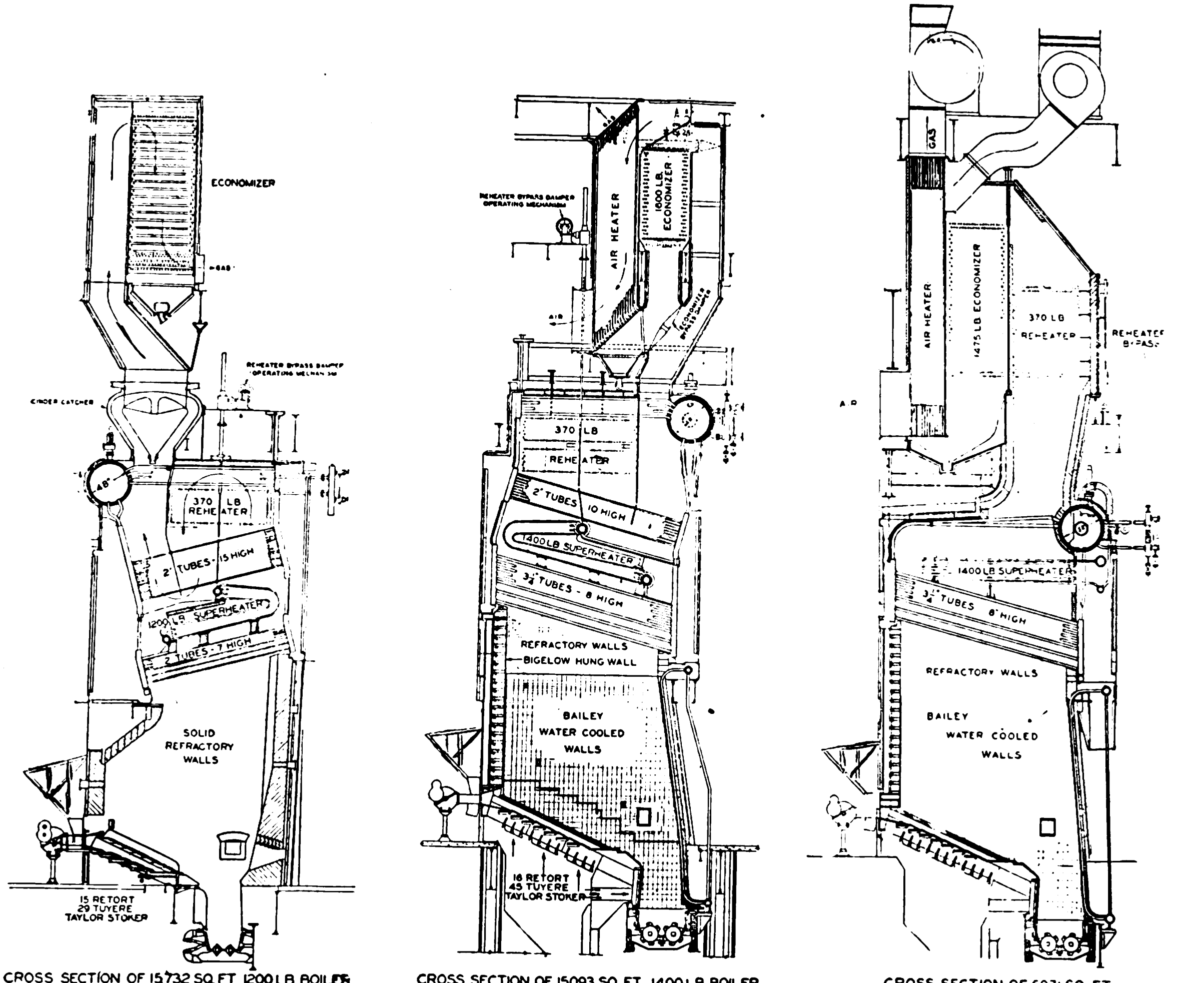
Water-cooled furnace walls have come into general use during the past few years, and operating troubles have shown that the heat-absorbing capacity of the walls of the various designs under various operating conditions is not fully known. Since this type of equipment has become such an essential part of the steam generating unit, both the manufacturers and the users of this equipment should cooperate and obtain all the essential data necessary to permit of safe and economical design. The present designs are far from being ideal.

The regenerative cycle has made the air heater an essential part of steam generating unit design. In fact, for certain operating pressures the air heater apparently cannot be omitted without a large sacrifice in commercial economy. Accurate data as to the relation of combustion air temperature to furnace temperature are needed. Information as to the maximum air temperature that can be utilized with various types and makes of fuel-burning equipment is lacking.

In other words, recent developments have been so revolutionary that accurate information as to the relation of the various pieces of equipment that go to make up a steam generating unit is lacking. As a result, it is probable that the designs now being utilized do not have the proper relation between the various parts.

Fig. 11 shows the developments that have been made in the design of steam generating units utilizing cross-drum boilers for pressures of from 1200 to 1400 lb. during the past five years. Let us compare them item by item.

The first two designs have 48-in. forged steel drums with dry pipes of the customary design. The third design has a 52-in. drum without a dry pipe. The saturated steam is taken from this drum at 12 different points, and the result is a material increase in the effective size of the boiler drum. This company does not agree with the advocates of smaller boiler drums. It is believed that the capacity of the boilers should be increased per section, and that the boiler drum should be of adequate size. Furthermore, by delivering the steam to the superheater header at 12 different points along


ECONOMIZER
GAS
REHEATER BYPASS DAMPER OPERATING MECHANISM
CINDER CATCHER
48"
370 LB REHEATER
2" TUBES - 15 HIGH
1200 LB SUPERHEATER
2" TUBES - 7 HIGH
SOLID REFRACTORY WALLS
15 RETORT 29 TUYERE TAYLOR STOKER
REHEATER BYPASS DAMPER OPERATING MECHANISM
AIR
AIR HEATER
1600 LB. ECONOMIZER
ECONOMIZER BYPASS DAMPER
370 LB REHEATER
2" TUBES 10 HIGH
1400 LB SUPERHEATER
3¼" TUBES - 8 HIGH
REFRACTORY WALLS
BIGELOW HUNG WALL
BAILEY WATER COOLED WALLS
16 RETORT 45 TUYERE TAYLOR STOKER
GAS
AIR HEATER
1475 LB ECONOMIZER
370 LB REHEATER
REHEATER BYPASS
AIR
1400 LB SUPERHEATER
3¼" TUBES 8" HIGH
REFRACTORY WALLS
BAILEY WATER COOLED WALLS

CROSS SECTION OF 15,732 SQ FT 1200 LB BOILER EDGAR STATION

CROSS SECTION OF 15,093 SQ FT 1400 LB BOILER EDGAR STATION EXTENSION

CROSS SECTION OF 6971 SQ FT 1400 LB BOILERS NO'S 7 AND 8

FIG. 11—DEVELOPMENT OF THE HIGH-PRESSURE BOILER, EDGAR STATION, THE EDISON ELECTRIC ILLUMINATING CO. OF BOSTON.

its length, much better distribution is obtained and the effective size of the superheater inlet header is materially increased. Those who have had trouble with the distribution of steam in superheater headers can readily appreciate the advantages of this change in design.

The first boiler is constructed of 2-in. tubes throughout, and due to the tube size the section headers are perpendicular to the boiler tubes. The tubes are 15 ft. long and arranged in two banks. The second design utilizes 3¼-in. tubes in the lower deck and 2-in. tubes in the upper deck. The 3¼-in. tubes permit the use of vertical headers for the lower bank, which in turn allow the use of tubes 19 ft. long. This construction materially improves the shape of the furnace and gives a much better design of boiler. Quite a radical step is taken in the third design. The upper bank of boiler tubes is omitted, and the boiler made single-pass instead of three-pass; the tubes are 20 ft. long. Additional economizer surface is installed to do the work formerly done by the upper bank of boiler tubes.

The superheater in the first design is four-pass across the width of the boiler and is designed for 700 deg. fahr. total steam temperature. In the second design the superheater is three-pass across the boiler and is designed for 733 deg. fahr. The superheater in the third design is four-pass from the bottom to the top and is designed for 750 deg. fahr. As will also be noticed, in the third design the superheater headers are entirely removed from contact with the flue gases.

The 370-lb. steam reheaters in the first two designs are located above the first and second passes of the boilers below the horizontal circulators. In the third design the reheater is located above the boiler beside the economizer with a consequent material improvement in accessibility. The reheater in the first design is designed for an outlet temperature of 700 deg. fahr., and in the second and third designs for 750 deg. fahr.

The first design has a steel tube economizer with square boxes connecting the ends of the tubes. The second and third designs utilize both economizers and air heaters, and the economizers are of the return bend type. In the third design the economizer tubes are hairpin shaped, which reduces the number of joints to approximately one-half that in the first two designs.

The use of air heaters in the second and third designs requires the installation of water-cooled walls on three sides of the furnaces.

Many other refinements have been made in the design which do not show in the picture. The net result of these changes in design has been a lower cost per unit of capacity and a further reduction in the building space required per kw. of station capacity without a sacrifice in overall efficiency.

Table IV shows the distribution of surface between the various pieces of equipment that go to make up the steam generating units shown in Fig. 11. As can be seen, the area of the boiler heating surface has been reduced 54 per cent, while the steam generating capacity has been doubled. However, the total heating surface has been increased approximately 67 per cent. It simply means that an attempt has been made to distribute the heat-absorbing surface between the boiler, economizer and air heater so as to obtain the most economical combination for the steam generating unit.

TABLE IV

COMPARISON OF SIZE AND CAPACITY OF HIGH-PRESSURE, CROSS-DRUM BOILERS—EDGAR STATION

Boiler No	3	5 & 6	7 & 8
Pressure for which boilers were designed, lb	1,200	1,400	1,400
Boiler heating surface, sq. ft	15,732	15,093	6,971
Superheater surface, sq. ft	2,923	3,483	5,096
Reheater surface, sq. ft	5,938	8,879	6,936
Economizer surface, sq. ft	11,091	5,596	9,634
Air heater surface, sq. ft	0	33,032	29,665
Water cooled furnace wall surface, sq. ft	0	1,235	1,206
Total surface, sq. ft	35,684	67,318	59,508
Temperature of steam leaving superheater, °F	700	733	750
Temperature of steam leaving reheater, °F	700	750	750
Temperature of feed water entering economizer, °F	250	420	420
Capacity in lb. per hr	143,000	250,000	300,000

Soot Blower Test

The object of the test was to determine the effect of the operation of soot blowers upon the performance of a boiler, superheater and economizer, when operated for a prolonged period under normal station conditions.

Considerable thought was given to the selection of the factors whose variation might be used to measure the effect of the soot blower operation. The combustible consumed per kw-hr. is the best measure of performance; however, the errors entering into its determination might be greater than the entire difference caused by the soot blowers. For instance, the saving in coal which can be attributed to the use of soot blowers would only amount to a small per cent, whereas the effect of errors in weighing coal and of fluctuations in moisture content, ash content and volatile combustible might easily exceed this amount. It is, therefore, apparent that some other standard of comparison should be adopted.

Soot blowers are designed to increase the heat absorbing power of the boiler, superheater and economizer tubes by keeping them free from soot. Therefore, their use should reduce the flue gas temperature at the economizer outlet and increase the steam temperature at the superheater outlet. The fluctuations in flue gas temperature and in superheated steam temperature were therefore selected for comparison. Both of these can be determined within 1 per cent and both have a direct bearing upon the quantity of combustible consumed.

Another object in using soot blowers is to keep the tube surfaces free from hard slag, thereby reducing the draft losses and, under certain conditions, increasing the time between shut-downs for thorough cleaning.

The object of the tests may, therefore, be more specifically stated as the effect of soot blower operation upon flue gas temperature, steam temperature and draft loss.

The tests were run on No. 4 boiler at the Edgar Station, which was operated by the regular boiler room forces at normal variations in steam output.

No. 4 boiler, Fig. 12, is a B. & W. cross-drum boiler operating at 375 lb. gage pressure. It is equipped with an interdeck superheater and an economizer; is stoker fired and operates with forced and induced draft.

The soot blowers are supplied with saturated steam at boiler pressure from both ends of the superheater inlet header. There are ten pairs of horizontal elements in the boiler and superheater, designated by the letters A to J, and located as shown on the cross-section. The economizer contains ten single vertical elements.

The boiler instruments record steam pressure, steam flow from the boiler, gas flow to the boiler, and temperatures of flue gases and feed water at the inlet and outlet of the economizer. Draft and steam temperatures were recorded hourly by the station operators, the former by an Ellison draft gage and the latter by a thermocouple. All instruments were calibrated at the beginning and at the end of each period of the test.

Before the tests the boiler, superheater and economizer were thoroughly cleaned. They were then inspected and all parts found commercially clean and in proper condition for the test.

The boiler was put on the line on April 6, 1928, and operated under station load conditions 42 days until May 17, all soot blowers being operated three times each day. Units A, B, C, D, E and F were operated for three revolutions and the other units for one revolution at each blowing period. At the end of this period the boiler was again inspected. As soon as it could be shut down, on June 9, it was again thoroughly cleaned and inspected to insure that its condition was the same as before the start of the test. It was then put on the line June 14 and operated for thirty days without soot blowers under station load conditions. At

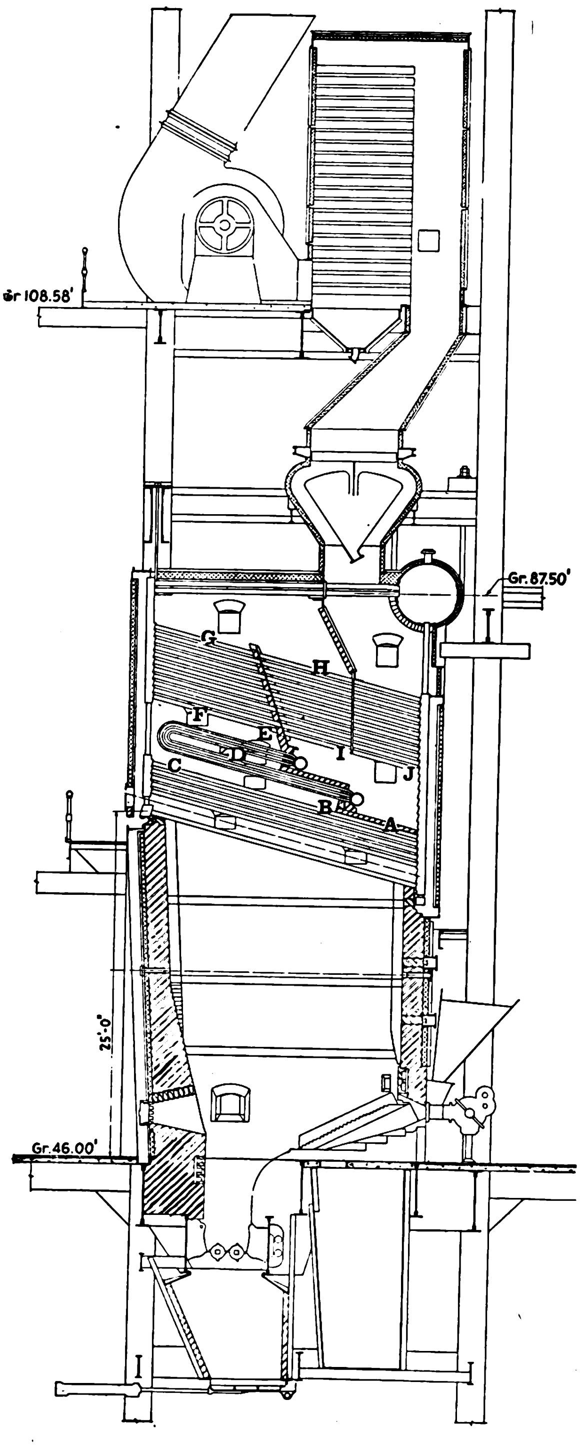


FIG. 12—19,743 SQ. FT. BOILER NO. 4, EDGAR STATION, THE EDISON ELECTRIC ILLUMINATING CO. OF BOSTON.

the end of this period it was shut down and inspected again.

At the completion of the tests a large amount of data was available, reflecting the effect of many varying conditions. Inasmuch as the two most important of these, viz., load and excess air, might affect the boiler performance far more than the soot blower operation, they were eliminated by selecting only readings at which they were substantially the same.

Fig. 13, 14 and 15 show the change in superheated steam temperature and flue gas temperature at the economizer outlet for three conditions during the test.

Fig. 13 is a comparison based on a steam output of 120,000 to 125,000 lb. per hr. and excess air of 35 to 40 per cent. It shows the steam superheat maintained constant at 670 deg. fahr. during thirty days of operation using soot blowers, and dropping from 670 to 630 deg. for an equal period when the soot blowers were not operating, a difference of 40 deg. in favor of the soot blowers. It also shows the flue gas temperature at the economizer outlet maintained at 277 deg. while operating soot blowers, and increasing from 280 to 292 deg. during the period when soot blowers were not operating; a gain of 12 deg. in favor of soot blower operation.

Fig. 14 is a similar comparison for steam outputs of 145,000 to 150,000 lb. per hr. and excess air of 35 to 40 per cent; it shows a reduction in steam temperature of 10 deg. while using soot blowers and of 40 deg. when not using soot blowers, a gain of 30 deg. in favor of soot blower operation. The gas temperature at the economizer outlet shows a reduction of 7 deg. while soot blowers were operated and a rise of 8 deg. when they were not operated, a gain of 15 deg. in favor of soot blower operation.

Fig. 15, which is based on steam outputs from 165,000 to 170,000 lb. per hr. and excess air of 30 to 35 per cent shows a drop of 7 deg. in steam temperature while operating them, a gain of 35 deg. in favor of soot blower operation. However, the gas temperature shows an increase of 10 deg. while operating soot blowers and an increase of 12 deg. while soot blowers were not operating, a gain of 2 deg. in favor of soot blower operation.

These curves are not entirely consistent, so that it is possible to draw only approximate conclusions from them. However, based on a study of the curves and of a large amount of uncorrelated data obtained during the tests, we are of the opinion that the use of soot blowers during a period of thirty days of operation at 120,000 lb. of steam per hr. would retard the drop in superheated steam temperature by 30 deg. or by 1 deg. per day, and that it would also retard the rise in flue gas temperature by 15 deg. or by ½ deg. per day at a load of 120,000 lb. of steam per hr. Therefore, our subsequent calculations have been based on these figures and upon a steam output of 120,000 lb. of steam per hr., the average output of boilers No. 1 to 4 at the Edgar Station during the three months of the test.

Fig. 16 shows the daily net saving in tons of coal each day by the use of soot blowers, based on the assumption that the retarded change in superheat and flue gas temperature takes place at a uniform rate. This saving takes into consideration the coal equivalent of the steam which was required to operate the soot blowers. The curves show that for several days after a clean boiler is placed in service, the cost of the steam required to operate the soot blowers exceeds the saving obtained by their operation. Considering all soot blower elements this period is 7 days, after which there is a gain each day by using soot blowers. This sheet also shows separately the saving from the elements which clean the superheater only and the saving from all other elements in the boiler unit. The gain from increased superheat offsets the steam consumption of the blowers on the fifth day while twelve days are required before the saving of the other elements equals their steam consumption.

Fig. 17 shows the cumulative savings due to the operation of superheater elements and to all other elements. It shows that it takes ten days of operation before the saving due to higher steam temperature is sufficient to offset the steam used by the soot blower elements and twenty-three days before the lower flue gas temperature offsets the steam consumption of the other soot blower elements.

Assuming a period of thirty days of operation between thorough cleanings of the boiler unit, the fuel saving due to operating the superheater soot blower elements would amount to 20 tons of coal for the period, while the saving due to all other elements would amount to about 2 tons of coal. These indicated savings are also subject to further reduction by the cost of maintaining the soot cleaning equipment and by the fixed charges on its initial cost.

An examination of the data of draft losses through the boiler for both operating conditions gives no evidence that soot blower operation makes any change in boiler draft loss.

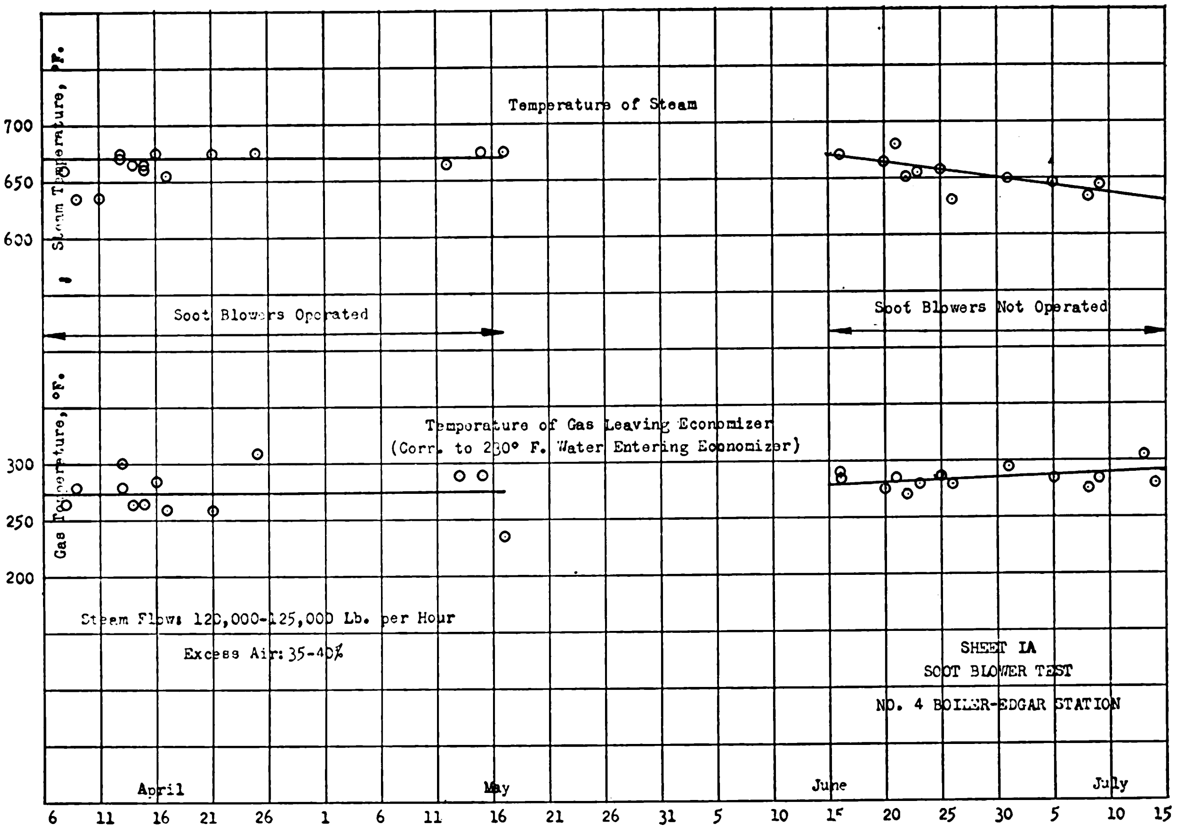


FIG. 13—Effect of Soot Blowers on Gas and Steam Temperatures, 125,000 Lb. per Hr. Rating, Edgar Station.

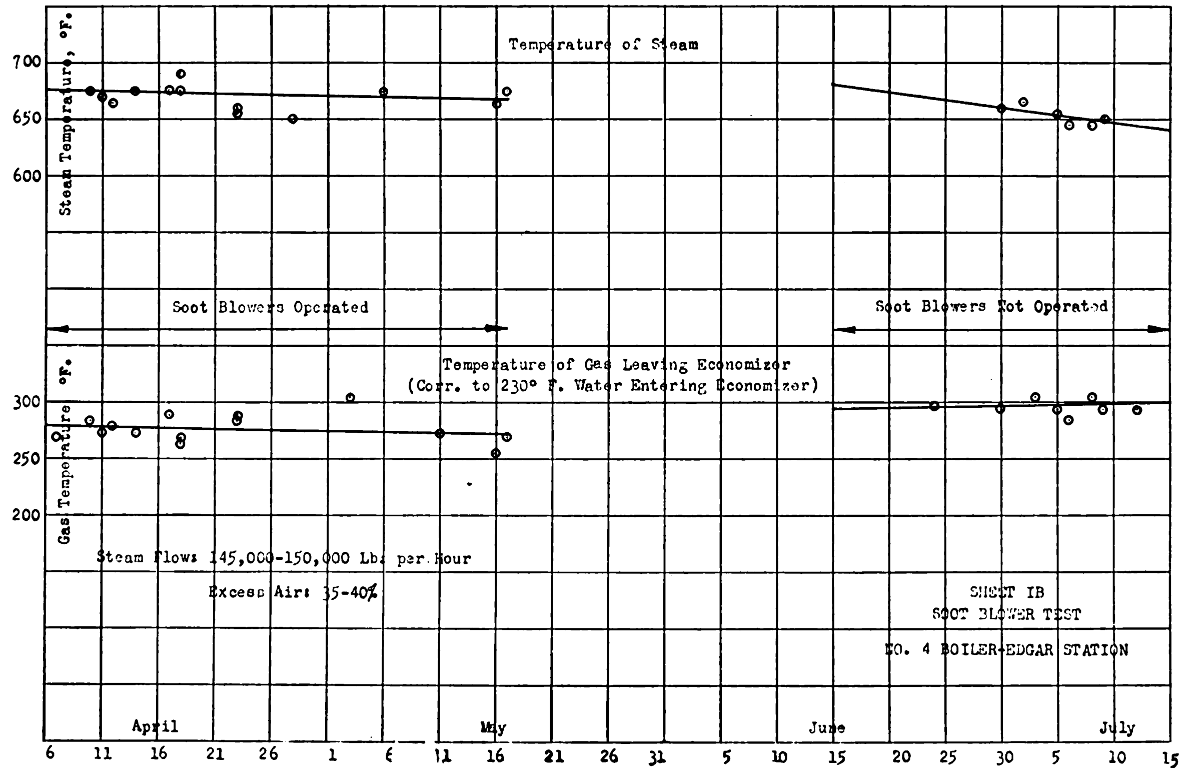


FIG. 14—Effect of Soot Blowers on Gas and Steam Temperatures, 150,000 Lb. per Hr. Rating, Edgar Station.

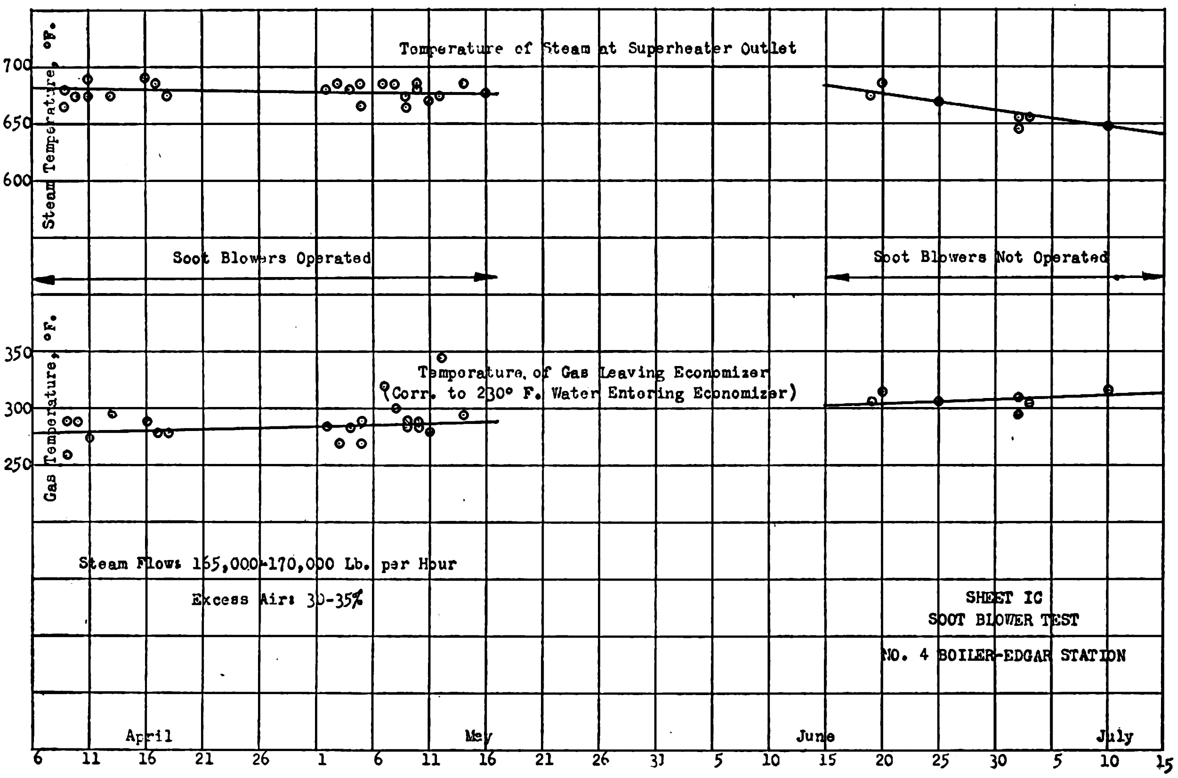


FIG. 15—Effect of Soot Blowers on Gas and Steam Temperatures, 170,000 Lb. per Hr. Rating, Edgar Station.

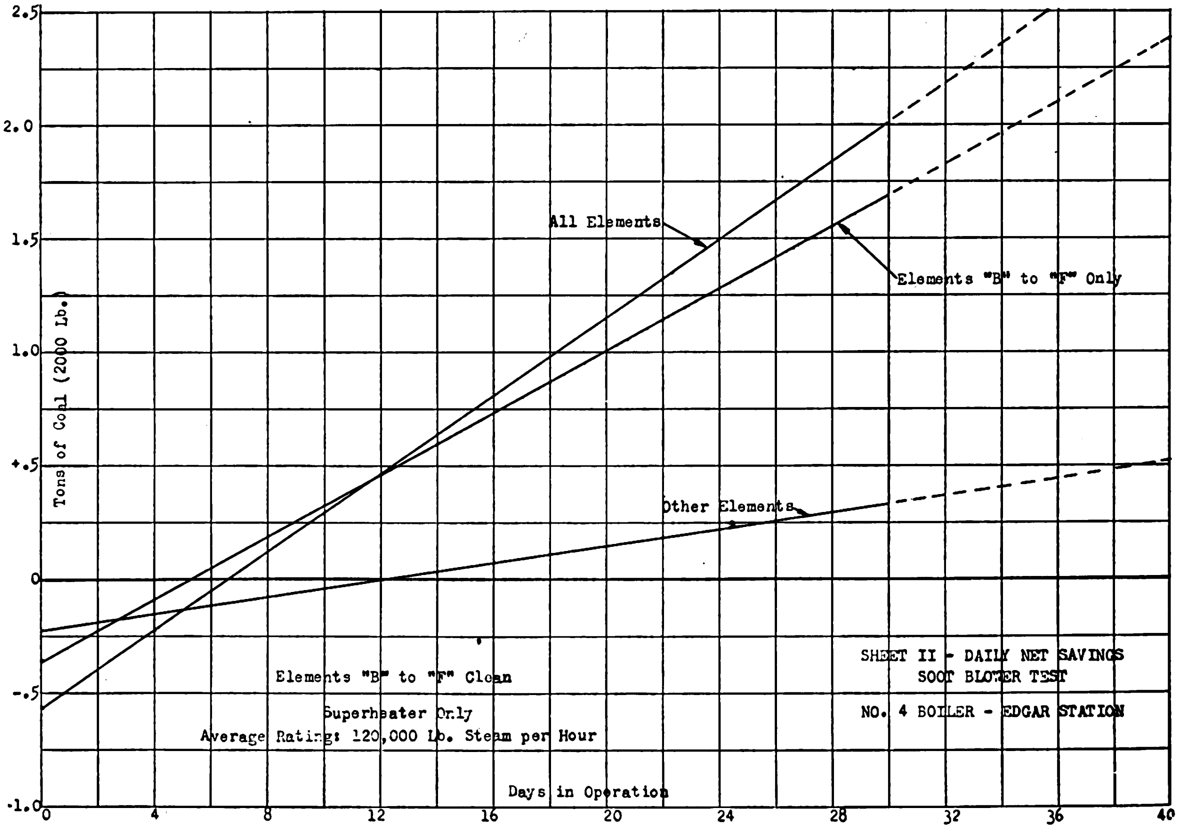


FIG. 16—Daily Net Saving Due to Use of Soot Blowers, Edgar Station.

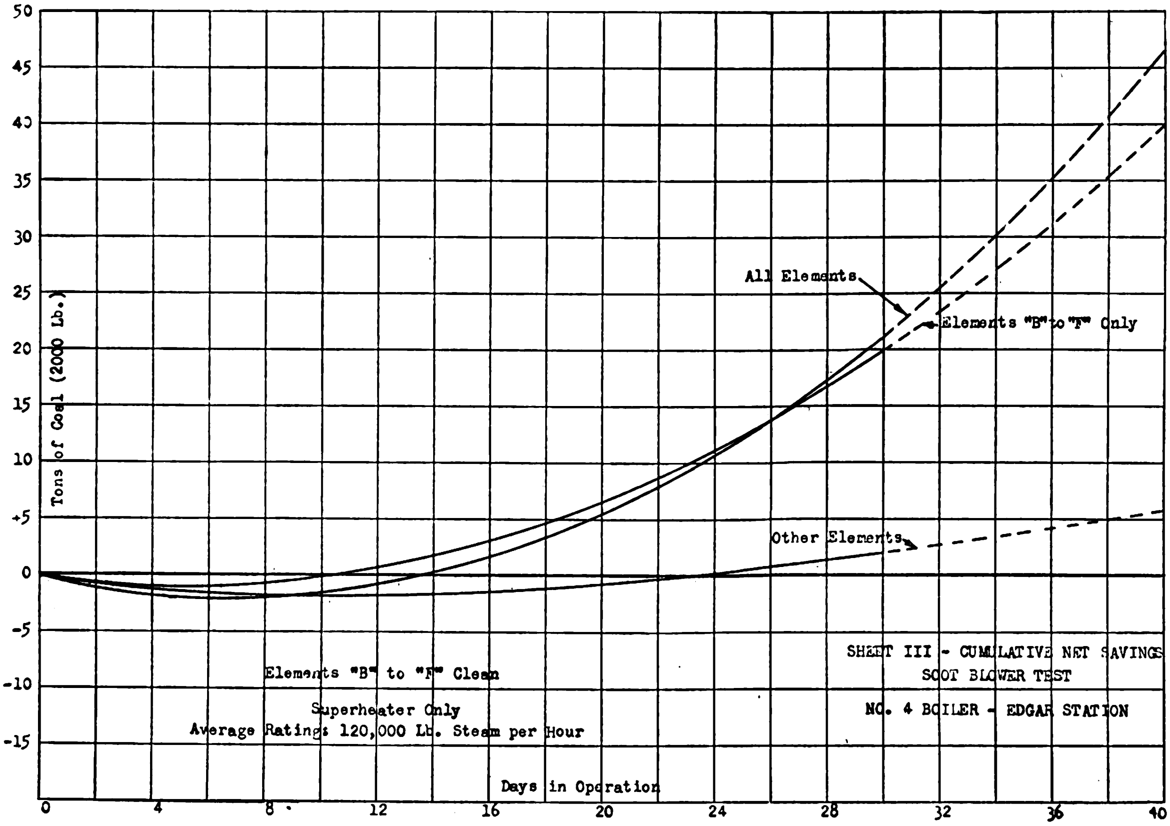


FIG. 17—CUMULATIVE NET SAVING DUE TO USE OF SOOT BLOWERS, EDGAR STATION.

The following conclusions can be drawn from the test:

1. Soot blower operation results in an increase in steam temperature at the superheater outlet, the gain from which is substantially greater than the steam consumption of the soot blower elements.
2. It also results in a reduction in the temperature of flue gases leaving the boiler unit, the saving from which is but little greater than the steam required to operate the soot blower elements.
3. Soot blower operation has a negligible effect upon draft loss.
4. The use of soot blowers appears to reduce the amount of slag deposited on the lower deck of boiler tubes. However, the slag deposit when soot blowers were not used was not sufficient to cause the boiler to be taken out of service for cleaning. It is possible, however, that higher boiler ratings might alter this condition.
5. These conclusions might have been somewhat more favorable to soot blower operation had the elements been operated less frequently, or for a fewer number of revolutions, thereby reducing their steam consumption.

STATEMENT BY THE GREAT WESTERN POWER COMPANY OF CALIFORNIA, SAN FRANCISCO, CAL.

San Francisco Steam Plant

The Great Western Power Company of California has under construction a new reserve steam plant in southeast San Francisco, with an initial capacity of 35,000 kw. and ultimately at least three more units designed for unusually low annual load factors and quick load "pick-up" conditions.

This company's system and that of the San Joaquin Light & Power Company, both under the same management, are tied together by a transmission line. The former serves part of San Francisco and nearby cities and towns and others northeastward, principally from the Caribou, Bucks Creek and Big Bend hydroelectric plants on the Feather River. The Caribou plant and its 1,300,000 acre feet of storage are farthest upstream, about 200 miles from San Francisco. The San Joaquin system serves the valley south to Bakersfield about 300 miles from San Francisco.

The hydro capacity of the combined systems is now about 343,000 kv-a., the steam capacity about 87,000 kv-a., not including the capacity of the new plant, or a total of 430,000 kv-a. This new steam plant is near the end of the transmission lines, terminating through 11 mile long bay cables from the step-down station at Oakland, with one small, old steam plant in Oakland and another in the northern part of San Francisco for reserve.

The hydro plants are of sufficient capacity and have sufficient water storage to require very little output of the steam plants, the estimated average annual load factor of the new steam plant being about 5 per cent. The steam plant capacity must be immediately available to prevent interruptions in service when submarine cables are damaged by dragging ships' anchors, or when other transmission line outages occur. The steam plant is designed to take on almost instantly the San Francisco load up to the full capacity of the turbine-generator.

Specially designed Hedges-Walsh-Weidner boilers have been provided. For the first turbine there will be two 22,250 sq. ft. cross-drum boilers, each 56 sections wide, 13 tubes high, 24 ft. long. Each boiler will be equipped with a 72-in. main drum, about 40 ft. long. Eleven feet above the main drum is an auxiliary drum 36 in. in diameter and 30 ft. long, connected to the main drum through 45 4-in. tubes. This auxiliary drum has two steam purifiers connecting to the two 10-in. outlets which go to the convection type superheaters located above the tube bank. The boiler design pressure is 450 lb., and the initial total temperature 625 deg. fahr. The boilers will have initially a capacity of 300,000 lb. per hr. each and an ultimate capacity of 450,000 lb. per hr. each. By the addition of radiant surface to superheaters, the total temperature can be later increased to 725 or 750 deg. fahr. There will be no air heaters or economizers initially, but space and provision has been left for adding them when capacity increase becomes desirable. The boilers will be oil-fired with 20 main burners and 9 pilot burners, arranged to operate over a range of 800 to 30,000 lb. of oil per boiler. Furnaces will be of the air-cooled type, 33 ft. wide and with a total volume of 17,400 cu. ft., designed for the addition of water walls when capacities are increased and for the possible ultimate use of powdered coal.

The very wide boiler gives relatively low velocities of steam leaving the tubes and entering the drum, and the relieving area in the 72-in. drum is large compared to practice for more usual conditions. These features, combined with the dry drum and steam purifiers, are specially provided for preventing water from being carried over to the turbine.

Under normal conditions, the main turbine and house turbine will operate as synchronous condensers for power factor correction with sufficient cooling steam going through the main unit to prevent injurious heating. Special overload valves have been provided on the turbine to permit development of full capacity with steam pressures as low as 235 lb. gage, dry and saturated steam, although the machine is of 400-lb. design. It is expected that the unit will be able immediately to take on any load up to its capacity, and that the boilers will be steaming at required capacity within a few minutes after the assumption of load with a steam pressure drop of 125 lb. During this interval, due to the particular design of part of the turbine, the steam pressure can be permitted to drop 125 lb., and in doing so utilize the large water storage capacity as an accumulator to make steam while the boiler is being brought from stand-by condition of say 5 per cent load to required steam output. Special automatic equipment will be provided to synchronize and adjust the various auxiliaries which will have to be started or increased in capacity during this period.

STATEMENT BY THE MILWAUKEE ELECTRIC RAILWAY & LIGHT COMPANY, MILWAUKEE, WIS.

Radiant Superheaters

Approximately two and one-quarter years' operation of the high-pressure installation at the Lakeside plant, a total of 14,000 service hours, has proved the use of radiant surfaces for the 1300-lb. superheater and 300-lb. reheater to be a commercial success. Heat transfer has averaged 45,000 B.t.u. per sq. ft. per hr., and temperatures have been as desired. The average outlet temperatures during the major portion of the operating time are:

	1927	1928
Superheater outlet temp., deg. fahr......	733.5	728.6
Reheater outlet temp., deg. fahr..........	713.1	708.3

Both reheater and superheater temperatures have averaged 750 deg. for over 100 hr. operation. There is no doubt that the radiant superheater affords unlimited opportunities for high steam temperatures.

Reliability of the superheater and reheater elements has been satisfactory, for at no time has an enforced outage been occasioned by failures. Outside of reducing the superheater surface 3 per cent, no concern has been caused by the high-pressure superheater. Metal temperatures and stresses are such in the high-pressure installation, due to high mass flow of the dense high-pressure steam and due to its high specific heat giving good heat transfer characteristics, that creep limits of the high carbon-steel employed are not exceeded.

Radiant vs. Convection Superheaters

For a high-pressure installation, consideration of the radiant superheater characteristics will show it more desirable than the convection superheater because of its rising temperature characteristic at lowered ratings. Reference to Fig. 18 shows that although the superheater outlet temperature increases 50 deg. when lowered to 40 per cent maximum rating, first-stage turbine temperatures vary less than 10 deg. and are almost identical at low loads and high loads. Consideration of the Joule-Thomson effect of lowering temperatures when throttling high-pressure steam explains this condition and points out the desirability of using superheaters with radiant characteristics if maximum gain of high steam temperatures is desired at high pressures. Even the flat temperature characteristic of the combination radiant and convection superheater is undesirable, and the drooping characteristic of the convection superheater causes a 100-deg. drop in first-stage temperature of a high-pressure turbine from full to zero load.

Uniform first-stage temperatures result in uniform stage temperatures throughout the machine if the unit is operating in compound with a condensing turbine. There is no doubt but that this characteristic of uniform steam temperature throughout the turbine is desirable when running with the small clearances found necessary in high-pressure machines.

High superheat temperatures at low loads cause no concern as regards superheater metal temperature. The actual metal temperature is the criterion of safety—not the steam temperature. At full load the temperature difference between the steam and metal is about 250 deg. At half load this temperature difference decreases approximately to 200 deg. In spite of 50 deg. higher steam temperature, the internal metal temperature is thus no higher at low ratings. Temperature drop through the metal decreases, and the external metal temperature is actually lower at reduced ratings.

There being no heat transfer through the metal piping and fittings, their temperature is essentially that of the steam, and they present no problem when subjected to the higher temperatures attendant with low ratings, providing they are purchased originally with proper specifications. Creep phenomena limit the safe steam temperatures only in metals considerably higher in temperature than the steam. Close clearances demand careful consideration of temperature at the turbine, but the problem presented by intermediate piping and fittings is much less in degree.

Consideration of the above points indicates that the radiant superheater is desirable for high-temperature, high-pressure installations. Used in combination with a convection reheater, and the high-pressure turbine operating in compound with a low-pressure one, the overall combination results in remarkably uniform steam temperatures in both turbines over a wide range of load. The Joule-Thomson throttling effect at low pressures is greatly less than at 1300-lb. pressure, as shown by Fig. 19, rendering a flat temperature curve characteristic fairly acceptable for the low-pressure turbine. Use of the combination radiant superheater and convection reheater plan, in most cases, greatly facilitates and improves the overall unit design.

From the experience with the radiant-superheater high-pressure installation, there seems little doubt but that the radiant design will be retained in the future, and will be found increasingly desirable as higher temperatures are used.

STATEMENT BY THE NEBRASKA POWER COMPANY, OMAHA, NEB.

Boiler Outage

Four boilers are operating at 300 lb., and eight 5000 sq. ft. boilers are operating at 200 lb., being connected with the high-pressure boilers through a reducing valve. The following data will give the most concise picture of the operation of the 300-lb. boilers during the year 1928:

Boiler Number.............	20	21	22	23
Year installed	1920	1922	1922	1924
Water-heating surface, sq. ft.	13,828	13,828	13,828	18,923
Total steaming hr...........	8,173	7,338	5,783	8,315
Average steaming rate, k-B.t.u./sq. ft./hr.	6.5	6.7	6.9	6.1
Total hr. banked...........	138	1,057	2,496	20
Total service, hr............	8,311	8,395	8,279	8,335
Service hr., % of total......	94.6	95.5	94.2	94.8

It will be noted that the average service hours for these boilers were 8330 hr., or 94.8 per cent.

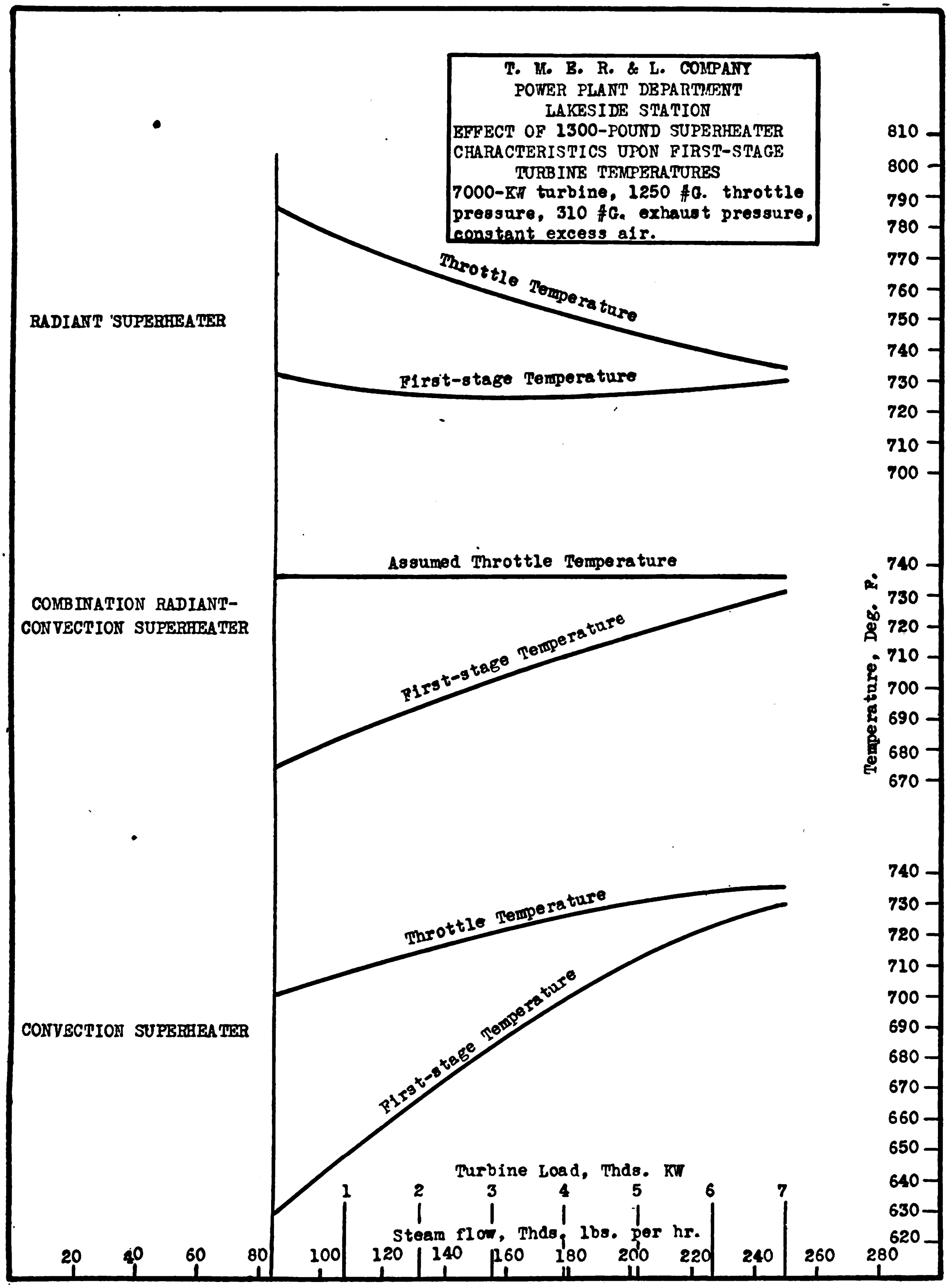


FIG. 18—EFFECT OF 1300 LB. SUPERHEATER CHARACTERISTICS ON FIRST STAGE TURBINE TEMPERATURES, THE MILWAUKEE ELECTRIC RAILWAY & LIGHT CO.

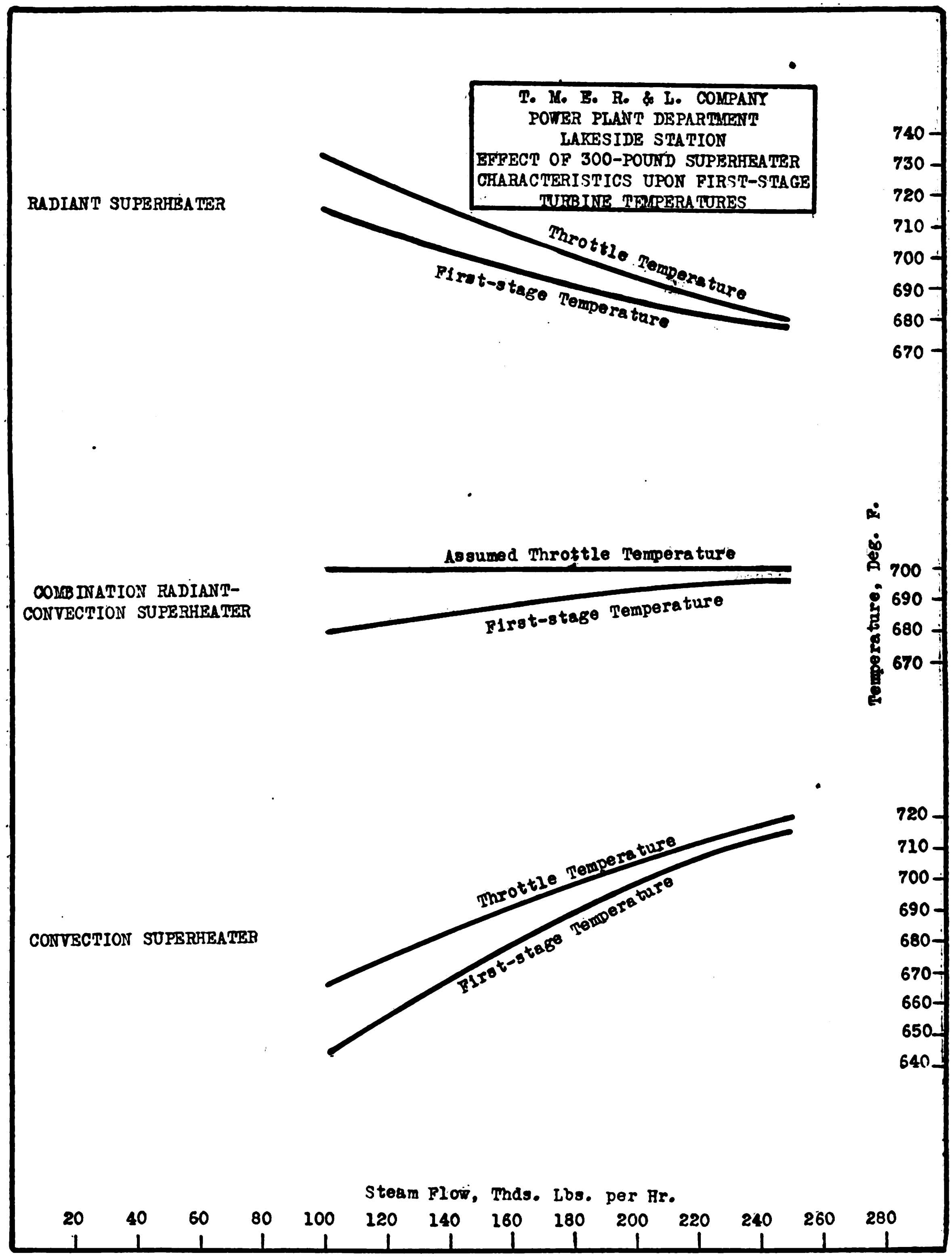


FIG. 19—EFFECT OF 300 LB. SUPERHEATER CHARACTERISTICS ON FIRST STAGE TURBINE TEMPERATURES, THE MILWAUKEE ELECTRIC RAILWAY & LIGHT CO.

Owing to the increased cost of operating the low-pressure boilers and turbines, every effort is made to use only high-pressure equipment. These boilers give varying superheats so that the boiler schedule is arranged to bank those boilers which give the lowest superheat at low ratings. Three boilers are run after 10 P. M. at about 3.3 k-B.t.u. per sq. ft. rating, the fourth boiler being banked.

Every Saturday night one unit is let down as soon as the other three can carry the load, usually about 10:30 P. M. At midnight, the induced draft fan is started and the boiler cools until 7:30 A. M., when the bricklayers get in to repair the furnace lining. The boiler is generally quite hot at this time, but it has been possible to do most of the work under these conditions.

This work is finished by noon, and a crew of slaggers gets in to clean the tubes in the first pass and superheater. This cleaning requires from 4 to 8 hr., depending on the kind of coal burned during the preceding weeks. As a usual thing the unit is ready to be fired up by 5 P. M. Sunday. However, if the coal has been particularly high in ash, causing severe slagging, or if soot conditions require extra cleaning of the superheater, the boiler may be kept off the line and put on Monday morning.

While the above-mentioned gangs are at work inside the boiler the mechanics and steam-fitters go over the various portions of the boiler and stoker, including fans.

The unit generally has been let out for about 18 to 20 hr. once a month for general cleaning and inspection. Once a year each unit is let out for 3 or 4 days for complete overhaul. There is nothing spectacular in this proceeding except that the crews are well organized, every man being assigned to a definite job, and every minute is made to count. In this way the boilers are kept out of service a minimum number of hours throughout the year.

During the summer months this work has been a little hard on the bricklayers who have to get into the boiler early in the morning; in the future it may be possible to operate in such a way that the boiler will always be left off until Monday morning, giving it a chance to cool a little longer after it has been shut down, before starting work.

STATEMENT BY THE NEW YORK STEAM CORPORATION, NEW YORK, N. Y.

Kip's Bay Station

The design of the Kip's Bay Station of the New York Steam Corporation was discussed in a statement appearing in the August, 1927, Report of the Subcommittee on Pulverized Fuel. This report may be referred to for details of design not appearing in this statement.

On Dec. 23, 1926, the first boiler at Kip's Bay Station was put into service, and boilers 2 and 3 were put into service within six months thereafter, although building construction, equipment installation and minor operating installations were still in progress. The station was shut down for the summer of 1927 in order that construction could be completed without interference from operation. Thus, the first period which could be depended upon to bring out any features of design and construction as related to capacity and continuity of service, was the winter of 1927-1928.

Boiler No. 4 was put into service on Dec. 2, 1927. In any statement of the operating experience at Kip's Bay Station, the experiences were common to four boilers unless specific reference is made to the contrary.

Three difficulties developed during the winter 1927-1928 which, until recently, have delayed the realization of some of the guarantees and expectations. These were:

1. Feed water treatment.
2. Moisture in steam.
3. Changes in coal characteristics, resulting in the slagging of the boiler tubes.

The plants of the New York Steam Corporation operate with no returns other than the steam from the plant auxiliaries. This feature of operation is not met with in other utilities and the importance of feed water treatment under these conditions of operation can be readily understood. During the winter season approximately seven million pounds of raw water are fed each day to each boiler at Kip's Bay, and although this water is drawn from the drinking water supply of New York City, it contains sufficient dissolved material to endanger the heating surfaces within ten days of operation at the existing rates. The protection of the heating surfaces by turbining would be costly, inasmuch as that part of the plant investment represented by boilers would have to be increased about 20 per cent for sufficient spare capacity to permit cleaning. The chemical method of preventing scale deposit is used and has been successful to a remarkable degree, but before the boilers were operated at high capacities for long periods, it was necessary to insure that the treatment was keeping the surfaces clean. The frequent inspections which were made and the earlier lack of assurance prevented the attainment of peak capacities and high percentages of active hours. All of the details and refinements of the treating system have not been worked out, but the boilers have been cleaned internally only two or three times within the last 16 months, and this only to insure against deposits on surfaces not readily inspected. No water wall tubes have been lost in this period, and such few boiler tube failures as have occurred have been caused by soot blower impingement and similar causes not traceable to deposits on the heating surfaces.

The economizer surfaces have required the greatest amount of cleaning. The cause of the formation of the deposit on these surfaces is understood, and it is expected that a minor change now being made in the treating system will completely eliminate this condition. The deposit has a major effect on water pressure loss which limits the peak attainable.

The chemical conditions in the boiler, the boiler design, and the rate of operating the units have all combined to produce an excessive amount of moisture in the steam. After an extensive investigation, a solution to the problem has been found which has eliminated the moisture problem in one boiler and which is being adapted to the other boilers as rapidly as operating conditions permit. The increase of moisture with rating naturally restricted capacity under normal conditions but did not constitute an absolute limitation.

It was found that the amount of moisture in the steam increased rapidly with increases in rating. With some types of separating equipment, there was a critical point on the rating curve above which the steam was very wet and below which the steam was commercially dry. The equipment now installed in one boiler, and which is being adapted to the other three, gives steam with less than ½ of 1 per cent moisture at an average rate of evaporation of 21.5 lb. per sq. ft. of boiler and furnace surface. The problem of moisture and the investigations carried out by the New York Steam Corporation will be discussed in detail in a paper to be presented before the A. S. M. E.

Variations in the composition of the ash in the coals used have caused serious curtailment of capacity at infrequent intervals because of the deposit of ash on the tubes at the entrance to the boiler and, until the cause was found, made it inadvisable to force the boilers to their greatest capacity. The coal used is a mixture from a number of mines among which there are some with a very low ash fusion temperature and with comparatively large quantities of pyritic sulphur in the ash. There was apparently no other variable than the coal to which the infrequent trouble with slag could be attributed, and it was found eventually that, although approximately constant proportions of the total coal used came from each mine, the shipments were separate and were not mixed at the piers in the same proportions in each barge. Therefore, a single barge might contain a comparatively high proportion of the harmful ingredients, and although the analyses were carefully made, sampling errors might cover up the troublesome features. After the proportioning of barge loadings had been stressed, no further trouble arose due to stoppage of the gas passage by slag. The units were designed to burn coal with an ash fusion temperature of 2200 deg. fahr. at a liberation rate of approximately 22,000 B.t.u. per cu. ft. and have burned this coal at liberation rates of 30,000 B.t.u. per cu. ft. for sustained peaks without trouble.

Fluctuating water levels have not given trouble. The reasons for this are probably two: First, that the multi-drum boiler has a large internal volume which can diminish the effect of changes in fluid volume, and second, that instantaneous load fluctuations are very rare. In addition, the effect of the economizer on these units is to decrease the condensing effect of large quantities of comparatively cold feed water which otherwise would enter the boiler directly from the open feed water heater.

Continuity of operation has been excellent in the last few months and no instance of enforced boiler outage is recalled for the period from Nov. 1, 1928, to the date of the preparation of this statement (Jan. 16, 1929). During this period the total outage of boilers was less than 14 per cent of the time and was made up principally of internal inspections, moisture experiments and ash cleaning. The figures are summarized in the following table:

ANALYSIS OF PRODUCTION

	Period			
	Nov. 1-30	Dec. 1-31	Jan. 1-16	Total
Total steam gen., M-lb.	679,738	798,048	760,348	1,938,134
Peak load, M-lb.......	1,467	1,466	1,513	1,513
Load factor, %........	64.3	73.2	79.2	69.3
Average rate per productive boiler hr., M-lb.	283	316	326	306
ANALYSIS OF SERVICE HOURS				
On the line, %........	83.4	84.7	91.8	86.2
Off for inspection and cleaning, %	2.0	7.0	4.1	4.4
Off for moisture experiment, %	5.8	5.8	0.0	4.5
Off for slag and ash removal, %	6.4	1.5	2.1	3.5
Off for minor repairs, %	2.2	0.9	1.1	1.4

In reference to the above table, it is interesting to note that the original guarantees covered a steam production of 325,000 lb. per hr. at maximum and, although some changes have been made to the boilers, the furnaces are exactly as installed and peak loads 15 to 20 per cent in excess of guarantees have been carried. On Jan. 16, 1929, the last day included in this summary, the plant generation averaged 1,501,000 lb. per hr. for 11 consecutive hours on 4 boilers.

STATEMENT BY THE PACIFIC GAS & ELECTRIC COMPANY, 245 MARKET ST., SAN FRANCISCO, CAL.

Large Boilers at Station "C," Oakland

The installation at Station "C," Oakland, consists of two oil-fired boiler units for operation at 450 lb. gage drum pressure, one of which is shown in Fig. 20. Each unit consists of boiler, water walls, superheater and air heater. Each unit was designed for a maximum output of 425,000 lb. of steam per hr., 730 deg. fahr., feed water at 365 deg. fahr., temperature of air to furnace 498 deg. fahr. and temperature of gases leaving air heater 353 deg. fahr.

The boilers are B. & W. cross drum, each with a heating surface of 35,453 sq. ft. The drums are 60 in. diameter and the tubes are 4 in., No. 6 gage (0.203 in.), 24 ft. long, arranged 51 wide and 24 high. Each drum is provided with a separating baffle to reduce moisture in the steam to the superheaters. The boilers are steel cased.

The furnaces are water cooled with Bailey walls in side and rear walls and front wall above burner wind box. The total water wall surface for each boiler is 1674 sq. ft. The furnaces are 25 ft. high at the uptake end; heat liberated at maximum output is at the rate of 37,000 B.t.u. per cu. ft. per hr. The external surface of the water walls is finished with hard surface insulating plaster.

The superheaters are B. & W., three-pass, interdeck, each with 6553 sq. ft. heating surface. The tubes are 2-in., No. 10 gage (0.134 in.).

Each air heater is of the tubular type, having a total heating surface of 51,323 sq. ft. The tubes are 2½ in. diameter, No. 11 gage (0.120 in.), 36 ft. long, arranged 32 deep by 68 wide.

There is one forced and one induced draft fan per boiler unit. These are both Sturtevant vane control type. The forced draft fans each have a capacity of 550,000 lb. of air per hr. against a pressure of 15 in. of water. The capacity of each induced draft fan is 600,000 lb. of gases per hr. at 7½-in. draft.

Each fan is driven by two 2300-volt, squirrel cage motors, one high speed and one low speed, either one of which may be started by throwing directly across the line. All of the higher speed motors are 400 h.p.; the lower speed motors are 150 and 210 h.p. for the forced and induced draft fans respectively.

Firing is controlled by the Bailey Control System, arranged for either push button or automatic control. Automatic devices have been installed to shut down the fans in the event of excessive furnace draft; also, to shut off fuel supply in case the induced draft fan stops.

The water columns are approximately 50 ft. above the firing floor and a periscope was installed for showing the water level at the firing floor. This has proved very satisfactory, but in addition, distant water level gages were provided.

The water level in the drums is automatically maintained by S-C controllers. A differential pressure regulator is cut in ahead of each controller and a constant pressure of approximately 550 lb. is maintained at the feed water header to each boiler.

A power control valve was installed on each superheater outlet principally in order to permit of higher operating pressure at the superheater outlet.

The single stack for the two units is 150 ft. above the firing floor and is of welded steel, lined with Gunite.

These units went into service about the middle of October, 1928, and have been in continuous service since. Experience, so far, indicates that very large boiler units, equipped with water walls, and with proper feed water are going to prove very reliable with low maintenance and operating costs. It is believed that they will be as reliable as other equipment in the plant. Especial mention should be made as to the flexibility and ease of control of these large units as compared with a larger number of small units. Brief experience indicates that the anticipated advantages of very large boiler units will be realized in every respect.

1200-Lb. Installation at Station "A," San Francisco

In the new 1200-lb. installation at Station "A" it is expected that the operating pressures and temperatures will be as follows: Boilers, 1350 lb., 750 deg. fahr.; turbines, high pressure, 1200 lb., 750 deg. fahr.; low pressure, 400 lb., 750 deg. fahr.; feed water 430 deg. fahr.; air temperature to furnaces approximately 450 deg. fahr.; final gas temperature approximately 325 deg. fahr.

Some of the boilers will have reheaters and the remainder will be of standard design. The standard boiler unit will consist of boiler, water walls, superheater, economizer and air heater. The boiler will be 8 high and 62 wide, with 20-ft. tubes, and the unit will have a maximum output of 400,000 lb. per hr.

The reheat units will be exactly like the standard unit with the addition of a 400-lb. reheater with a capacity of 440,000 lb. per hr. Live steam reheaters will be used in connection with the convection type gas reheaters to maintain the temperature at approximately 750 deg. fahr. at all loads and also to give some reheat if the reheat boilers are out of service.

The boiler feed pumps will probably be of the so-called "interrupted" type, driven by steam turbines.

The station will contain two compound units rated at 50,000 kw. (55-60,000 kw. maximum).

STATEMENT BY THE PENNSYLVANIA POWER & LIGHT COMPANY, ALLENTOWN, PA.

Boiler Outage, Water-Cooled, Hopper-Bottom Boilers

At the Pine Grove Steam-Electric Station one of the boilers has been equipped with a water-cooled hopper bottom only since May, 1928, and so the proportions given below for that boiler are for only a part of a year:

Boiler Station No.	8	9
Period reported on	June-Dec. inc., 1928	Year, 1928
Available hr., %	82.5	81.2
Repair hr., %	17.5	18.8
Operating hr.	3,725	5,843
Available hr.	4,238	7,129

The data given in the above tabulation are not strictly typical, even for these boilers. Due to their newness, considerable experimenting has been done and the outage caused by changes in furnaces, superheaters and soot blowers included, cannot be classed as outage for maintenance.

To date outages have been due chiefly to furnace maintenance, caused by failure of the arches on top of the Dutch ovens. Failure of the upper part of the back wall above the water-cooling surface also accounted for numerous outages. Soot blower misalignment, causing cutting of the tubes, was also responsible. Difficulties in obtaining the proper steam temperature from the superheaters caused the boilers to be taken out of service a number of times. In all, each of these boilers has averaged about one outage a month.

It should be possible this coming year to predict nearly all maintenance required, and schedule the outages accordingly. It is hardly likely, though, that it will be possible to keep these boilers available for service 95 per cent of the time which, as has been stated, is the goal for which to strive. However, as familiarity is gained with their peculiar characteristics, it may become possible to approach that very desirable goal.

Boiler Baffling, Shamokin Station

The results with cross baffling and parallel baffling are widely different and could not be called comparable. In addition to changing the baffling of two boilers, their furnaces have been changed to an entirely different type to utilize No. 4 buckwheat and culm, where previously No. 3 buckwheat was burned. The stokers also have been changed, and although of the same type are of later design. In all, combustion conditions have been improved, permitting operation with considerably less excess air due, largely, to reducing stratification of gases in the furnace throat.

To what extent flue gas temperature has been improved by the changed baffling is hard to say. Draft losses appear to be greatly decreased. Specific data for comparison are not available as these units have only been in service about two months and tests are under way at this time.

STIRLING BOILERS (5890 Sq. Ft.)

	Parallel Baffling		Cross Baffling	
Output, lb./hr.	26,400	39,800	27,000	37,000
CO_2, per cent	9.2	11.9	12.3	13.9
Flue gas temp., deg. fahr.	606	657	571	613
Draft, in. H_2O				
Furnace	—0.09	+0.05	+0.03	+0.01
Throat	—0.13	—0.05	+0.04	+0.01
Top 1st pass	....	....	+0.02	+0.05
Top 2nd pass	—0.18	—0.09	—0.01	—0.08
Bottom 2nd pass	—0.67	—0.62	—0.04	—0.10
Under damper	—0.85	—0.86	—0.08	—0.17

STATEMENT BY THE PHILADELPHIA ELECTRIC COMPANY, PHILADELPHIA, PA.

Soot Blower Tests

At the Chester Station a series of tests were run to determine the effect of economizer soot blowing on stack losses and also on scale or soot formation. To determine the

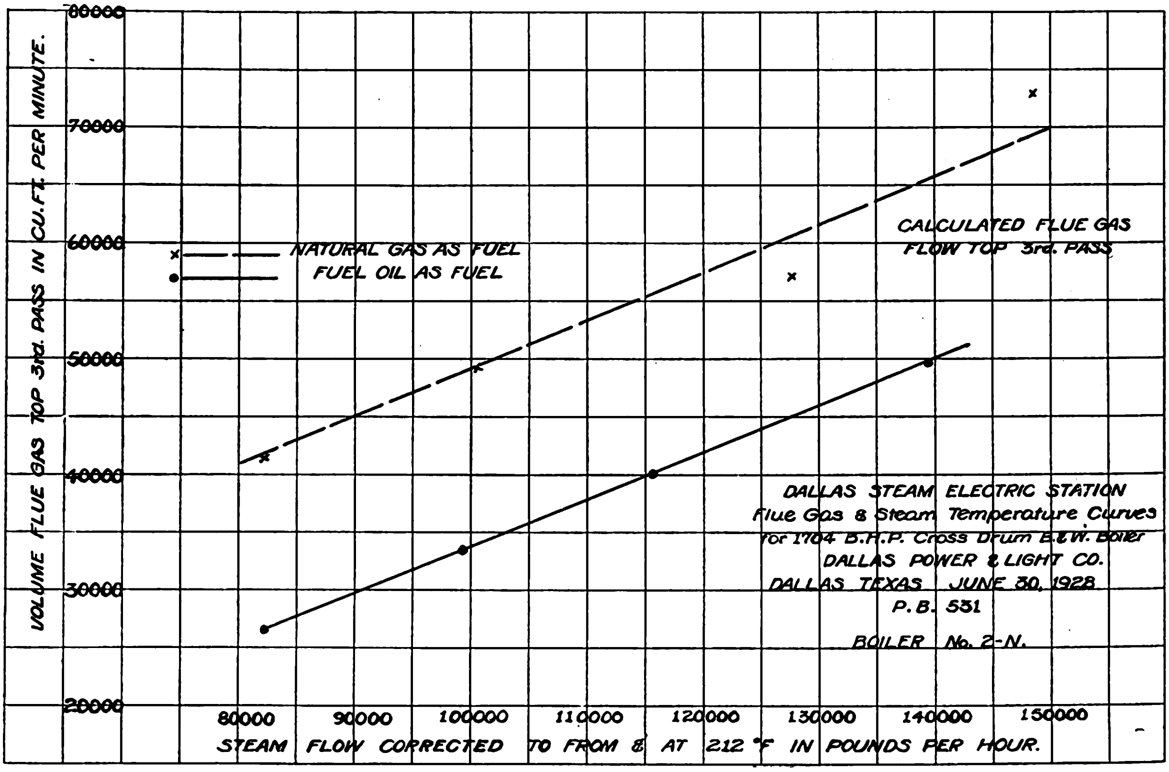


FIG. 21—FLUE GAS FLOW, 17,041 SQ. FT. BOILER, DALLAS POWER & LIGHT CO.

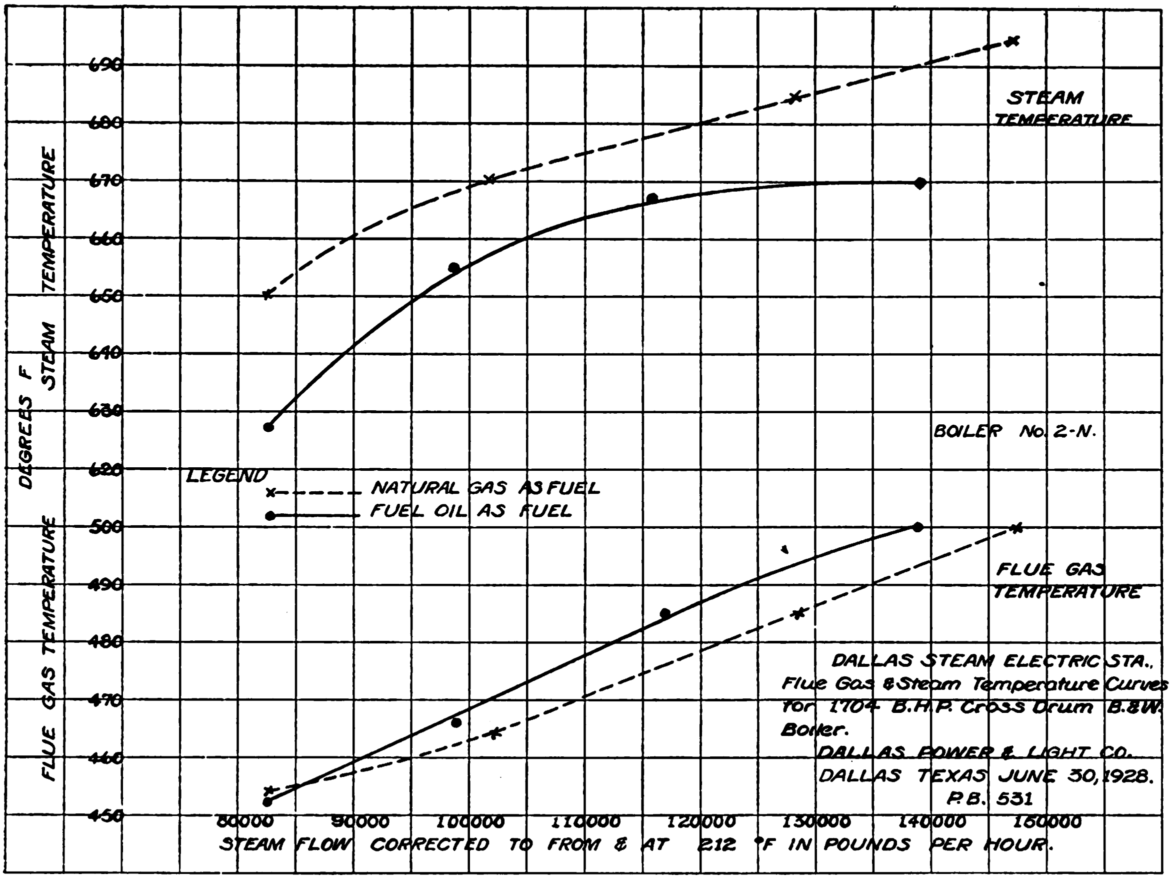


FIG. 22—FLUE GAS AND STEAM TEMPERATURES, 17,041 SQ. FT. BOILER, DALLAS POWER & LIGHT CO.

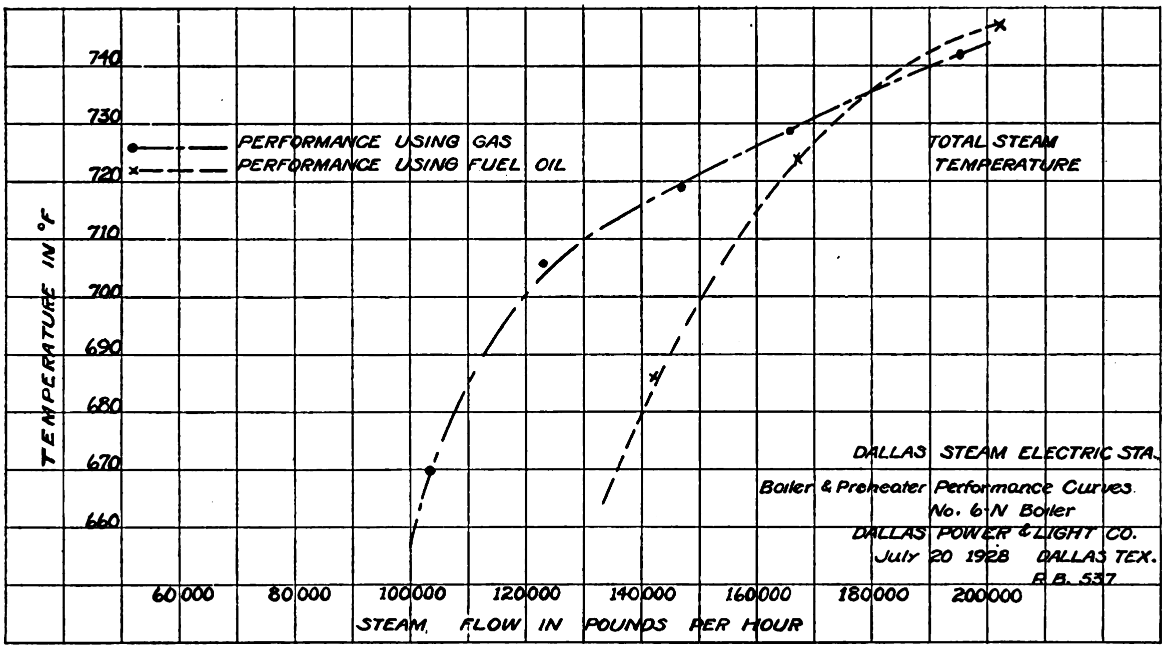


FIG. 23—STEAM TEMPERATURE, 14,220 SQ. FT. BOILER, DALLAS POWER & LIGHT CO.

effect on stack losses, tests were run on four boilers, two with soot blowers and two without. The tests were taken over a period of six months, during which readings were recorded on boiler exit gas temperature, economizer exit gas temperature, boiler feed temperature, steam temperature, air flow and CO_2. The data did not indicate any perceptible difference between the stack losses on the soot blown boilers and on those that were not blown.

To determine the effect of soot blowing on soot or scale formation on the economizer, two boilers were cleaned equally well. On one of these the soot was blown from the economizer, and the other was merely given the usual brushing during the regular inspection period. At the end of three months it was found that the operation of the economizer soot blowers made no appreciable difference in scale or soot formation.

Tests were also run at Delaware Station similar to those at Chester to determine the effect of economizer soot blowing on stack losses, and similar results were obtained; that is, it was found that economizer soot blowing caused no appreciable decrease in flue gas exit temperatures.

The test at Richmond Station was made to determine, in this case, the effect of superheater soot blowing on steam temperature. The steam temperatures on two boilers were recorded for several months, one boiler having a soot-blown superheater and the other not provided with a soot blower. The steam temperatures in the two cases were found to have approximately the same average, showing that there was no appreciable effect on the superheat due to soot blowing.

As a result of the investigations referred to above, soot blowers are not being used in connection with either the boilers, the superheaters or the economizers in the Chester, Delaware and Richmond Stations of the Philadelphia Electric Company.

STATEMENT BY THE SOUTHWESTERN GEOGRAPHIC DIVISION, N. E. L. A.

C. A. LILLY, *Chairman*

N. G. HARDY, *Vice-Chairman*

Comparative Results with Oil and Natural Gas as Fuel

There is some little difference in results obtained from superheaters when change is made from natural gas to oil, or vice versa. There is also some difference of opinion as to whether the superheat is greater with gas or oil firing. The probable reason for this apparent discrepancy is that the amount of superheat changes with the rating at which the boiler is operated, and the curves showing superheat with the two kinds of fuels burned where results are carefully taken over a wide range show that at some ratings superheat with gas firing is higher and at other ratings lower than with oil firing. It is, therefore, necessary to run a series of very careful tests over a wide range of ratings in order to obtain reliable data as to the superheat to be expected from any particular set of boilers.

The amount of superheat is dependent upon the amount of excess air, the location of superheating surface, the presence or lack of water wall surface and the rating at which the boiler is being operated. The volume of the products of combustion from natural gas is greater than from fuel oil for any given rating when the percentage of excess air is kept the same.

Fig. 21, 22 and 23 show curves obtained from a series of tests conducted by the Dallas Power & Light Company on two types of boilers with oil and natural gas burned under each of them. Extreme care was taken during these tests to maintain stable conditions, and the boilers were operated as nearly as possible under similar conditions. The excess air was approximately 15 per cent with each fuel, and the feed water temperatures were kept as closely as possible to the same values. The gas was burned with Forney gas burners, manufactured by the Forney Combustion & Engineering Company, Dallas, Texas, and the oil with B. & W. San Diego type oil burners. The description of the two boilers tested is as follows:

Boiler No. 2N is a B. & W. cross drum water tube boiler, 22 tubes high, having 17,041 sq. ft. of water heating surface, baffled for 3 passes. There is installed a 2361 sq. ft. B. & W. interdeck superheater located above the 6th row of tubes. The setting is of the ventilated fire brick type.

Boiler No. 6N is a B. & W. cross drum water tube boiler having 14,220 sq. ft. of water heating surface with water walls having a surface of 609 sq. ft. The 3210 sq. ft. superheater is of the interdeck B. & W. type located above the 9th row of tubes.

Table V gives the data obtained from tests of these boilers.

TABLE V

TEST OF BOILER NO. 2N

Natural Gas Firing

Boiler output, lb. per hr......	82,500	100,500	127,500	147,000	......
Steam temperature, °F.......	650	671	685	695	......
Flue gas temperature, °F......	454	465	484	500	......
Vol. flue gas top 3rd pass, c.f.m.	41,750	48,500	57,500	73,500	......

Fuel Oil Firing

Boiler output, lb. per hr......	82,000	98,500	116,500	139,000	......
Steam temperature, °F.......	628	655	667	670	......
Flue gas temperature, °F......	452	466	485	500	......
Vol. flue gas top 3rd pass, c.f.m.	26,000	33,500	40,000	48,500	......

TEST OF BOILER NO. 6N

Natural Gas Firing

Boiler output, lb. per hr......	103,500	123,000	147,000	166,000	195,000
Steam pressure, lb. per sq. in..	337	347	347	344	354
Boiler efficiency with preheaters, %...............	81.7	78.2	81.2	77.9	80.1
Efficiency increase due to preheaters, %...............	3.9	3.9	5.9	6.1	5.9
Feed water temperature, °F...	308	290	294	321	317
Total steam temperature, °F..	607	706	719	729	742

Fuel Oil Firing

Boiler output, lb. per hr......	112,500	142,000	165,000	220,200	......
Steam pressure, lb. per sq. in..	357	350	354	357	......
Boiler efficiency with preheaters, %...............	84.9	81.2	84.8	84.0	......
Efficiency increase due to preheaters, %...............	5.5	5.6	5.6	5.9	......
Feed water temperature, °F...	302	302	311	316	......
Steam temperature, °F.......	......	686	724	747	......

Fuel Analysis

GAS		*OIL*	
Methane, %.............	94.4	Carbon, %............	85.83
Ethane, %...............	2.9	Hydrogen, %..........	12.40
Carbon dioxide, %........	0.2	Oxygen, %............	0.80
Oxygen, %...............	0.2	Nitrogen, %..........	0.21
Nitrogen, %.............	2.3	Sulphur, %...........	0.70
B.t.u. per cu. ft...........	1,000	B.t.u. per lb...........	19,346

Products of Combustion

CO_2....................	10.0	CO_2..................	13.8
CO_2+O_2................	13.6	CO_2+O_2..............	16.8
CO_2+O_2+CO...........	13.6	CO_2+O_2+CO..........	16.8

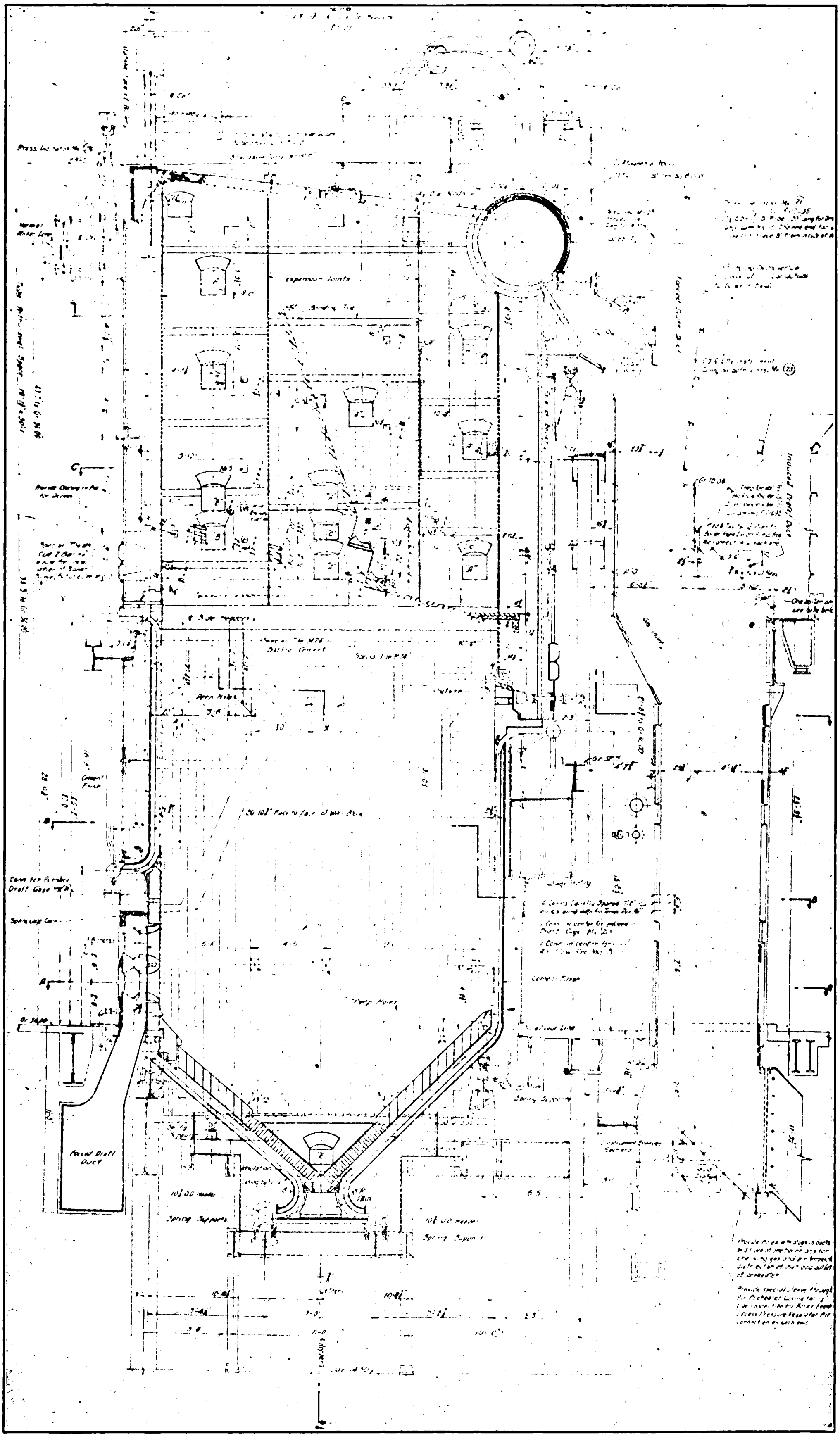

Expansion Joints
Forced Draft Duct
Induced Draft Duct
Spring Supports
10" O.D. header
Spring Supports

FIG. 24—TYPICAL CROSS-SECTION OF BOILERS 49, 50 AND 51, LONG BEACH STEAM PLANT NO. 3, SOUTHERN CALIFORNIA EDISON CO.

TABLE VI

SUMMARY OF OPERATION RESULTS, BOILERS 49, 50 AND 51, JUNE 20, 1928, TO JAN. 15, 1929—LONG BEACH STEAM PLANT, SOUTHERN CALIFORNIA EDISON CO.

	June	July	August	Sept.	Oct.	Nov.	Dec.	Jan.
Elapsed days	11	31	31	30	31	30	31	15
Hr. operated: Boiler 49	53	215	498	603	715	622	682	360
Boiler 50	73	209	519	600	701	696	643	360
Boiler 51	47	215	527	615	729	632	700	360
Total feed water, M lb.	18,857	159,159	436,262	495,803	602,515	588,056	669,465	366,908
Average output, M lb. per hr	109	249	283	273	281	302	345	340
Lb. of water per cu. ft. of gas	0.849	0.917	1.001	0.992	1.002	0.998	1.009	0.993
*Steam pressure at turbine throttle, lb. per sq. in. gage	409	404	403	409	402	400	401	401
*Steam temperature at turbine throttle, °F.	661	688	693	682	682	687	706	716
*Feed water temperature, °F.	298	354	357	366	378	376	395	375
*Overall efficiency boiler, superheater, air heater and water-cooled furnace and piping, %	74.86	84.86	84.57	82.90	82.27	82.48	83.73	84.67

*Note: Operating records are of steam temperature and pressure at turbine throttle and feed water temperature at outlet of 5th stage heater. All heat losses in steam and feed water piping between these points and the boiler are charged to the boiler

STATEMENT BY THE SOUTHERN CALIFORNIA EDISON COMPANY, LOS ANGELES, CAL.

Operation of Three 34,164 Sq. Ft. Cross Drum Boilers

Early in 1928 three 34,164 sq. ft. B. & W. cross drum boilers were installed with the first unit in the new Long Beach Steam Plant No. 3. These boilers have been in operation about 7 months, supplying steam for a 94,000 kw. turbine-generator unit. The unit has carried gross loads of 110,000 kw., the steam for which was generated by the three boilers. At the present time no spare boiler is provided.

The boilers (Fig. 24) are 51 tubes wide and 23 tubes high. The tubes are 4 in. diameter, No. 6 gage (0.203 in.); the drums are 60 in. diameter. The furnaces are directly below the boilers, and are completely inclosed by water-cooled walls. The burners are combination gas and oil, manufactured by the Peabody Engineering Corporation. Twenty burners are installed in each furnace. The furnace volume is 19,800 cu. ft., about 14,000 cu. ft. of which is above the lower burners. The lower portion of the furnace forms a hopper for possible future pulverized coal burning. The water-cooled walls are of the Bailey type, manufactured by the Fuller Lehigh Company, constructed of refractory-faced cast iron blocks, cemented and bolted to the water-cooling tubes. Each B. & W. air heater contains 2176 tubes, 2½ in. diameter and 36 ft. long. The total external heating surface is 51,232 sq. ft.

The superheaters are convection type, three-pass, quadruple deck and located immediately above the lower deck of boiler tubes in the first pass. The tubes in the first two passes of the superheater are of steel. The tubes in the third pass are of seamless Enduro S-188, a chrome nickel steel alloy. The contract heating surface of each superheater was 6553 sq. ft., of which only 5823 sq. ft. was initially installed. It is intended that the full amount of heating surface shall be installed as soon as the boilers can be released for this purpose.

Each boiler is served by two forced draft fans, each driven by a 140 h.p. type BTS variable speed motor, and one induced draft fan, driven by a 300 h.p. type BTS variable speed motor. The fans are manufactured by the Green Fuel Economizer Company and the motors by the General Electric Company. The capacity of each forced draft fan is 53,000 cu. ft. per minute, and the capacity of the induced draft fan is 180,000 cu. ft. per minute. The maximum forced draft air pressure is 15 in. of water, and the maximum induced draft fan pressure is 7 in. of water. To insure tightness at these pressures the flues and forced draft air ducts are all welded.

The maximum allowable boiler operating pressure is 460 lb. All joints in the feed water piping on the boiler side of the valves nearest the boiler are Sargol, welded for tightness, as are all steam joints, including the joint between the safety valves and the boiler drum. All joints in the water-cooled furnace walls, except where tubes are rolled into headers and drums, are welded. By this precaution of welding all joints for tightness, the danger of being forced to shut down one of these large boilers because of blown gaskets is minimized.

Complete automatic combustion control manufactured by the Bailey Meter Company is used. In addition to the Bailey boiler meter and multipoint draft gage, each boiler gage board is equipped with a Foxboro water level recorder, a flow meter for feed water, a flow meter for fuel oil, a Westcott gas flow meter for fuel gas, a Mono CO_2 and CO recorder, and a Leeds & Northrup six-point temperature recorder. The water and oil flow meters are Venturi type, manufactured by Builders Iron Foundry. Flat gage glasses are used in the water column gages, located 49 ft. above the floor.

The summary of operation results, boilers 49, 50 and 51 for the period from June 20, 1928, to Jan. 15, 1929, in Table VI, presents a summary of operation data from the date of placing these boilers in service to the date of this report (Jan. 16, 1929).

The weighted average evaporation per boiler for the period reported was 293,000 lb. per hr., or 262 per cent of builder's rating. The maximum evaporation for one hour was 433,000 lb. of steam, or 386 per cent of builder's rating. The longest continuous operation period for one boiler was 2601 hr.

No unusual operating conditions developed during the seven months that these boilers have been in practically continuous service. Sudden changes in load cause considerable changes in water level in the boiler drum, but not great enough to cause concern. The apparent reliability of the water level recorders has contributed to this assurance. Fluctuations in output from 200,000 to 325,000 lb. of steam per hr., cause 4 in. fluctuation in water level. An accidental closure of the main steam lead from boiler No. 49 on Oct. 20, 1928, with a sudden drop in output from 310,000 lb. of steam per hr. to zero, dropped the water level to 1.5 in., with a momentary swing up to 14.5 in. when the valve was opened. Of course, the safety valves were blowing during this period, although the fuel flow, which was gas, was immediately cut to zero.

Tested moisture contents in the saturated steam line were found as follows:

Output, lb./hr.	100,000	200,000	300,000
Water in glass, in.	Moisture, per cent		
5	0.10	0.12	0.13
10	0.13	0.16	0.18
15	0.16	0.21	0.24
20	0.20	0.25	0.30
Highest observed value with 20 in. in glass, per cent	0.20	0.29	0.36

The realized steam temperature has been lower than anticipated. It is hoped, however, that the manufacturer's guarantee of 750 deg. fahr. total temperature at a steam flow of 350,000 lb. per hr., or 322 per cent rating (10.8 k-B.t.u. per sq. ft. per hr.) will be realized when all of the superheater surface has been installed. The pressure drops through the superheater have conformed closely to the manufacturer's predictions.

Burning gas with about 11.5 per cent CO_2 and operating the boiler at about 320 per cent (10.7 k-B.t.u. per sq. ft. per hr.) rating, the following temperatures are observed:

Gases leaving boiler, °F	510
Gases leaving air heater, °F	295
Air entering air heater, °F	100
Air leaving air heater, °F	385

Under these conditions steam is delivered to the turbine throttle at 400 lb. gage pressure, 709 deg. fahr. total temperature, with feed water to the boiler at 388 deg. fahr. The feed water is heated by steam extracted from four stages of the turbine.

Statement by the Texas Electric Service Company, Dallas, Texas

Comparative Results with Oil and Natural Gas as Fuel, Wichita Falls Steam Electric Station

A series of tests were recently run on two Edge Moor 5870 sq. ft. boilers for the purpose of determining the effect on the temperature rise and pressure drop across the convection and radiant superheaters at various ratings when burning either gas or oil. Fig. 25 shows a vertical section of these boilers, the general arrangement being the same for both of them. In No. 6 boiler short U bends have been substituted for the original convection elements, and the radiant superheater is of two pass design. In No. 7 boiler the original Foster convection superheater has been retained, and the radiant superheater is single pass. Fig. 26 shows relative temperature rises and pressure drops through superheaters on boiler No. 6 when burning oil and gas. Fig. 27 gives similar data for No. 7 boiler. Table VII summarizes the pressures, temperatures and combustion conditions for each test.

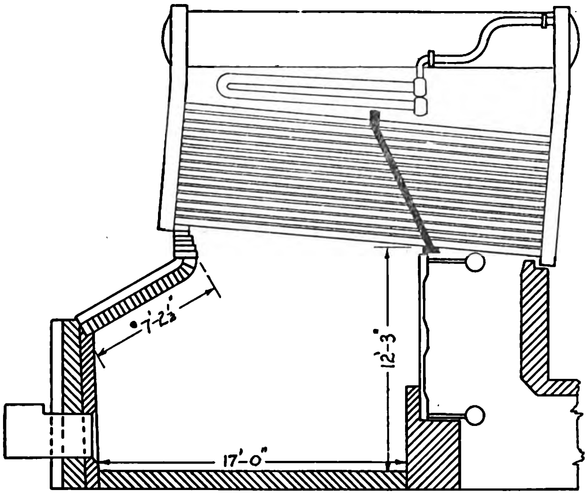


FIG. 25—5870 Sq. Ft. Boiler, Wichita Falls Steam Electric Station, The Texas Electric Service Co.

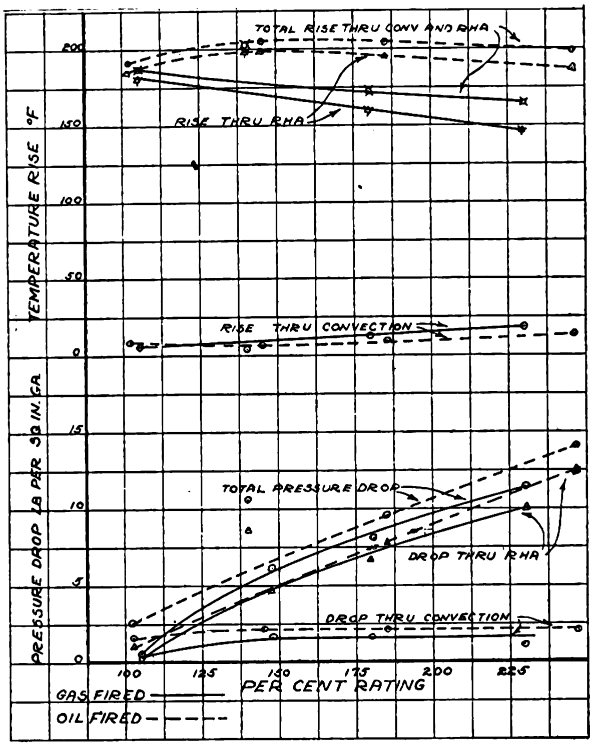


FIG. 26—Boiler No. 6, Superheater Characteristics, Wichita Falls Steam-Electric Station, The Texas Electric Service Co.

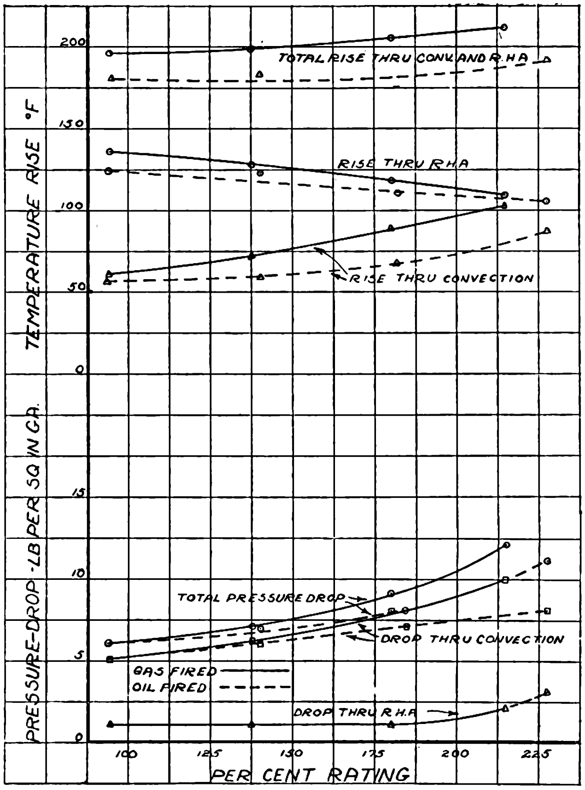


FIG. 27—Boiler No. 7, Superheater Characteristics, Wichita Falls Steam-Electric Station, The Texas Electric Service Co.

TABLE VII

TEXAS ELECTRIC SERVICE CO., WICHITA FALLS GENERATING STATION, SUPERHEATER TEST

Test No.	% Rating	Pressure Lb. per Sq. In. Gauge							Temperature, Deg. Fahr.							Furnace Draft	Last Pass Draft	Gas Analysis		
		Feed Water	Boiler Outlet	Conv. Outlet	Conv. Press. Drop	R.H.A. Outlet	R.H.A. Press. Drop	Total Drop	Boiler Feed	Boiler Outlet	Conv. Outlet	Rise Through Conv.	R.H.A. Outlet	Rise Through R.H.A.	Total Rise			CO_2	O_2	CO
Boiler No. 7—Gas Fired																				
1	214	276	248	238	10	236	2	12	211	405	507	102	616	109	211	0.26	0.65	9.6	3.4	0.4
2	180	278	246	238	8	237	1	9	212	405	493	88	610	117	205	0.16	0.42	9.8	3.3	0
3	138	277	247	241	6	240	1	7	211	405	476	71	603	127	198	0.08	0.22	10.1	3.3	0
4	94	277	248	243	5	242	1	6	207	405	465	60	600	135	195	0.02	0.10	10.2	3.6	0
Boiler No. 7—Oil Fired																				
1	227	282	251	243	8	240	3	11	211	407	493	86	598	105	191	0.21	0.57	12.9	4.2	0
2	182	278	250	243	7	242	1	8	212	406	473	67	583	110	177	0.09	0.26	14.2	2.5	0
3	140	269	248	242	6	241	1	7	211	405	463	58	587	124	182	0.01	0.09	14.3	2.6	0.1
4	95	271	250	245	5	244	1	6	212	406	462	56	586	124	180	0.04	0.10	13.5	3.3	0.1
Boiler No. 6—Gas Fired																				
1	230	290	254	253	1	242.5	10.5	11.5	210	407	424	17	570	146	163	0.20	0.66	10.1	3.2	0
2	181	285	250.5	249	1.5	243	6.5	8.0	212	406	418	12	577	159	171	0.10	0.37	10.1	3.3	0
3	147	285	251	249.5	1.5	245	4.5	6.0	211	406	409	3	608	199	202	0.10	0.24	10.6	2.4	0
4	105	268	252	251.7	0.3	251.5	0.2	0.5	211	406	411	5	592	181	186	0.14	0.27	9.0	6.0	0
Boiler No. 6—Oil Fired																				
1	247	288	250.5	249	1.5	236.5	12.5	14.0	212	406	418	12	604	186	198	0.18	0.66	13.5	3.7	0
2	186	281	249	247	2	239.5	7.5	9.5	212	405	414	9	608	194	203	0.06	0.26	14.1	2.8	0
3	145	281	249	247	2	238.5	8.5	10.5	210	405	411	6	609	198	204	0.04	0.18	14.0	3.2	0
4	102	272	250	248.5	1.5	247.5	1.0	2.5	212	406	412	6	596	184	190	0.13	0.24	11.0	6.9	0

Tests were run on each boiler at four different ratings. Excess air was kept as low as possible during all tests. With the low rating on oil only the two center burners could be used, and considerable excess air passed through the two outside burners. The curves, Fig. 26 and 27, show the superheat obtained divided between rise in convection and radiant superheaters.

Superheater Test

Boiler No. 6 is an Edge Moor 3 drum, 2 pass boiler, 250 lb. pressure, 5870 sq. ft. There are 263 tubes, 4 in. by 20 ft. arranged 18 tubes wide by 15 tubes high.

The Foster Wheeler convection superheater is located at the top of the first pass and consists of short U bends to replace the original convection superheater elements. There are 19 U bends with an approximate area of 48 sq. ft. each.

The Foster Wheeler radiant superheater, 2 pass type, is located at the furnace rear wall and consists of 20 elements, 4 in. by 111 in., or an area of 62 sq. ft. A curtain wall of brick is 27 in. high above the bottom of the elements, leaving 47 sq. ft. of superheater exposed.

Furnace dimensions are 10 ft. 5 in. wide by 17 ft. deep, with an average height of 12 ft., making the furnace volume 2400 cu. ft.

There are four Duquesne low-pressure gas burners located in a Dutch oven at the front of the furnace. For emergency oil burning a Leahy steam atomizing oil burner is inserted in center of each Duquesne gas burner.

Boiler No. 7 is the same as boiler No. 6. The Foster Wheeler convection superheater with cast iron external surface is located at the top of the first pass. There are 22 U shaped elements of 2 in. tube, 20 ft. long overall.

The Foster Wheeler radiant superheater, single pass type, located at the rear wall of the furnace, consists of 12 elements, 4 in. by 91 in., or an area of 30 sq. ft. A curtain wall of brick 15 in. high above the bottom of the elements leaves 25 sq. ft. of superheater exposed. Furnace and burners are the same as in boiler No. 6.

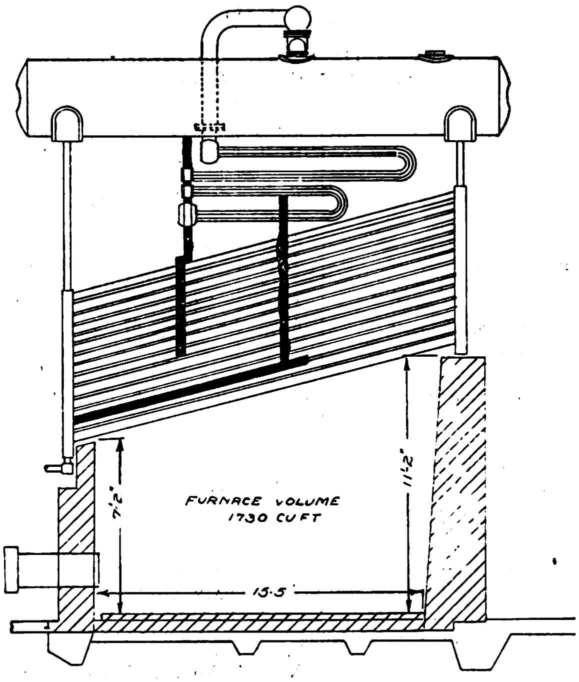


FIG. 28—6000 SQ. FT. BOILER, WACO STATION, TEXAS POWER & LIGHT CO.

STATEMENT BY THE TEXAS POWER & LIGHT COMPANY, DALLAS, TEXAS

Effect of Variation in CO_2 Content of Flue Gas on Superheat, Waco Steam Electric Station

In the 1923 Report of the Subcommittee on Boilers, Superheaters and Economizers, the effect of variation in CO_2 content of flue gas on superheat in a 6000 sq. ft. B. & W. boiler was reported. Recently a number of tests were run on a duplicate boiler arranged for gas firing for the purpose of determining the effect on superheat temperature when varying the CO_2 in the flue gas. Fig. 28 shows a section of this boiler as arranged at present. It is a 6000 sq. ft., 3 drum B. & W. boiler with 294 tubes, 14 tubes high by 21 tubes wide. The B. & W. superheater is a double loop convection type with 1277 sq. ft. of heating surface located at the top of the first pass. Fig. 29 shows the variation in superheat, flue gas temperature and draft loss with variation in CO_2 at different ratings.

For comparative purposes the superheat data given in the oil burning tests mentioned above have been included in Fig. 29. In comparing these results for oil firing, due consideration should be given to the change in furnace and baffle arrangement from that shown in Fig. 342, p. 252 of the 1923 Report.

Operation of Three 18,750 Sq. Ft. Cross Drum Boilers, Trinidad Station

Table VIII gives the history of boiler operation at Trinidad for 1928.

During the past year considerable outage has been due to soot blower maintenance and troubles, superheater troubles and special jobs. Because of the high cost of soot blower maintenance and the increased length of outage for soot blower inspection and repair, their use has been discontinued

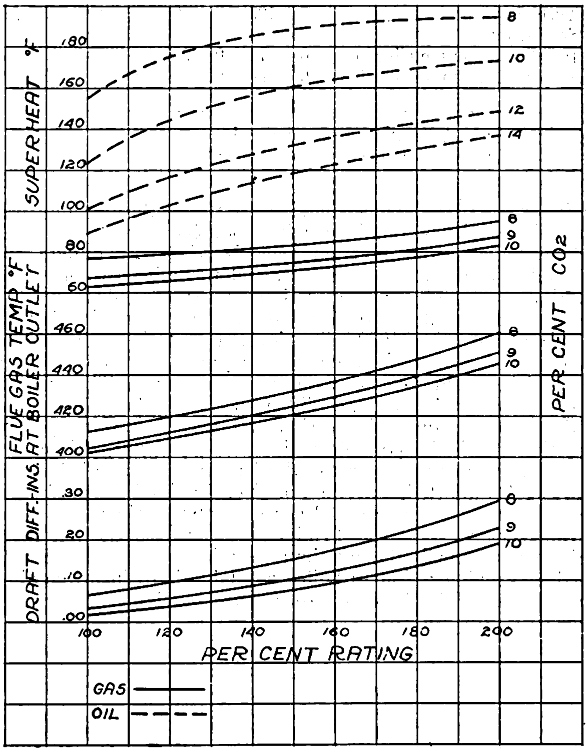


FIG. 29—EFFECT OF CO_2 ON SUPERHEAT, FLUE GAS TEMPERATURE, AND DRAFT LOSS, WACO STATION, TEXAS POWER & LIGHT CO.

TABLE VIII

BOILER OPERATION DATA, TRINIDAD STEAM ELECTRIC STATION, TEXAS POWER & LIGHT CO.

Year 1928	Boiler No. 1	Boiler No. 2	Boiler No. 3	Boiler No. 4
1. Period, hr.	8,784	8,784	6,784	8,784
2. Service, hr	6,746	5,509	5,890	5,450
3. Demand, hr.	6,746	5,509	5,890	5,456
4. Idle hr	2,038	3,275	2,894	3,334
5. Reserve hr. (hot or cold)	718	804	1,704	1,386
6. Hr. crippled for repair	1,320	2,471	1,190	1,948
7. Service demand factor $\frac{\text{Item 3}}{\text{Item 1}}$	76.8%	62.7%	67.1%	62.1%
8. Unit operation factor $\frac{\text{Item 2}}{\text{Item 1}}$	76.8%	62.7%	67.1%	62.0%
9. Max. possible unit operation factor $\frac{\text{Item 2}+\text{Item 5}}{\text{Item 1}}$	85.0%	71.9%	86.5%	77.8%

CLASSIFICATION OF REPAIR HOURS

	Boiler No. 1		Boiler No. 2		Boiler No. 3		Boiler No. 4	
	A	B	A	B	A	B	A	B
1. Scheduled inspection and mechanical adjustments	0	648	0	780	0	590	0	1082
2. Brickwork	0	264	0	237	0	168	0	336
3. Soot blower maintenance and troubles	0	48	0	1125	0	48	0	0
4. Superheater troubles	0	0	0	0	0	0	6	145
5. Turbining tubes	0	192	0	0	0	192	0	192
6. Special Jobs:								
Installing water sampling line.	0	72	0	233	0	96	0	85
Stopping leaks in steam baffle.	0	96	0	96	0	96	0	96

Note: Column A is outage during demand.
Column B is outage during no-demand.

in favor of a hand lance, in view of the negligible improvement in efficiency obtained with soot blowers.

The table shows that on a basis of boiler outage for scheduled inspections, brickwork and turbining of tubes, the maximum possible unit operation factor ranged from 87.4 per cent for boiler No. 1 up to 89.2 per cent for boilers No. 3 and 4. For 1929 operations, a tentative schedule of two weeks' outage in each four months' period has been set which would give an availability factor of 88 per cent.

It is believed that the difficulties have been overcome which made frequent inspection and long outage necessary, and that it will be possible to increase the length of service between outages and decrease the length of outage below the two weeks allotted, but do not feel justified in predicting better than an average of 88 per cent at this time.

Boiler capacity at the Trinidad Station is such that three boilers will supply the maximum station load, and the only need of keeping a fourth boiler available is to insure against curtailment of load in case of unexpected boiler failure.

STATEMENT BY THE UNITED GAS IMPROVEMENT COMPANY, PHILADELPHIA, PA.

Deepwater Station

The Deepwater Station, which is now in the process of construction, will contain six 1400 lb. boilers, each of which will have 9000 sq. ft. of heating surface. Two will be erected with reheaters installed having 23,562 sq. ft. of surface. The steam temperature delivered by the superheaters will be 725 deg. fahr., and that delivered by the reheaters will be 750 deg. fahr. The four standard boilers will have 18,326 sq. ft. of economizer surface, and the reheat boilers 4765 sq. ft. of economizer surface. All boilers will be equipped with plate type preheaters containing 42,693 sq. ft. of surface, from which the outlet temperature is expected to be about 460 deg. fahr. at maximum rating.

The boilers will be fired with pulverized coal. Three boilers, having the bin system and Couch burners, will be equipped with bare tube water walls of 2540 sq. ft. heating surface, consisting of vertical tubes backed up with fire brick. The other three boilers, fired with the unit system and Fuller Lehigh cross tube burners, will contain 2755 sq. ft. of water walls of the same design. The furnace volume will be 19,080 cu. ft., and the maximum liberation 22,640 B.t.u. per cu. ft. The firing system for the three boilers on the bin system will be manufactured by the Combustion Engineering Corporation. The other boilers will be fired with the Fuller Lehigh unit system.

The maximum steaming capacity of the four standard boilers will be 331,000 lb. of steam per hr. each, and that of each reheat boiler will be 290,000 lb. per hr.

STATEMENT BY THE WEST PENN ELECTRIC COMPANY, 14 WOOD ST., PITTSBURGH, PA.

Cleaning of Economizers, Springdale Power Station

Being in doubt as to what method of cleaning to employ on the economizers, only one unit, No. 7, was equipped with soot blowers. An element was placed at one end, having nozzles its full length. In the opposite end two elements were installed, one to clean the tubes in the upper section, the other, those of the lower section. These elements were operated every 8 hr. Inspection of this unit when taken out of service for general cleaning showed the ash to be packed between the tubes and against the headers in such quantities that removal was necessary with hooks and scrapers.

A washer was then installed on No. 10 unit. Test results proved to be very satisfactory, and the remaining units were so equipped, with the exception of No. 7. Unit No. 7 was left as originally installed for comparison, due to the trouble which was being experienced at other stations from leakage at the tube roll.

From September, 1925, to March, 1926, each unit was given a daily washing of three minutes for each of the 8 elements, the boiler operating at approximately 200 per cent (6.7 k-B.t.u. per sq. ft. per hr.) rating.

Tests made at this time showed that weekly washings of one hour each with all elements washing were more efficient than the daily washings, and could be done during the time the boiler was banked to wash the superheater. The units were found much cleaner when taken out of service for general repairs, and that the time required for general cleaning of the boiler was reduced one day. The curve, reproduced in Fig. 30, shows the results obtained.

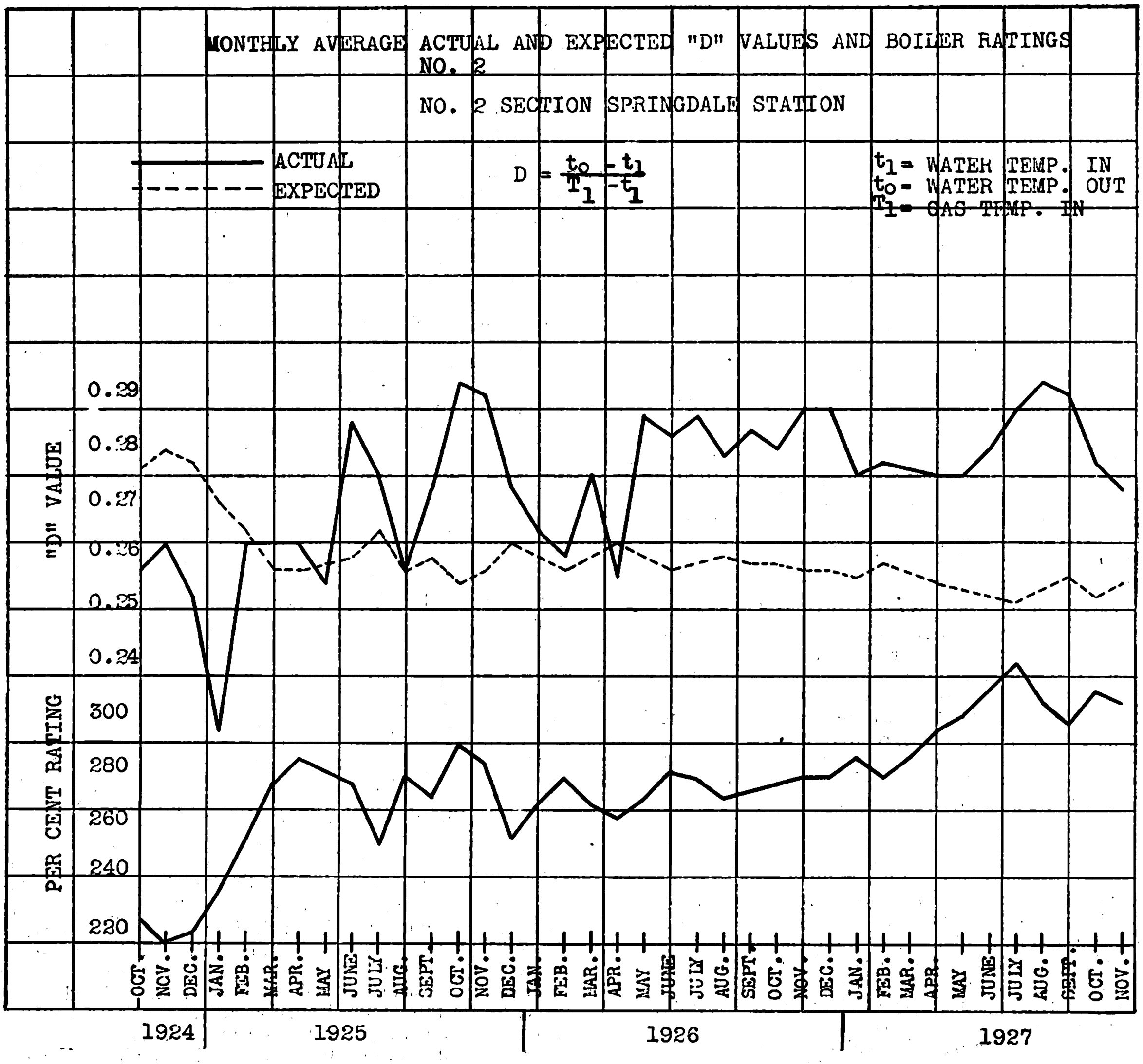


FIG. 30—EFFECT OF ECONOMIZER WASHING, THE WEST PENN ELECTRIC CO.

MANUFACTURERS' STATEMENTS

The Prime Movers Committee does not accept responsibility for any manufacturers' statements in this report.

BOILERS AND WATER WALLS

STATEMENT BY THE BABCOCK & WILCOX COMPANY, 85 LIBERTY ST., NEW YORK, N. Y.

1928 *Design of Stirling Boiler*

With developments in fuel burning equipment, increased furnace sizes and furnace wall protection methods, rates of B.t.u. release per ft. of furnace width became possible that were out of proportion to the amount of heating surface per foot of such width in the earlier designs of Stirling boilers.

With increased rates of combustion, draft losses through the boiler increased correspondingly, but such losses were not a serious factor as economizer, air heater or combination installations came more and more into common use. With lower exit temperatures and increased total draft requirements, natural draft stacks became impracticable, and the use of induced and forced draft fans became a necessity.

To meet these conditions the 1928 design of Stirling boiler was developed. The amount of boiler heating surface per ft. of furnace width was increased over earlier designs some 60 per cent. The increased amount of heating surface per ft. of furnace width, besides a baffle arrangement for making the gases hug the tubes more closely particularly in the second pass, tends toward increased efficiency.

The superheater location relative to the furnace and first baffle results in a flatter superheat curve than in the earlier classes. The new location makes the superheater, in effect, a combination convection and radiation superheater in that it "sees" the furnace through the tube lanes.

The arrangement of tubes relative to the various drums and the number and arrangement of steam and water circulators is such that the new design is able to operate with a higher degree of concentration without priming.

Slagging

The problem of slag screen design and arrangement of boiler tubes in the first pass is very difficult to crystallize in the form of certain definite recommendations because of the number of variable factors which tend to produce slagging. Different fuels and different methods of firing may be expected to cause varying degrees of difficulty, ranging from complete freedom from slag with natural gas to a maximum of slagging with pulverized coal, high in ash of low fusion point. The most trouble occurs with pulverized coal firing because of the higher percentage of ash in suspension. High ratings sustained for long periods and low excess air are other conditions which aggravate boiler tube slagging.

Since high furnace temperatures are necessary for best efficiency and since this aggravates slagging, the problem is one of reducing temperatures to the zone between the minimum temperature for complete combustion and the maximum temperature entering the boiler tubes which will not create troublesome slagging. Factors which must be taken into account are: design of slag screen, arrangement of boiler and superheater tubes, heat liberation in the furnace (particularly above the top of the burners), heat absorbed by radiation, burner performance, size and velocity of ash particles impinging on the tubes.

Close tube spacing in the lower rows makes it easier for formations to build out between tubes and close the gas passages. Close tube spacing results in higher gas velocity, so that a particle of ash does not remain in "sight" of cold tube surface as long as at lower velocity and hence does not have as much time to be relieved of heat by radiation. Certain types of boilers have small tubes grouped close together, the groups being situated relatively far apart. Calculations may show that the total area between tubes is sufficient for a moderate gas velocity, but the actual velocity may be much higher, due to ash and slag quickly filling up the narrow spaces between the tubes in the several nests. High velocity may carry molten slag particles some distance into the pass. A closely set arrangement of superheater tubes will form the final barrier which will intercept slag and ultimately close off the passage.

Some typical arrangements of slag screens with B. & W. boilers are shown in Fig. 31. A satisfactory slag screen has been developed for a Stirling boiler by bending every other front tube of the front bank in such manner that alternate tubes of this row are in a different plane crosswise of the setting, forward of their normal position.

B. & W. Cross Drum Steam Baffles

With cross drum B. & W. boilers operating at capacities up to 150,000 lb. of steam per hr., satisfactory steam quality is obtained with a vertical baffle plate placed somewhat back and away from the steam discharge tubes or circulators. With this construction, steam and water coming into the drum from the circulators are separated beneath the baffle, in the travel lengthwise of the drum under the baffle, and again in the partial lengthwise travel of the drum outside the baffle in the reverse direction.

As capacities are increased materially above this output, the high steam velocities prevent proper separation and actually result in picking up water from the surface. It has, therefore, been necessary to change this standard type of design. The fundamental change was the substitution of transverse flow for longitudinal flow of steam in the drum. The method of accomplishing this is shown in Fig. 32.

Over the steam circulators is installed a set of shutter baffles, the function of which is largely to dissipate the velocity of the incoming steam and water and to separate most of the water from the steam. Outside of the shutter baffles is a typical vertical baffle with an inclined top portion; above this inclined portion another inclined baffle plate forms a channelway for the steam flow. Above this, a box type dry-pan replaces the old round dry-pipe, giving considerably more headroom. This baffling is now standard for capacities in excess of 150,000 lb. per hr.

Sulphate-Carbonate Ratio

The question of sulphate-carbonate ratio has been raised in connection with the possibility of embrittlement in boilers operating at pressures above those considered at the time the A. S. M. E. Code of "Suggested Rules for the Care of Power Boilers" was issued. This company cannot state specifically what ratio would be required to insure absence of caustic embrittlement at high pressures. Further, there are little data on which to base a conclusion, since the mechanism of caustic embrittlement has never been demonstrated. It would, therefore, appear that there was little to do other

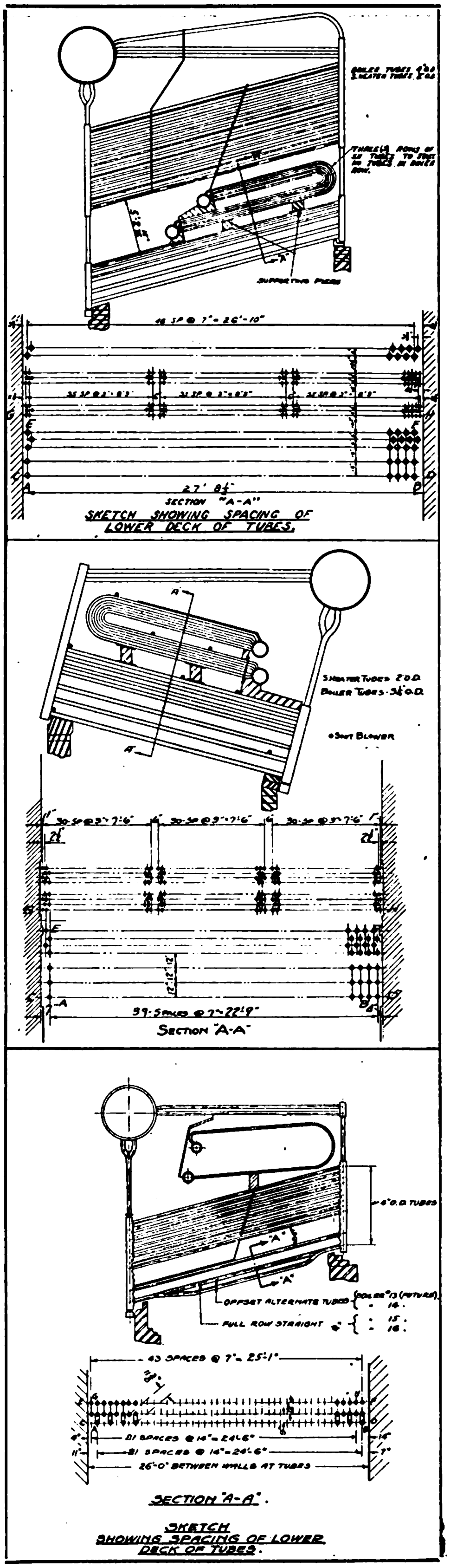

SUPPORTING PIECES
"A"
46 SP @ 7" = 26'-10"
27' 8½"
SECTION "A-A"
SKETCH SHOWING SPACING OF LOWER DECK OF TUBES.
A'
SHEATER TUBES 2" O.D.
BOILER TUBES 3¼" O.D.
SOOT BLOWER
30 SP @ 3" = 7'-6"
39 SPACES @ 7" = 22'-9"
SECTION "A-A"
4" O.D. TUBES
"A"
OFFSET ALTERNATE TUBES
FULL ROW STRAIGHT
BOILER 13 (FUTURE)
14
15
16
43 SPACES @ 7" = 25'-1"
21 SPACES @ 14" = 24'-6"
21 SPACES @ 14" = 24'-6"
26'-0" BETWEEN WALLS AT TUBES
SECTION "A-A".
SKETCH
SHOWING SPACING OF LOWER DECK OF TUBES.

FIG. 31—SLAG SCREEN ARRANGEMENTS, THE BABCOCK & WILCOX CO.

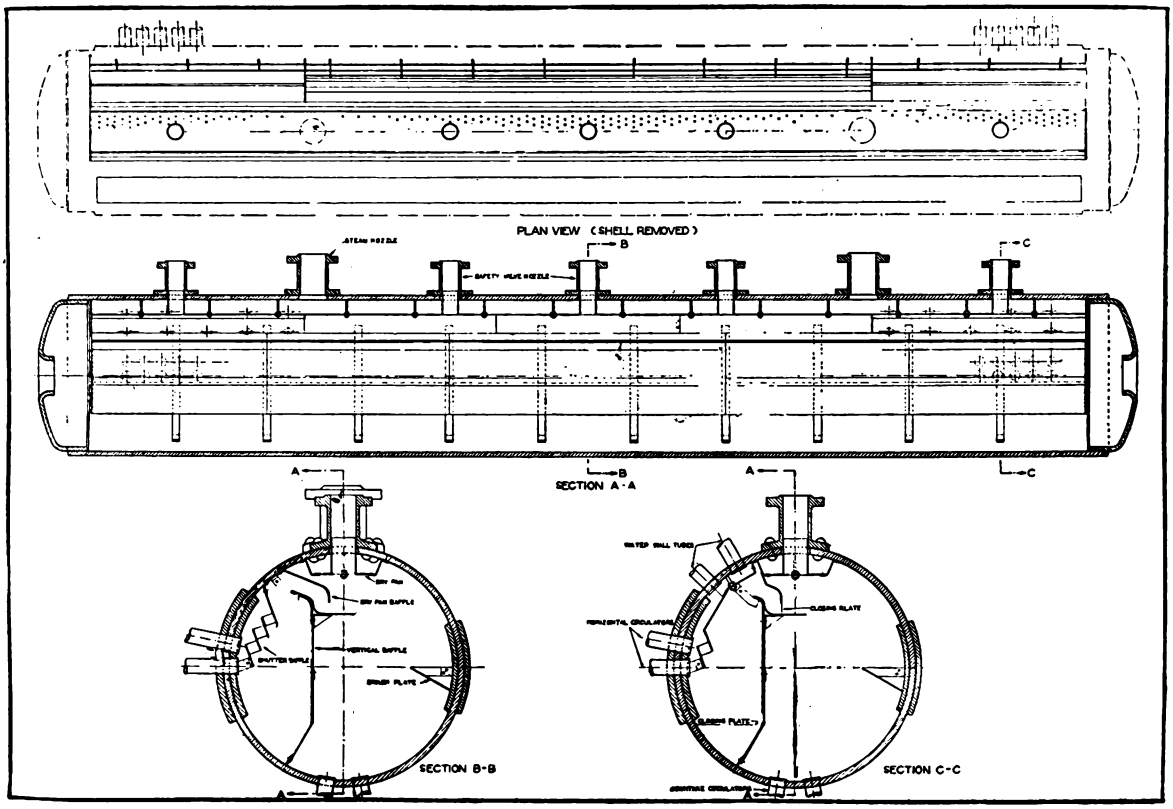

PLAN VIEW (SHELL REMOVED)
STEAM NOZZLE
SAFETY VALVE NOZZLE
B
C
SECTION A-A
A
DRY PAN
DRY PAN BAFFLE
VERTICAL BAFFLE
SHUTTER BAFFLE
SECTION B-B
WATER WALL TUBES
CLOSING PLATE
HORIZONTAL CIRCULATORS
CLOSING PLATE
SECTION C-C

FIG. 32—SHUTTER TYPE STEAM DRUM BAFFLE, THE BABCOCK & WILCOX CO.

than to proceed on the present basis until developments show what must be done; in the meantime it is recommended to design and operate power plants in such a way as to eliminate condenser leakage and to maintain in the boiler water a minimum amount of foreign material.

STATEMENT BY THE BIGELOW COMPANY, NEW HAVEN, CONN.

Fig. 33 shows the side elevation of a stoker fired boiler designed for 250,000 lb. of steam per hr. Attention is called to the special slag screen in front of the boiler tube nests.

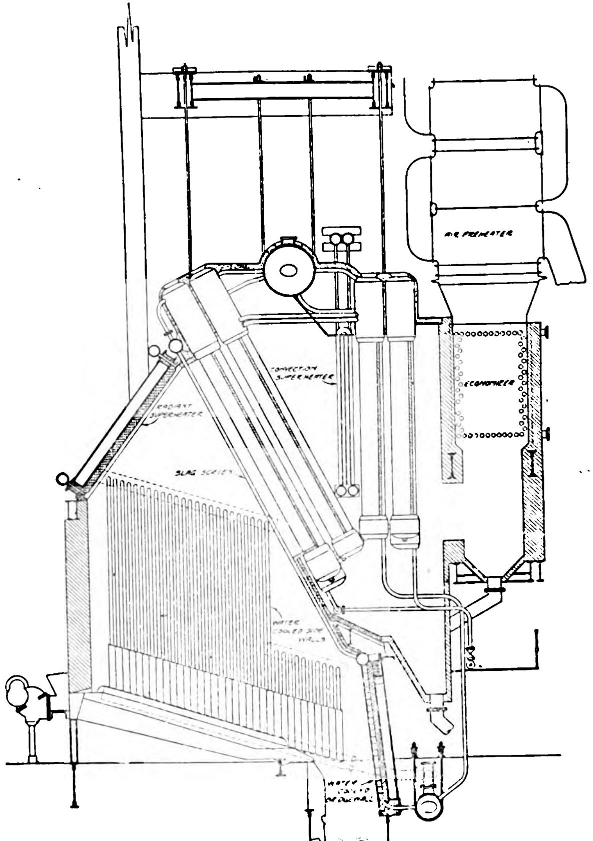

AIR PREHEATER
CONVECTION SUPERHEATER
ECONOMIZER
RADIANT SUPERHEATER
SLAG SCREEN
WATER COOLED SIDE WALLS

FIG. 33—BIGELOW-HORNSBY BOILER AND WATER WALL, THE BIGELOW CO.

STATEMENT BY THE COMBUSTION ENGINEERING CORP., 200 MADISON AVE., NEW YORK, N. Y.

Boilers

Generally speaking, the horizontal water tube boiler is a more efficient heat absorber than the vertical boiler, and it is capable of higher rates of driving without priming. For moderate rates of operation with feed water containing scale forming solids, where turbining and washing of the boiler is necessary at frequent intervals, undoubtedly the bent tube or vertical boiler is preferable. For extremely high pressures the vertical boiler has a definite advantage in that the structure is more flexible and less likely to cause trouble with leaking tubes.

The sinuous header and vertical two and three drum boilers are adapted to pressures up to 1500 lb. or thereabouts. The four drum boiler is not included in this classification because of the additional drum and high price. In general riveted drums are used up to 450 lb., and forged or hammer welded drums for higher pressures. The box header boilers and the horizontal tubular boilers are limited to pressures up to about 250 lb.

The New York Edison Company—East River Station

The three steam generating units for the East River Station of The New York Edison Company are noteworthy because of the high steaming capacity for which they are designed, each having a guaranteed maximum capacity of 800,000 lb. per hr. Normally they will operate through a range from 500,000 to 700,000 lb. per hr. Each boiler, Fig. 34, is designed for 500 lb. pressure with a normal drum pressure of approximately 425 lb. Elesco superheaters will be installed to deliver steam at a total temperature of approximately 725 deg. fahr. Each of the boilers will be of the double-ended, bent-tube type, with four upper water and steam drums and four lower water drums for the complete unit; all drums will be 54 in. in diameter. Steam will be delivered from the two 54-in. upper rear drums into two 48-in. diameter dry drums; from these the steam will pass through a header to the superheater. Each of the three boilers, together with the integral economizer, water-cooled furnace walls, and water-cooled slag screen, will comprise a total area of 67,470 sq. ft. of heat-absorbing surface. Each boiler will be equipped with two plate type air preheaters, each of which will have a total area of 41,360 sq. ft. The furnace will have a volume of approximately 39,000 cu. ft. The unit will be fired by twenty vertical Lopulco burners, ten burners on each side of the furnace. It is expected that the gas temperature leaving the air preheater will range from 365 deg. fahr. at 500,000 lb. per hr., up to approximately 400 deg. fahr. at 800,000 lb. per hour.

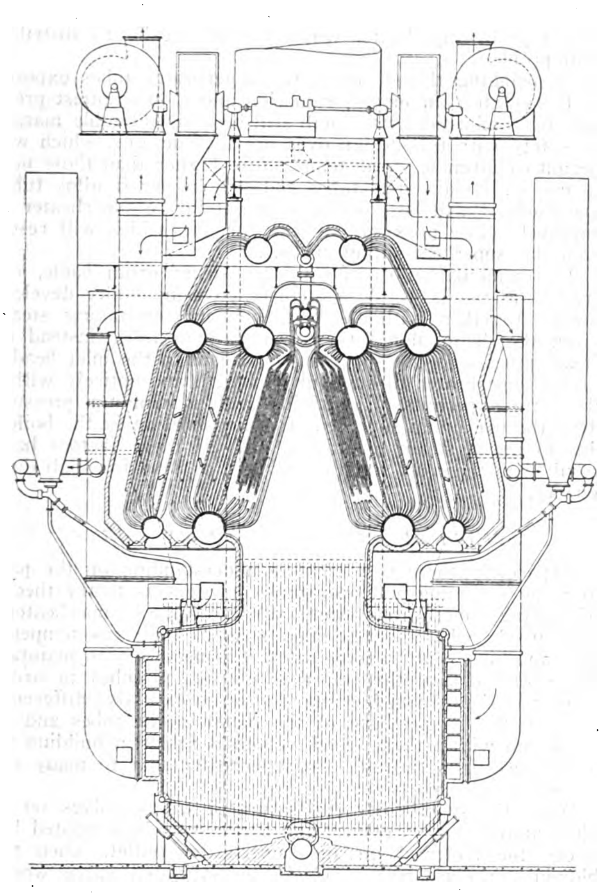


FIG. 34—800,000 Lb. Steam Generating Unit for New York Edison Co., East River Station, Combustion Engineering Corp.

The Philip Carey Co.—High-Pressure Units

Two high-pressure steam generator units are being built for the Philip Carey Company. Each of these units will be designed for a steaming capacity of 150,000 lb. per hr. at an operating drum pressure of 1840 lb. The steam will be superheated to a temperature of 825 deg. fahr. The boilers will be pulverized fuel fired and will have a completely water-cooled furnace. The combustion rate will be held down to a moderate figure.

Slagging

Continuity of boiler operation is largely in the hands of the operators except insofar as the designer has over-rated the boilers or furnaces for the conditions to be met. The two most frequent causes for interruption of operation are fouling of the internal surface of the boiler and fouling of the gas passages with ash or accumulation of large masses of slag in the furnace. The condition of the interior of the boiler is a problem for the operators and can be taken care of within definite limits on any particular job by treatment of the feed water, proper control of the steaming rate at which the boiler is operated, control of boiler water concentration and systematic washing or turbining of the boiler tubes. To minimize fouling of the gas passages, particularly in the front bank of boiler tubes, more moderate combustion rates and complete water cooling of the furnace are recommended.

Probably the most definite limitation to continued operation is the plugging of the first pass of the boiler due to the accumulation of slag or ash on the tubes. There are five contributing causes for these accumulations:

1. Melting point of the ash.
2. Temperature of the gas entering the first pass of the boilers.
3. Velocity of the gas.
4. Carbon in the gas.
5. Gas composition as to relative content of oxygen and carbon monoxide.

Of these items, the last four are directly dependent on the combustion rate, and it is believed they have an accelerating effect on the ash accumulation on the tubes. Obviously, the remedy is reduced combustion rate.

Water Walls and Screens

The problem of cooling pulverized coal-fired furnaces by water-cooled walls and slag screens is exceedingly complex, and although the design of the slag screen has a great effect in keeping the ash below the screen at a temperature below the slagging temperature, the distribution of the flame, the location of the hot zone, the turbulence in the furnace and the fineness of the coal, all have a contributing effect. In some instances a double slag screen was installed with two rows of tubes, each row spaced 10.5 to 14 in. apart horizontally, the two rows being staggered and located 10 to 12 in. apart vertically. This is a logical extension of the basic idea, the additional cooling surface being of value in lowering the ashpit temperature.

An important point which has often been overlooked is that the cooling effect of water-cooled walls is much greater on small furnaces than on large furnaces. In other words, the cooling effect may be expressed as a function of $\frac{A}{V}$, A being the projected area of the walls and boiler surface facing the furnace, and V the volume of the furnace in cu. ft.

Quality of Steam

One of the important problems is the delivery of steam having negligible moisture content to the superheater. In the past few years, operators and manufacturers have coöperated to the extent of securing much higher outputs from boilers without proper regard to steam quality until after the installation was completed. This has intensified the study of baffles to reduce the moisture content.

During the past year this company has made studies and experiments along this line, and progress is being made, though not as rapidly as desired. It is necessary to study at the same time the concentration in the boiler since there is a relation between the quality of steam and the concentration of dissolved and suspended solids in the boiler water. In this connection the matter of feed water control is very important. The usual automatic control by water level in the boiler is entirely inadequate for the high capacity boiler unit. This company is investigating water control by steam flow; some regulator companies are also developing regulators of this type. This is extremely important, and it is believed that eventually a satisfactory regulator must be developed that will proportion the boiler feed water to the actual steam output with, perhaps, an auxiliary or check control by water level.

It is believed that water walls tend to decrease steam quality because of the extremely large volume of water passed into the drum from the walls and the high velocity of the mixture entering the drums. An attempt is being made to minimize this effect by a different distribution of the riser connections to the drum and raising the point of entrance so that the moisture discharge from the water walls will not necessarily pass through the water in the drum.

Sulphate-Carbonate Ratio

This company has made no original investigations on caustic embrittlement, but Professor Straub of the University of Illinois has been consulted in a number of cases where caustic embrittlement has been found. Apparently no recommendations have been made of the sulphate-carbonate ratio for pressures in excess of 450 lb., at which pressure the recommended ratio is 4.5 or 5 to 1. This indicates a prohibitive ratio for pressures of 600 lb. and higher. This company's view is that up to 340 lb., proper control may be had by the sulphate-carbonate ratio and that for pressures in excess of this, there is promise in obtaining the required inhibition by trisodium phosphate. It is this company's opinion that no attempt should be made to operate boilers at pressures of 1200 lb. and over unless 100 per cent condensate is available or unless the feed make-up is evaporated water.

SUPERHEATERS

STATEMENT BY THE BABCOCK & WILCOX COMPANY, 85 LIBERTY ST., NEW YORK, N. Y.

1928 *Design of Superheater*

In the 1928 design of B. & W. superheaters there is but a single row of tube holes in the inlet and outlet headers, each tube being continuous from the inlet to the outlet without intermediate boxes. The total pressure drop thus occurs in the flow of steam through the tubes without intermediate points interfering with the distribution thus obtained. This construction further eliminates the necessity of distribution baffles or ferrules. With this design, short radius tube bends which would maintain a proper cross-sectional area through the tube in the bend and also maintain the proper tube gage on the bend are required, and a new method was developed by this company to make this construction possible.

While it is appreciated that the majority of superheaters in high duty plants seldom, if ever, require cleaning, the evidence is that occasionally something unforeseen occurs when such cleaning is necessary, and the new type of superheater is designed to permit thorough turbine cleaning. This is accomplished by the use of a Y-type return bend on one end of each loop, each Y being fitted with a valve of simple and approved design which can readily be opened for turbining. The location of these valves is such as to be outside of the range of stresses caused by heating and cooling, the entire fitting being protected from soot and ashes. The superheater as arranged is completely drainable. Where temperatures are beyond the limit where expanded joints will remain tight, the outlet superheater tubes can readily be welded to the header.

One of the design problems in connection with minimum pressure drop in superheaters is that of proper steam distribution. In the new design the steam is brought from the drum to the inlet header through a number of tubes arranged with approximately equal spacing along the length of the header, the tubes being located inside of the tube doors. This method of bringing the steam to the inlet header not only gives an improved distribution of the steam, but also eliminates the necessity of either a dry pipe or dry box within the steam drum of the boiler. Further improvement in distribution is obtained by making use of a large diameter outlet header, a source of supply for such headers now being available. The combination of these features results in a type of superheater which has practically no distribution problem.

By bringing the steam to the superheater tubes exposed to the greatest amount of radiation and to the hottest products of combustion, there will still be a considerable margin of safety with this design over previous designs, which will permit of ultimate steam temperature higher than those now in use with plain steel tubes and still higher if alloy tubes are used; it will be possible to maintain the superheater in relatively close proximity to the furnace, which will result in a flat superheat-output curve.

The combination of the shutter steam drum baffle, described in the B. & W. statement covering boiler developments, together with the arrangement for taking steam from the drum along its length through tubes instead of steam pipes, and the supplying of steam to the inlet header of the superheater throughout its length and entirely within the setting, permits of obtaining with a minimum pressure drop the maximum superheat for any location in the boiler, due to better steam separation. All of these factors have resulted in the most satisfactory type of unit for high duty service.

Setting of Superheater Safety Valves

Apparently there is a lack of understanding on the part of some designing and operating engineers as to the theory of setting superheater safety valves. In all superheaters, particularly where located in a zone of high gas temperature and high heat transfer rates, it is necessary to maintain a certain velocity through the superheater tubes in order to protect them from burning, due to an excessive difference between the temperature of the metal in the tubes and of the steam within them. Such velocities result in building up a pressure drop through the superheater that to many engineers seems excessive.

Were the superheater and saturated safety valves set to blow at the same pressure, and a pressure drop existed between the boiler drum and superheater outlet, when the blowing pressure was reached, the saturated valve would blow first and the superheater would have no flow, or little flow, of steam through the tubes for their protection. It is necessary to set the superheater safety valves at a pressure below that of the saturated valves in order that the superheater valves may blow first, insuring a sufficient flow of steam through the superheater at all times.

Other conditions which make lower superheater safety valve setting necessary occur in installations where a number of boilers are connected to a common steam main. Under such conditions, if a saturated valve were to blow before a superheater valve, all of the steam generated by the boiler blowing would not pass through the superheater and the amount of superheat would increase. On slacking back the fire in order to cause the safety valve to shut, a smaller and smaller amount of steam would pass through the superheater, and there would be a corresponding increase in the superheat. Where non-return valves are used between the boiler and the steam main, it is possible for such valves to close on the lowering of pressure in the boiler, after which there would be no flow of steam through the superheater until the pressure is raised to that in the main and the non-return valve opened. Under such conditions it is possible for the superheater tubes to be overheated.

STATEMENT BY THE FOSTER WHEELER CORP., 165 BROADWAY, NEW YORK, N. Y.

In one of the designs of radiant heat superheaters manufactured by this company, heavy-wall rectangular-section forged steel elements are used. These elements are spaced about ¼ in. apart and are backed up by refractory and insulating material, steel casing plates and a reinforcing steel frame. In general, all construction and maintenance problems originally encountered in the development of this type of superheater have been solved, and about 200 are now in satisfactory operation.

The principal difficulties that had to be overcome may be summarized as follows:

1. Overheating of elements due to internal scale, insufficient steam velocity, lack of uniform steam distribution to all elements, and improper operation when taking boilers on or off line.
2. Deterioration of elements due to internal strains resulting from heating of elements on only the one side exposed to the furnace.

About two years ago another design of radiant heat superheater was brought out. In this type relatively thin-wall circular-section elements are used. They are spaced about 3 in. apart and about 10 in. out from refractory walls. This spacing is such that ash does not build up rapidly on the brick behind the elements, nor across the spaces between adjacent elements. Ash that does accumulate does not attack the brick, and is easily removed by permanent disappearing soot blowers or by hand lancing. Heat absorption on the side of the elements away from the furnace is sufficient to eliminate any trouble due to distortion or unbalanced internal strains from uneven heating. Under comparable conditions the heat transfer per square foot of surface around the entire circumference of the circular elements is practically the same as the transfer per square foot on the furnace face only of the rectangular elements in the old design. The effective surface per square foot of wall space occupied and, therefore, the work that can be done is about 30 per cent greater in the new than in the old design.

About 46 radiant superheaters of the new design are installed or on order. For steam temperatures up to 750 deg. fahr., chrome-vanadium steel elements, costing in standard sizes three to four times as much as low carbon steel boiler tubes, are recommended. For higher steam temperatures it would ordinarily be advisable to use high chrome-nickel alloy elements costing ten or more times as much as low carbon steel boiler tubes.

For central station service the Foster Wheeler Corp. is prepared to offer convection or radiant superheaters, separately or in combination for steam temperatures up to 900 deg. fahr. Higher steam temperatures increase the importance of a flat curve of superheat versus rating, and in this connection it is desired to point out that the use of series combination convection and radiant heat superheaters is a means of holding steam temperature within a safe operating range under varying load and combustion conditions that is preferable to the use of sprays or other desuperheating devices for accomplishing the same results.

STATEMENT BY THE SUPERHEATER CO., 17 EAST 42ND ST., NEW YORK, N. Y.

During the past year no striking changes in the design of Elesco superheaters have been attempted. As larger and larger steam units are being designed, the keynote becomes continuity of operation. Therefore, attention has been devoted toward improvement of the small details which make for lower maintenance and outage charges. To the latter end alloy steel bolts are used as standard for superheater supports located in the high-temperature gas zones. In the design of the supports themselves high heat-resisting alloys are being used more extensively.

Another important point is equalization of tube wall temperatures. This company's standard practice is to locate the coolest portion of the units (through which the steam first passes) in the hottest gas zone and the hottest portion (through which the hottest steam passes) in the cooler zone. Even with the increased transmission in the hottest zone, the metal temperature is cooler than in the balance of the unit. In addition to the above, it has been found necessary to design more intricate baffles to provide for the increased expansion of the larger units.

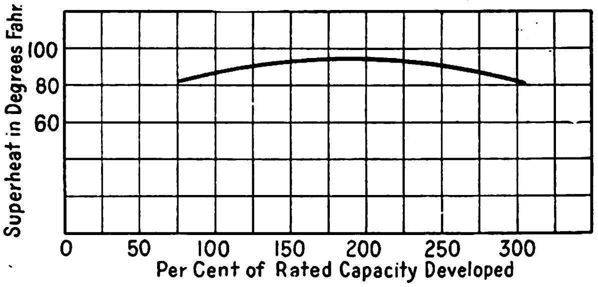


FIG. 35—CHARACTERISTIC SUPERHEAT-OUTPUT CURVE, THE SUPERHEATER CO.

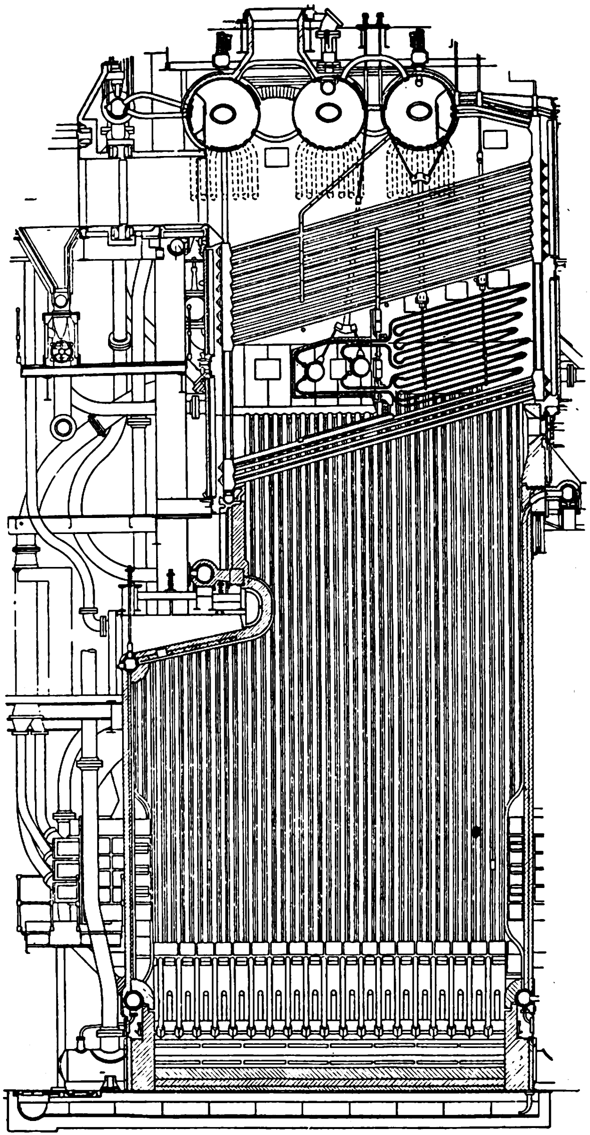


FIG. 36—1928 HELL GATE SUPERHEATER INSTALLATION, THE SUPERHEATER CO.

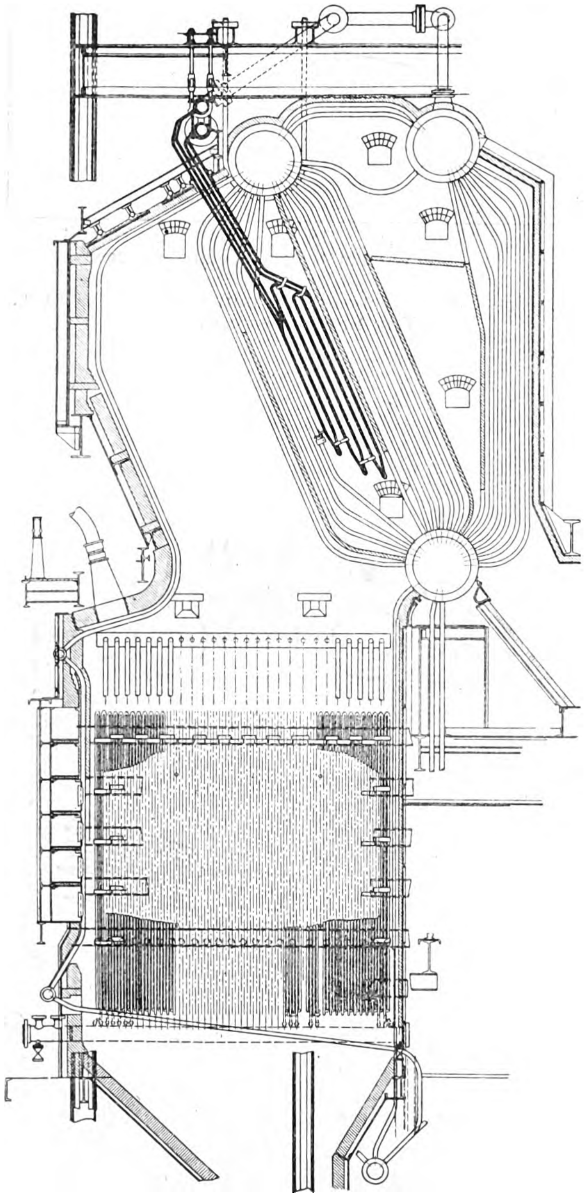


FIG. 37—RECENT SUPERHEATER INSTALLATION, NORTHEAST STATION, KANSAS CITY POWER & LIGHT CO., THE SUPERHEATER CO.

Increasing appreciation of the fact that the superheater is a device to superheat steam and not to evaporate moisture is shown by the greater use of steam purifiers. The problem of delivering dry steam has been intensified by the extensive use of water walls.

The necessity for having clean, dry steam enter the superheater increases with higher pressure and temperature stresses. The revelation that high-pressure boilers must have the purest feed water obtainable if tube failures are to be prevented has focused attention on the superheater, in which pressure and temperature stresses are much higher and into which scale-forming matter must be prevented from entering. This company's standard practice is to limit the moisture content of steam entering the superheater to 1 per cent. Experience has amply indicated that, when high steam velocities are used, the solids contained in 1 per cent moisture will not be deposited on the superheater tube wall. Experience may later indicate that it is necessary to lower the moisture specification for the highest pressures. The plant designer is well advised if he limits the moisture content to ½ of 1 per cent or less for 1400 lb. pressure and above.

Final steam temperatures have been limited to 750 deg. fahr. up to the present. However, superheaters are now being designed for one installation to operate at 775 deg. fahr. and another at 825 deg. fahr. With clean steam and careful supervision there is no great increase in the hazards of operation at 800 deg. fahr. as compared with 750 deg. fahr.

Fig. 35 shows the superheat curve for an Elesco radiant superheater, screened by 4 in. o. d. water wall tubes on 8 in. centers.

Outstanding superheater installations during the past year are listed below:

United Electric Light & Power Co.—Hell Gate Station, Fig. 36. These superheaters are designed to superheat a maximum of 400,000 lb. of steam per hr. at 285 lb. pressure to a final temperature of 705 deg. fahr.

Kansas City Power & Light Co.—Northeast Station, Fig. 37. This installation included a primary convection superheater operating at 1350 lb., 725 deg. fahr., and a radiant superheater, as a reheater, operating at 295 lb., 720 deg. fahr.

Detroit Edison Co.—Trenton Channel Station. Fig. 38. This superheater is designed to superheat a maximum of 360,000 lb. of steam per hr. at 420 lb., 720 deg. fahr. The

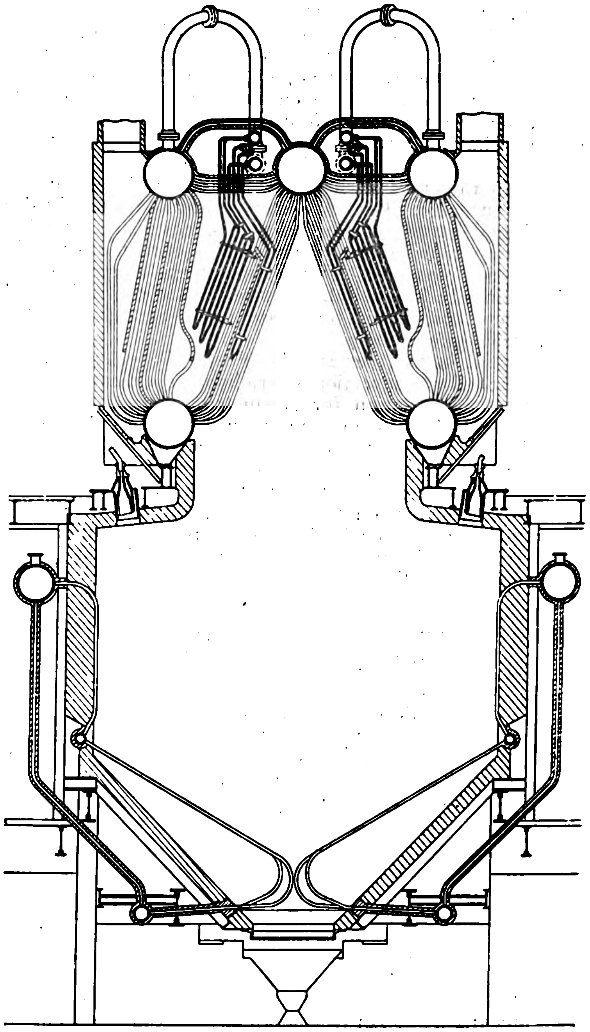


FIG. 38—SUPERHEATER INSTALLATION, TRENTON CHANNEL STATION, THE DETROIT EDISON CO., THE SUPERHEATER CO.

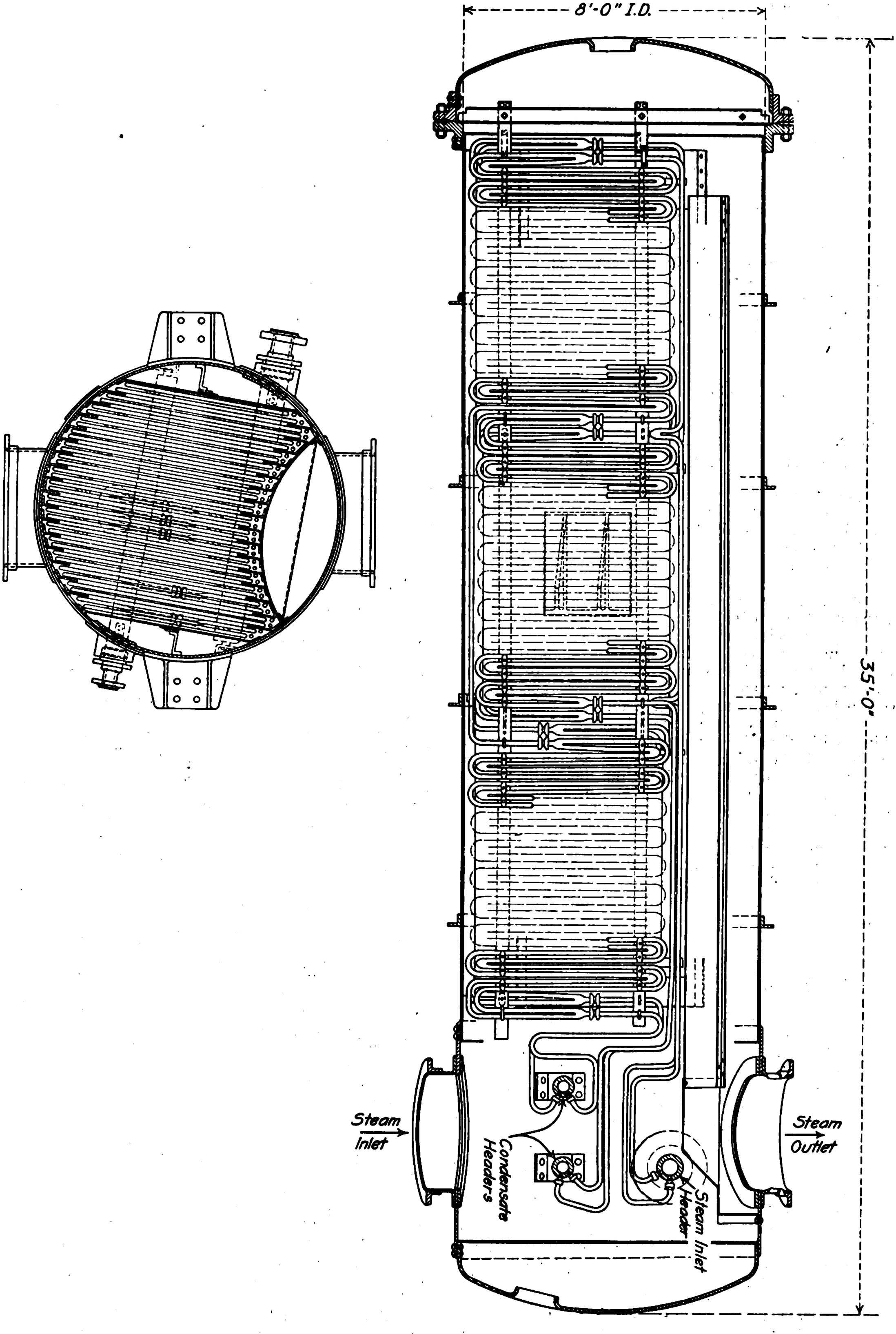

8'-0" I.D.
35'-0"
Steam Inlet
Steam Outlet
Condensate Headers
Steam Inlet Header

FIG. 39—ELESCO STEAM REHEATER, THE SUPERHEATER CO.

feature of this installation is the use of radiant loops in series with convection loops to obtain a more uniform superheat than can be obtained with a full convection type.

Steam Reheaters

That steam reheaters are a practical method of reheating steam is demonstrated by performance to date. Interest in this method is evidenced by the increasing use at pressures up to 1800 lb. Fig. 39 shows the latest design of Elesco steam reheater at the Crawford Avenue Station, Commonwealth Edison Co., Chicago. This company has made extensive studies of reheater design and has arrived at the conclusion that the simpler types will not give the continuity of service which is demanded. The very small number of joints in this design is a feature.

Due consideration must be given to the fact that heat transfer in the high-pressure side in the desuperheating zone is quite different from that in the condensing zone. A high steam velocity is necessary in the desuperheating zone and a low steam velocity in the condensing zone.

ECONOMIZERS

STATEMENT BY THE BABCOCK & WILCOX CO., 85 LIBERTY ST., NEW YORK, N. Y.

A development in economizer design of last year was a change in the design of return bends. These bends were formerly made of seamless steel tubing with threaded flanges on the ends having female facings; the bends are now forged from round bar stock with the flanges integral. The flanges are produced on the ends of the bar by the upset forging process. After the flanges are formed and before bending, the blank is drilled from end to end, making it a seamless tube. Special devices are used in forging and bending to insure the faces of the flanges being in the same plane after bending and having the same angularity, as well as maintaining uniform center distances of the ends.

The return bends for connecting the top and bottom rows of tubes to the headers were formerly made of seamless steel tubing with threaded flanges on each end, one end having male and the other female facing. In order to eliminate threaded flanges throughout on the return bends and at the same time to produce a return bend for the header connections more adaptable to the location than the solid forged bend, a type has been developed having loose flanges and facings similar to the Van Stone type. These bends are of seamless tubing, upset on the ends and having loose fitting bolting flanges bearing against the upset ends, one end being faced for male and the other for female connection.

STATEMENT BY THE COMBUSTION ENGINEERING CORP., 200 MADISON AVE., NEW YORK, N. Y.

This company is developing as rapidly as possible a standard line of straight tube economizers, using both 2 and 2.5 in. tubes, designed for pressures up to 2000 lb. The flexible design of a parallel series of tubes connected at the ends with return bends or expanded into junction boxes and expanded at the inlet and discharge ends into inlet and oulet headers has been definitely adopted. Each vertical coil, composed of return bends and straight tubes, is thus free to expand without stress in the bends or tube joints.

The junction boxes and return bends are outside of the gas passage and separated from it by cast iron plates. Stuffing boxes are provided where the tubes pass through the plates to insure against gas leakage and leakage of vapor from the junction boxes into the gas stream. The return bend connection is similar to an ammonia bend and is held to the tube by two bolts.

In the junction box type the junction box is a rectangular steel forging provided with oval handholes and caps opposite each tube. The latter type is in service at Kansas City and is operated under pressures up to 1880 lb. This high pressure is due to the fact that only one boiler is in use and that the motor speed is a little higher than expected. Changes will be made in the pump to reduce the excess pressure.

STATEMENT BY THE FOSTER WHEELER CORP., 165 BROADWAY, NEW YORK, N. Y.

In the April, 1926, report of the Prime Movers Subcommittee on Boilers, Superheaters and Economizers (N. E. L. A. Publication No. 256-11) a statement was made to the effect that investigations then indicated the life of Foster economizers could be safely estimated at from 15 to 20 years, depending upon inlet water temperature and quality of make-up water used. Later experience tends to confirm the correctness of this statement. For analysis of the reasons in back of it, only three causes of deterioration need be considered. These are:

1. Internal corrosion of elements
2. External corrosion of elements
3. Deterioration of casings.

Internal corrosion will be practically nil, if the oxygen content of water entering economizers is not over 0.2 c.c. per liter and if the hydrogen ion concentration or pH value is not less than 10. These conditions can be easily and regularly checked and maintained. Oxygen contents and pH values can both be determined with sufficient accuracy by means of simple and rugged apparatus permanently installed in or adjacent to the boiler room rather than in a distant laboratory. The installation and regular use of such apparatus by operating engineers is strongly recommended because it will inevitably better plant performance in respect to these two items. In this connection attention is called to an instructive article, "Hydrogen Ions Are the Key to Corrosion," by Messrs. A. A. Markson and Paul Fritz of the New York Steam Corp., which appeared in *Power*, Feb. 5, 1929.

External corrosion of elements will not be a factor in the life of economizer elements unless in operation gases are cooled below the dew point, or if, during shutdown periods, moisture is deposited on the elements by washing or by condensation from atmosphere and is not thoroughly dried before economizers are again put into operation. Some years ago the washing of Foster economizers was recommended. It has been found possible to discontinue this practice with certain fuels and that economizers can be kept clean, and contract heat transfer rates maintained in installations where soot blowers only are used for cleaning. When so operated Foster economizers are adequately protected against external corrosion of elements under all contingencies by shrunk-on, gilled cast iron rings, which completely cover the steel tubes and prevent any contact between them and sulphur bearing gases.

Foster economizer castings are made of flanged cast iron sections, with machined metal to metal joints about 2.5 in. wide, externally bolted together. The end and intermediate supporting tube sheets are also of cast iron so that in casings, as on elements, gases contact only with cast iron parts. This provides a casing that is practically indestructible, will resist any corrosion to which it might be subjected in normal operation, can be made gas tight, and will show less than ½ of 1 per cent loss of CO_2 from economizer inlet to outlet.

In this connection it may be noted that in a certain installation where Foster economizers replaced old cast iron vertical tube economizers without any change in induced draft fans, not only was the overall boiler unit efficiency improved, but the maximum steaming capacity per boiler was definitely increased from 140,000 to 165,000 lb. per hr., or about 18 per cent. This was due not to additional work done in economizers, but almost entirely to elimination of air infiltration into economizer casings and consequent reduction of load on fans per unit of steam generated.

Fig. 40 shows a Foster economizer with a cast iron sectional housing and access doors. Above the economizer is one of the new sectional, plate type Foster air heaters, the first which has been put into operation during the past year. The clips on the sides of the air heater are for holding in-

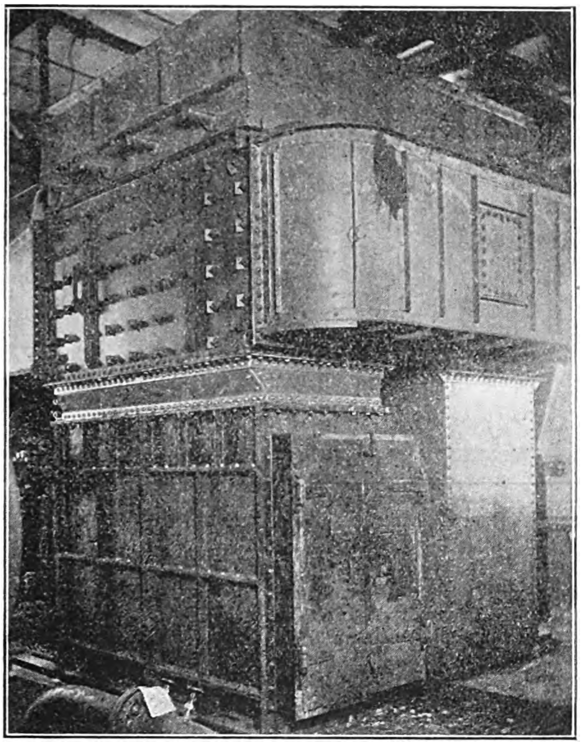


FIG. 40—FOSTER ECONOMIZER AND AIR HEATER, FOSTER WHEELER CORP.

sulation in place; the tubular projections above the air heater section house the ends of the soot blower elements providing for longitudinal movement during blowing.

The gases pass straight up through the economizer and air heater section, then to the right through the steel casing shown at the top and downward through a second air heater section and into the rectangular cinder catcher shown at the right of the economizer.

STATEMENT BY THE B. F. STURTEVANT CO., INC., HYDE PARK, BOSTON, MASS.

There have been no radical changes in the design of plain cast iron tube economizers for a number of years. There has been more of a demand for tubes in a horizontal position, although they can be furnished in both horizontal and the old vertical position. In the case of the horizontal position the economizers are built in two ways: with the headers vertical and the tubes horizontal, or with both headers and tubes horizontal. The latter is far more preferable as it greatly simplifies the installation.

Care must be used in installing any economizer of the vertical header-horizontal tube type to make sure that the water flow is upward. Installing them with the water flow downward is not recommended as convectional currents are set up in several of the different paths of water flow. The surface becomes ineffective in these paths, and there is the possibility of the formation of steam and breaking of the parts, particularly the bends. This is particularly true at low ratings where the velocity of flow is not great enough to overcome the convectional currents which are trying to force their way upward. As the flow increases, the convectional currents are overcome and the danger is eliminated.

This difficulty is not present in the second arrangement of apparatus where both headers and tubes are horizontal, for the reason that there is but one bend connecting each level and the water is forced through this bend at such high velocity that it overcomes the action of the convectional current. Another feature of this arrangement is that the water comes in at one end of the headers and leaves at the opposite end of this section. Thus, even if there is stratification of gases, the temperature of the water in each succeeding level is increased by steady increments.

During the last three or four years soot blowers have been adopted for cleaning cast iron economizers. Heretofore scrapers have been used for the vertical tube type, but it has been found that there is an appreciable amount of air leakage which tends to overload the fans. The present knowledge of combustion permits far more accurate calculation of gas quantities than heretofore, and therefore purchasing engineers are selecting fans with but little margin of safety. Air excluders were sometimes resorted to, but these are not thoroughly effective. Soot blowers can be installed to operate in tight bushings, thus reducing leakage to a minimum. Even though this means the loss of a certain amount of scraper business incidental to economizer sales, this construction has been recommended in the interest of better performance and reduced cost of fan equipment.

Excellent results have been obtained in the application of extended surface steel tube economizers. The relative rates of heat transfer with plain and extended surface are shown in the test curves of both types plotted with velocity as abscissas. The slope of the transfer curve with the plain type is greater than the slope of the curve for the extended surface type. The disk making the extended surface has been so designed that there would not be more than a slight difference in temperature between the outside diameter of the disk and the tube, as this surface becomes less effective the further the distance from the tube. A steel disc pressed onto the tube is as efficient as if it were part of the tube itself and being of similar metal there is no difference in coefficient of expansion. These economizers show continuous operating results, proving that the contact between the tube and the disk is absolutely tight and permanent.

No difficulty has been experienced in maintaining clean surfaces in these economizers, and test results show that the machines can give continuously efficient service in accordance with their guarantees.

SOOT BLOWERS

STATEMENT BY THE DIAMOND POWER SPECIALTY CORP., 10340 OAKLAND AVE., DETROIT, MICH.

The development of a new process for manufacturing calorized soot blower elements was mentioned in last year's statement. After another year of service, these elements have proved to be more successful than was anticipated. Their life is not only very much longer, but they are usable at considerably higher temperatures. Fig. 41 shows the condition of a "New Process" calorized element after seventeen months' service, at a location where the temperatures are close to 1800 deg. fahr.; namely, at the top of the first pass of a Stirling boiler, back of the front bank.

For the hottest locations in the lower part of the first pass, Dialoy continues to be the only successful material. The successful production of seamless Dialoy elements in conjunction with an improved nozzle construction have increased their successful application. Further extended experiments on alloys of the heat resisting group confirm previous conclusions that no other alloy at present available can compare with Dialoy for high-temperature boiler service. That this alloy is immune to attack by the sulphur in the gases is particularly important.

The use of Dialoy bearings with Dialoy elements has now become general practice with this company. A particularly important development in this connection is the welding of these bearings directly to the boiler tubes. This construction is particularly suitable for hot locations, and it has proved entirely practical to weld Dialoy bearings to boiler tubes. Electric arc welding with Dialoy rod is used. This practice has been sanctioned by the Hartford Steam Boiler Inspection & Insurance Co., the welding being subject to approval by their inspection force.

Fig. 42 shows a soot blower element mounted in Dialoy bearings welded directly to the boiler tubes. As typical of the locations in which this construction is most satisfactory,

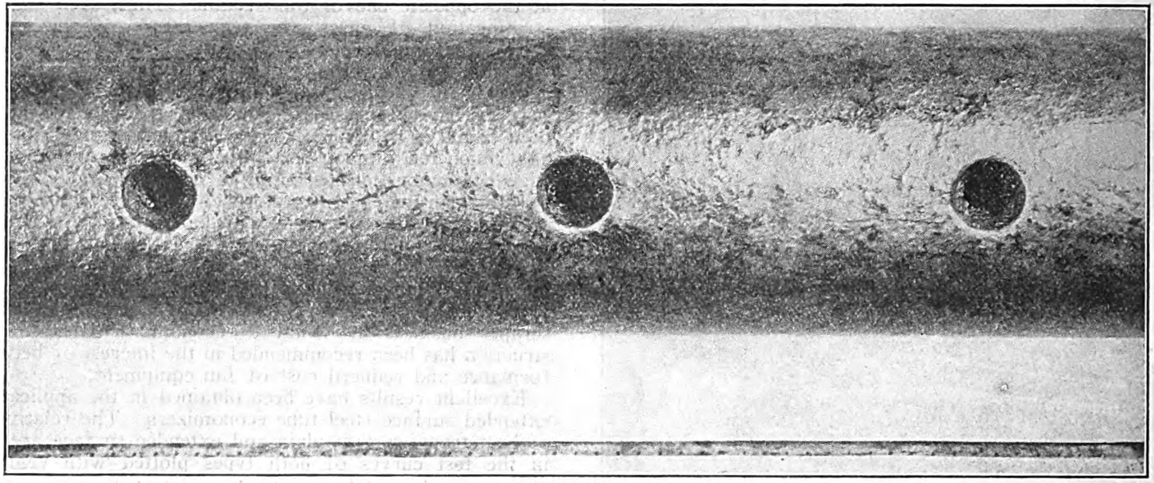


FIG. 41—"NEW PROCESS" CALORIZED SOOT BLOWER ELEMENT AFTER 17 MONTHS' SERVICE AT ABOUT 1800 DEG. FAHR., DIAMOND POWER SPECIALTY CORP.

Fig. 43 shows an installation made some twenty months ago; the unit designated as A is a Dialoy unit and was installed primarily for slagging purposes. The results of this installation have been entirely satisfactory.

The use of compressed air for blowing large boilers has been extended during the past year. Two large installations in central stations have been made; cleaning results are reported as satisfactory. The most important point is the maintenance of the maximum blowing pressure at all times, necessitating large piping and adequate storage facilities. It appears that air is being considered more frequently than heretofore, and it is probable that its use as a cleaning medium will be extended.

A series of investigations has been completed during the past year covering various phases of soot blower performance. The plants investigated are widely distributed and operate under varying conditions of fuel and load. It is thought that brief abstracts of the most pertinent data gathered in these studies will be of interest.

Decatur

At the Decatur Station of the Illinois Power & Light Corp. four 6000 sq. ft. Stirling boilers are used to supply saturated steam at 150 lb. gage pressure for heating purposes. The plant operates about 210 days per year. Fuel is Illinois screenings having a heat value of 13,000 B.t.u. dry basis. Average loads are 200 per cent. (6.7 k-B.t.u. per sq. ft. per hr.) rating.

A study was made in this plant of the relative efficiencies and cost of the hand lance method of cleaning as compared to the use of soot blowers. Hand lancing was formerly used entirely, and accurate data are available for comparison with present conditions under soot blowers. The total yearly cost of cleaning with soot blowers for all boilers is $936 as compared to $3,763 by hand lance methods. While the depreciation, interest and maintenance charges are higher for the soot blowers, the steam and labor costs for the hand lance method are much greater. The blowers maintain an average flue gas temperature of 395 deg. fahr. at the exit of the economizers. Hand lancing three times per shift was necessary to produce approximately this result. With the soot blowers, there is the further advantage of elimination of draft losses and furnace cooling which exists when the cleaning doors are opened for hand lancing, a not inconsiderable item where the boiler must be hand lanced three times per shift.

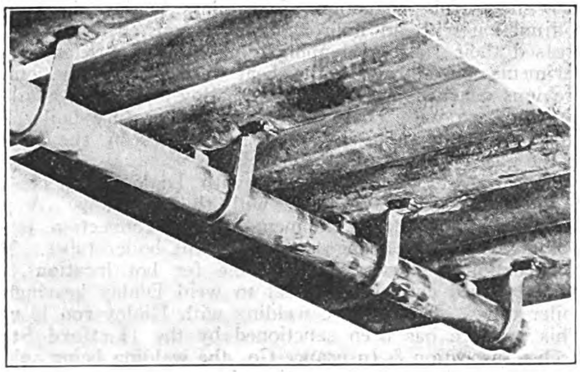


FIG. 42—DIALOY ELEMENT SUPPORTED IN DIALOY BEARINGS WELDED TO BOILER TUBES, DIAMOND POWER SPECIALTY CO.

Youngstown Sheet & Tube Co.

Five 7630 sq. ft. horizontal water tube boilers are fired with coke breeze at normal ratings of 173 to 200 per cent

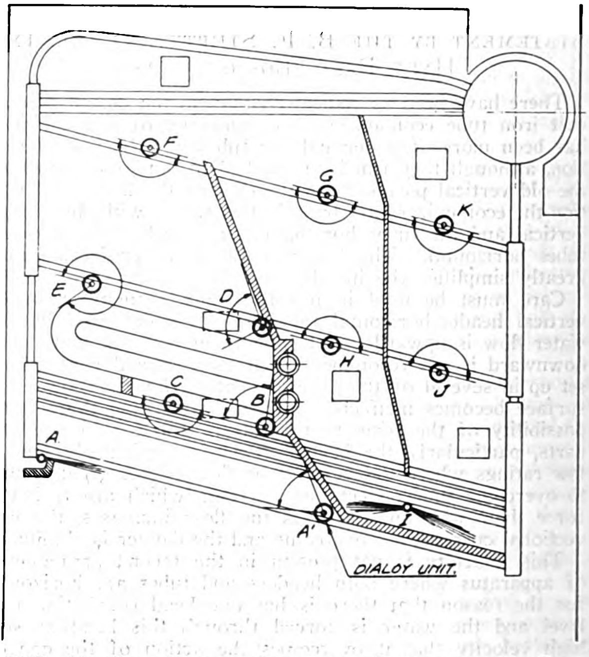


FIG. 43—SOOT BLOWER LOCATION, BOILER NO. 20, COLFAX STATION, DUQUESNE LIGHT CO.

(5.8 to 6.7 k-B.t.u. per sq. ft. per hr.). About 56 tons are burned per boiler per 24 hr., furnace temperatures of 2450 deg. fahr. being attained. Steam pressure is 175 lb. gage.

A severe slagging action takes place in the lower part of the first pass; one man on each shift rodding tubes continuously could not keep the deposit down, and drafts had to be increased until a positive pressure of 0.15 in. was produced in the furnace. This resulted in excessive stoker, door and furnace repairs and boilers could not be kept on the line over 10 days. The installation of one Dialoy slagging unit at the bottom of the first pass in each boiler has eliminated the difficulty. These are operated every 2 hr. and permit carrying of full loads with normal draft. The saving in de-slagging labor and repairs for the plant is $9,239 per year, to which may be added a substantial fuel saving.

Toronto

At the Toronto Station of the Pennsylvania-Ohio Power & Light Co. six 20,000 sq. ft. horizontal water tube boilers operate at ratings varying from 260 to 300 per cent (8.7 to 10 k-B.t.u. per sq. ft. per hr.). Pulverized coal is used, each boiler burning about 200 tons per 24 hr. Steam pressure is 385 lb. gage with superheat of 265 deg. fahr. An outline sketch of one of the boilers with the soot blower locations is shown in Fig. 44. The blowers are operated each shift, requiring 1 hr. of labor and 7440 lb. of steam per 24 hr.

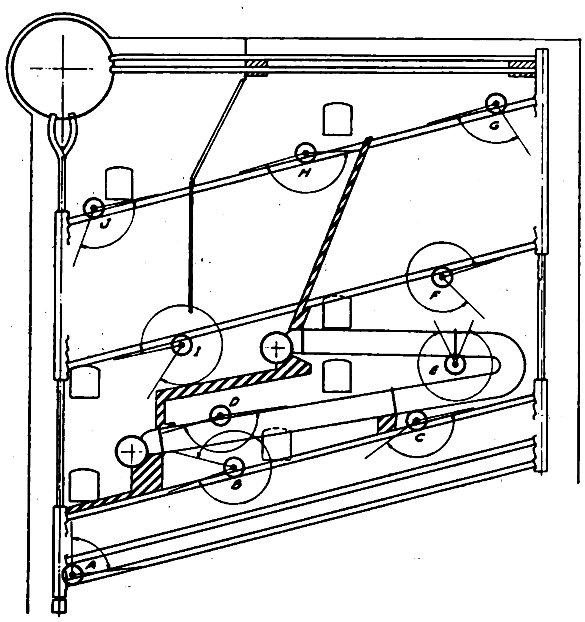


FIG. 44—SOOT BLOWER LOCATION, TORONTO STATION, PENN-OHIO POWER & LIGHT CO.

Tests carried out on one boiler, operating at constant ratings of 287 per cent (9.6 k-B.t.u. per sq. ft. per hr.), indicate a rise of 25 deg. fahr. in exit gas temperatures beyond the air heater when the use of soot blowers is discontinued. All operating conditions were held constant throughout the test, so that the rise in uptake temperatures is a direct indication of fuel saving. This amounts to $1,016 per boiler per year. Although the lower fuel consumption represents a material saving, this is looked upon as secondary to the advantage of keeping the passes between tubes free. The user believes that it would be impossible to maintain present ratings without mechanical soot blowers. Draft conditions are such that opening the inspection doors along the first pass for lancing does not materially affect boiler operation, whereas to open doors in the second and third passes would seriously affect evaporation. It is estimated that, to keep the boiler on the line, 1¾ hr. of hand lancing would be necessary per shift in the first pass alone. It is thought that such hand lancing would have slight, if any, effect in lowering flue gas temperatures below that obtained at the end of the test above described. However, the annual cost per boiler of hand lancing the first pass only, would amount to $674 more than the present cost of soot blower operation for the entire boiler.

Hell Gate

At the Hell Gate Station of the United Electric Light & Power Co., tests were run to determine the increase in flue gas temperatures when operation of the soot blowers was discontinued. In this station there are two groups of large horizontal water tube boilers, the first of 18,900 sq. ft. and the second of 12,560 sq. ft. The latter group is equipped with economizers and water walls. West Virginia coal averaging 14,000 B.t.u. is burned on stokers. Ratings run from 200 to 300 per cent (6.7 to 10 k-B.t.u. per sq. ft. per hr.), the latter being the peak ratings and the former, average.

The outlet temperature of one boiler of each group was taken at different ratings after the operation of soot blowers. Soot blowing was then discontinued and the rise in outlet temperature noted. Results of the tests made on the 18,900 sq. ft. boiler are shown in Fig. 45. At the end of four days the rate of increase of outlet temperature on the 18,900 sq. ft. boiler was practically constant, and the soot blowers were then operated. The curves show the drop in outlet temperatures. Taking the curves for 225 per cent (7.5 k-B.t.u. per sq. ft. per hr.) rating, it will be noted that the maximum boiler outlet temperature reached is 675 deg. fahr. The average temperature for the first day of operation without blowers is 613 deg. fahr., this being the mean of the boiler outlet temperature obtaining just after the blowers were operated and just before they would normally be operated again. In other words, the blowers are normally operated once every 24 hr. on this boiler, and during this period the boiler outlet temperatures increase about 25 deg. fahr., consequently 613 deg. may be taken as the average outlet temperature when blowers are being used normally every 24 hr. This 62 deg. increase in boiler outlet temperature due to omitting operation of the soot blowers is equivalent to 1.9 per cent fuel saving, amounting to $3,161 per year. The total cost of soot blower operation per year for one boiler is $1,887, including all fixed charges, maintenance, operating labor and steam consumption, leaving a net annual saving per boiler of $1,273. This figure is based only on the actual fuel saving, and does not take account of the other advantages of soot blower operation, namely, the maintenance of proper draft conditions and higher operating ratings. These factors are difficult of exact evaluation but are, by a great many, considered of even greater importance than the fuel saving.

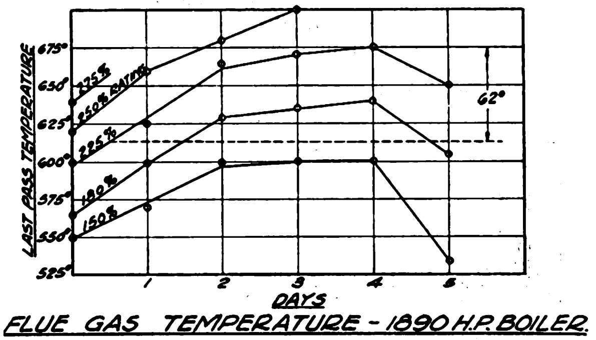


FIG. 45—RISE IN FLUE GAS TEMPERATURE AT HELL GATE AFTER DISCONTINUING SOOT BLOWER OPERATION FOR FOUR DAYS, DIAMOND POWER SPECIALTY CORP.

In the case of the 12,560 sq. ft. boiler equipped with water walls and economizer, the boiler outlet temperatures were rising at a practically constant rate, and there was no opportunity to continue the test to the point where this rise in outlet temperature would reach a constant level. Due to this fact and the lack of observation of the economizer outlet temperatures, the savings on this unit cannot be evaluated. The latter type of boiler is equipped with the automatic valved head, and the annual cost of operation of soot blowers on this boiler is estimated at $300 less than on the 18,900 sq. ft. boiler.

STATEMENT BY THE VULCAN SOOT CLEANER CO., DUBOIS, PA.

The Vulcan improved self-contained model "H" valve operating head is shown in Fig. 46, as re-designed to include the following changes: Accessibility, ample chain clearance, deep stuffing box, enclosed gear and flanged head, making it easy to mount or dismount the head. Use has been freely made of monel metal and stainless steel in order to reduce wear and corrosion.

One of the outstanding features of the head is the flange connection which is provided for connecting the operating head to the soot cleaner element. When ready to install the head, a flange weighing not more than 3 or 4 lb. is screwed on the end of the element. This is a big advantage, as all fittings and measurements can be made using this light-weight flange. When the assembly is complete the valve-operating head can be hoisted into place and attached by screwing on four nuts. In the past it has been necessary to lift the entire head into position in order to make the required measurements, and it was also necessary to turn the head or the element in order to screw the two together.

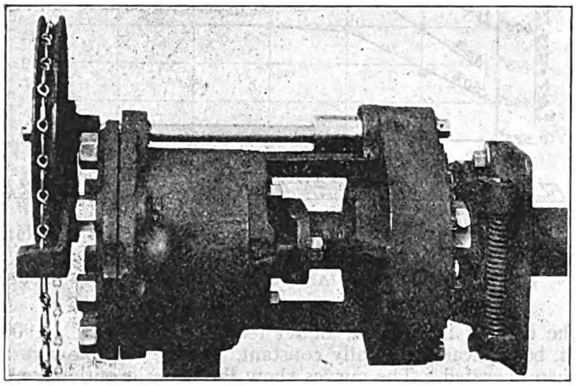


FIG. 46—MODEL "H" SOOT BLOWER VALVE OPERATING HEAD, THE VULCAN SOOT CLEANER CO.

With the flange connection this difficult operation is entirely eliminated. The soot cleaner elements, together with the sleeve mount, can be completely installed while the brickwork is going up. The installation of the heads themselves can be delayed until the bricklayers and other workmen are out of the way.

The model "H" head is driven through spur gears having an approximate ratio of 12 to 1; the gears are entirely inclosed, which does away with the necessity of cleaning them. There is never any danger of sticking and possible breakage due to clogged gear teeth which sometimes renders the operation of the head difficult and at times impossible. The stuffing box has been deepened to allow the use of six rings of packing, instead of four, and increased space has been left in front of the stuffing box to facilitate changing the packing. The chain or operating wheel of the cleaner head is located in a plane far enough away from the boiler wall for the chain to clear the steelwork on the side of the boiler.

The valve is an integral part of the head, and is a sliding disk type, self-adjusted for wear, with no tendency to stick. The valve is wide open while the element sweeps forward and back over the entire cleaning arc and closes steam tight when the work is completed. The valve is either of stainless steel or monel trim, the disk being made of a special material called "Nogall," which has high anti-friction properties under temperatures ranging from 700 to 800 deg. fahr. The use of this material has greatly reduced the effort needed to operate the head and eliminates the possibility of any damage to the valve seat under high pressure and temperature steam conditions.

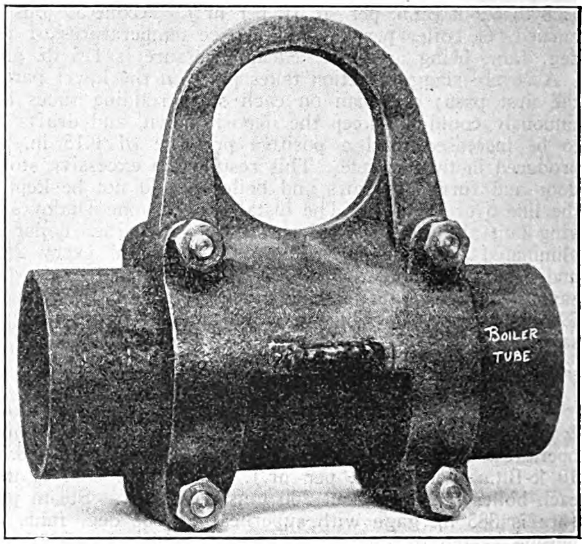


FIG. 47—SOOT BLOWER BEARING, THE VULCAN SOOT CLEANER CO.

The Vulcan intimate contact type of bearing is shown in Fig. 47. This bearing is an improvement over those offered for soot cleaner purposes in the past. It is so designed and constructed that the heat taken up from the boiler gases by the bearing, bolts and studs is rapidly passed on to the boiler tubes. This keeps the bearing comparatively cool at all times in practically any location in the boiler where it can be installed.

A view of a special steam soot blower for cleaning a tubular air heater recently designed for a central station is shown in Fig. 48. It is operated by a hollow rack through which the steam supply is led to the two headers which are equipped with steam nozzles. The two headers are held together by connecting pipes to which bearings are welded for the support of the four wheels on which the assembly runs. The rack is actuated by a small spur gear mounted on a vertical spindle which is turned the correct number of degrees to register the nozzles correctly with adjacent

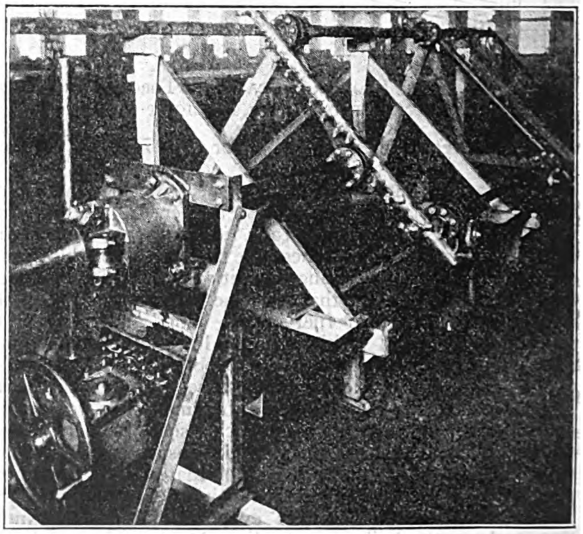


FIG. 48—SOOT BLOWER FOR TUBULAR AIR HEATER, THE VULCAN SOOT CLEANER CO.

longitudinal rows of air heater tubes. A visual indexing device is provided on the top of the gear box, made up of a disk having a radial slot. When the slot coincides with a corresponding slot in the cover of the gear box, indication is given of the traversing of one full space. The gear box which contains the reduction gears and the index mechanism is entirely closed and is filled with oil. The outer end of the rack is attached to three swivel joints.

The ratchet head shown in Fig. 49 is a re-design of the ratchet head exhibited in Fig. 50 of the 1922 report of the Prime Movers Committee. The springs which formerly actuated the pawls have been replaced by gravity action, the position of the pawls having been changed from bottom to top. A projection from the rear frame has been provided to cover and form a housing to prevent access of dust and dirt. The ratchet head has also been provided with a friction brake to avoid friction effect between the working frames and the element that would turn the element backward and thus prevent the engagement of the pawls with the ratchet wheel. This would sometimes occur where the elements were short.

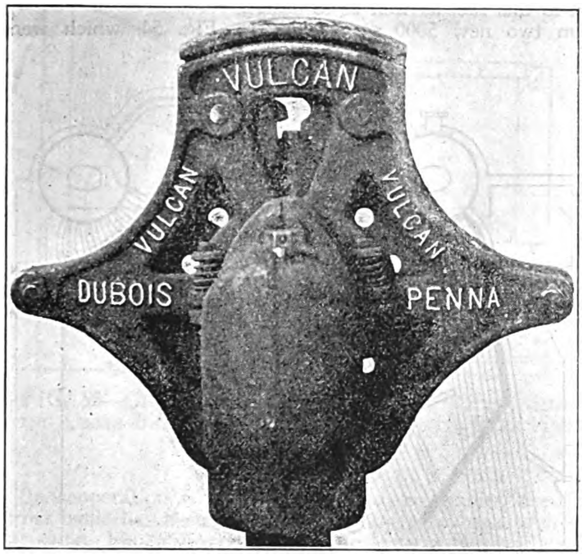


FIG. 49—SOOT BLOWER RATCHET HEAD, THE VULCAN SOOT CLEANER CO.

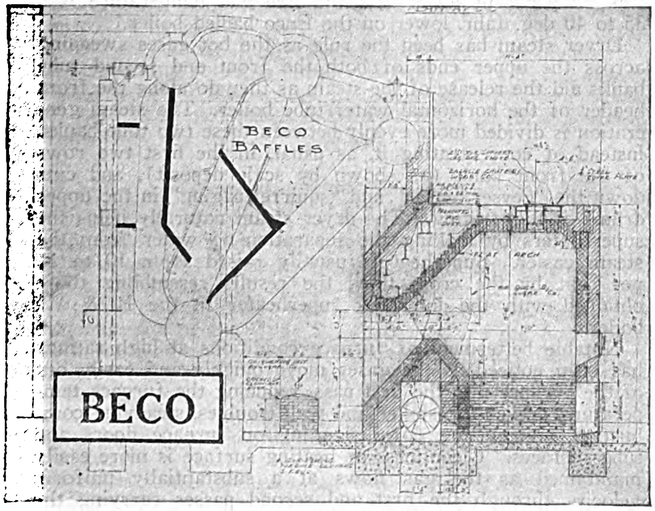


FIG. 50—BECO BAFFLE APPLIED TO CONNELLY BOILER BURNING BAGASSE, BOILER ENGINEERING CO.

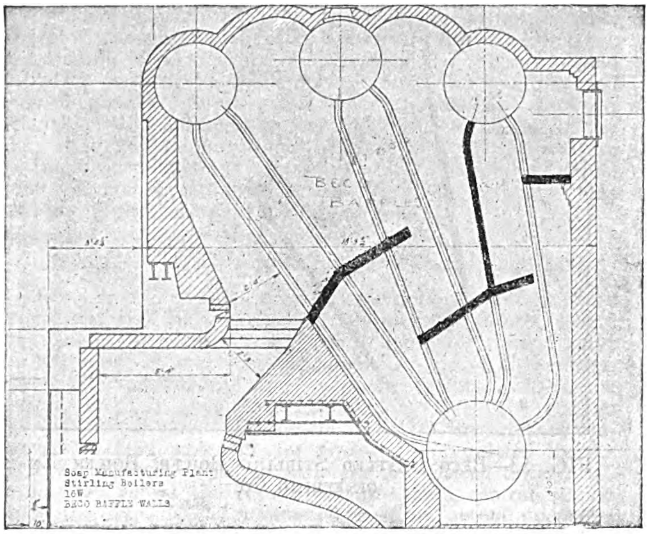


FIG. 51—BECO BAFFLE APPLIED TO STIRLING BOILER, BOILER ENGINEERING CO.

BAFFLING

STATEMENT BY THE BOILER ENGINEERING CO., 931 FEDERAL TRUST BLDG., NEWARK, N. J.

Cross baffling of horizontal water tube boilers has proved to be so successful and, in general, so superior to parallel baffling that the same principles are now being applied to all bent tube types of boilers. Fig. 50 to 53 inclusive show installations of cross baffling applied to bent tube boilers.

In most instances it is possible to cause the first bank of tubes to absorb considerable radiant heat. The employment of high gas velocities through the first bank is discouraged. Ample furnace volume and low gas velocity in the early stages of flow through the boiler give a higher resultant boiler efficiency, and the elimination, in most cases, of slagging troubles. In many instances it is desirable to place the first baffle as many tubes away from the fire as possible. This reduces gas velocity and increases absorption of radiant heat.

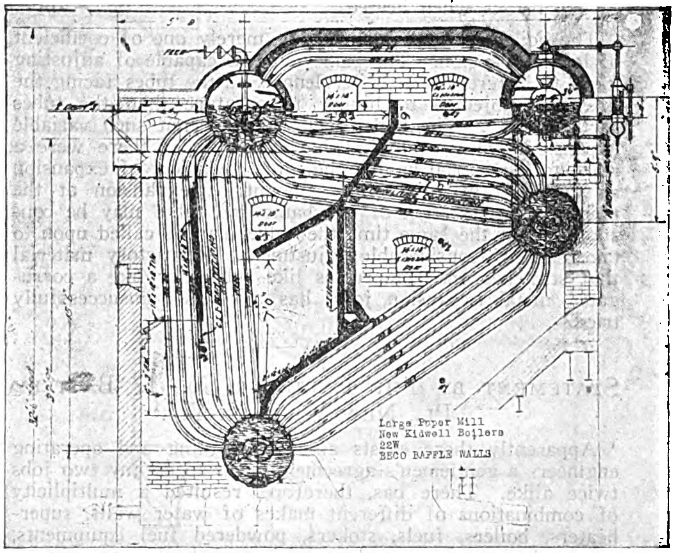


FIG. 52—NOVEL BAFFLING OF A KIDWELL BOILER, BOILER ENGINEERING CO.

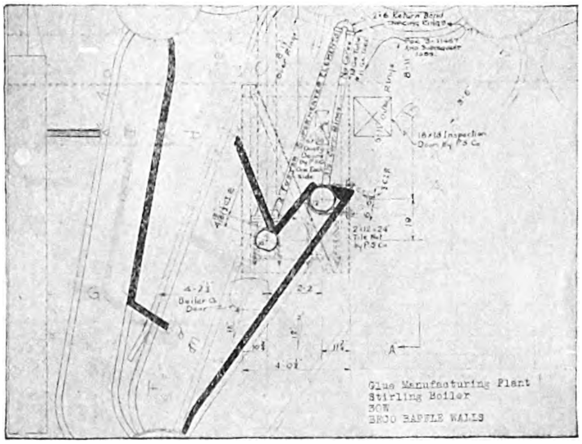


FIG. 53—BECO BAFFLED STIRLING BOILER, BOILER ENGINEERING CO.

An unusual method of baffling a Stirling boiler is shown in Fig. 53. In some installations the baffle has been built straight through the superheater instead of using the roundabout construction shown.

It has been found that reinforcing rods may be used where temperature variations are not great, as in curtain walls. Rods must not be used where there is considerable change in temperature. Corrugated sheet metal separators, 0.0126 in. thick, are inserted through the diagonal alleys. They may disintegrate and corrode without harming the wall in the least and without permitting leakage. The corrugations keep the sections of plastic in place, prevent gas leakage and provide positive expansion joints for preventing cracking.

The following paragraph, from page 5 of the University of Illinois bulletin, on "Thermal Expansion of Fire Clay Bricks," explains why difficulty is experienced in trying to unite steel and plastics where temperature variation is great:

> "It is of particular scientific interest because, as will be shown later, different brands of fire-clay brick expand to different degrees when heated; the expansions are seldom proportional to the increase in temperature, but are subject to very marked and characteristic irregularities; and silica and its various allotropic modifications, which are present in varying concentrations in fire-clay bricks, have very high and irregular, but characteristic, expansions when heated."

The boiler baffle problem is not merely one of coefficient of local expansion. The baffle must be capable of adjusting itself to differences in boiler length, as the tubes facing the fire are subjected to higher temperature than the tubes farther away. The boiler baffle must permit such variable expansion. This could not be done even if there were a refractory material having the same coefficient of expansion as the tube material. The amount of expansion at the points of intersection of the baffle and tubes may be constant, yet at the same time the baffle may be called upon to take care of considerable adjustment. Refractory material that stretches and compresses like rubber or like a corrugated metal expansion joint has also been unsuccessfully tried.

STATEMENT BY THE ENGINEER CO., 17 BATTERY PL., NEW YORK, N. Y.

Apparently there exists among designing and operating engineers a gentlemen's agreement never to do any two jobs twice alike. There has, therefore, resulted a multiplicity of combinations of different makes of water walls, superheaters, boilers, fuels, stokers, powdered fuel equipments, fans and air preheaters that makes each baffle an engineering study and delays the collection of comparable data. Now that experience in application has been gained, the cross baffle may be depended upon to reduce the draft loss through the boiler from 33 to 50 per cent of that obtained at the same ratings with longitudinal baffles. Higher boiler ratings with the same draft at the damper have invariably been obtained and the load on induced draft fans materially reduced; 50 per cent additional rating is usually obtained.

While reduction in flue gas temperatures has not invariably followed the change to cross baffles, it is the general rule; the amount depends, in a measure, on whether the tile baffles originally used leaked badly or only the usual amount. Enco baffles are gas tight so that the reduction is due in part to this fact as well as to design.

On two new 5000 sq. ft. boilers, Fig. 54, which were similar in every respect except the baffling, the draft loss at 300 per cent (10 k-B.t.u. per sq. ft. per hr.) rating was 50 per cent lower and the flue gas temperature was 35 to 40 deg. fahr. lower on the Enco baffled boiler.

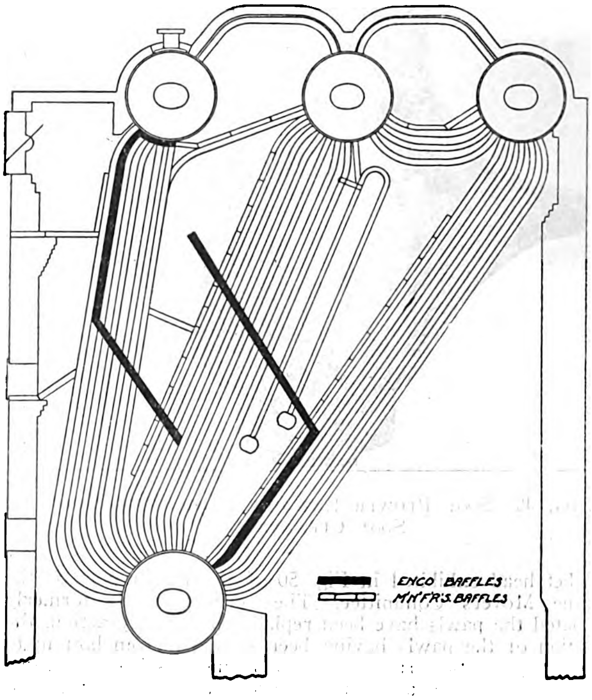


FIG. 54—STIRLING BOILER SHOWING CROSS BAFFLES AND CORRESPONDING LONGITUDINAL BAFFLES, THE ENGINEER CO.

Dryer steam has been the rule as the hot gases sweeping across the upper ends of both the front and second tube banks aid the release of the steam as they do along the front header of the horizontal water tube boiler. The steam generation is divided more evenly between these two tube banks, instead of concentrating it, as usual, in the first two rows of the front bank (as shown by scale deposit), and cuts down the "geyser action" and "squirrel caging" in the upper drums at high rating. The dryer steam naturally helps the superheaters by making the separation of water from the steam easier. Superheat is usually raised from 10 to 20 per cent by the cross flow, the results resembling those obtained with the interdeck superheater in the B. & W. boiler.

Notable betterment of furnace conditions at high ratings has been noticed as the gases move quickly and easily out of the furnace into the first pass, reducing the furnace temperature, preventing stoker and wall troubles, steadying combustion, and cutting down slagging on furnace floors and tube surfaces. Cleanliness of heating surface is more easily maintained as the gas flows at a substantially uniform velocity through the first and second passes carrying the ash and soot in suspension until the bottom of the third pass is reached, where the suspended matter is dropped behind the mud drum.

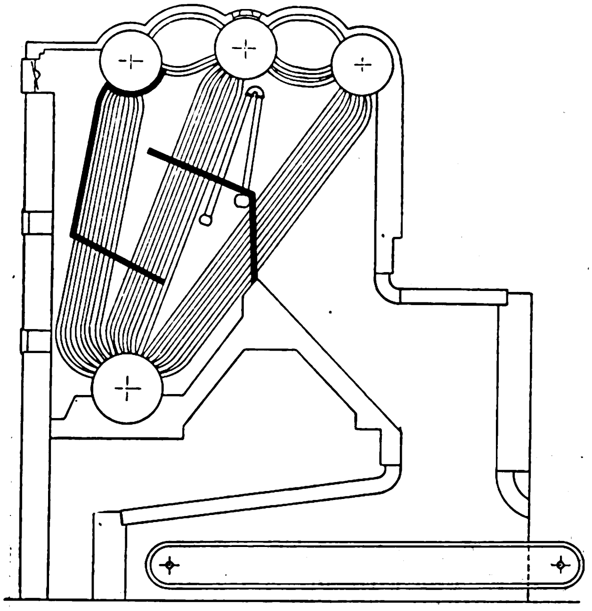


FIG. 55—CHAIN GRATE FIRED STIRLING BOILER SHOWING CROSS BAFFLES IN CONJUNCTION WITH REAR ARCH, THE ENGINEER CO.

In cooperation with one of the arch companies, the Enco cross baffle has been combined with the new back arch construction, Fig. 55, over chain grate stokers burning anthracite coal. An installation at a Pennsylvania public utility plant has given satisfactory results as to increased capacity, fuel economy, cost of maintenance, low ash pit losses, and absence of secondary combustion.

FEED WATER REGULATORS

STATEMENT BY NORTHERN EQUIPMENT CO., ERIE, PA.

Those engineers who have thoroughly studied feed water regulation now recognize that many of the difficulties which have heretofore been attributed to feed water regulators are really due to other causes which the feed water regulator is attempting to correct. For example, variations in excess pressure are really problems of pump discharge pressure control. Changes in feed water temperature which cause violent surges are really heater problems. The change of load from one boiler to another is really a furnace problem. Recognizing all this, a new line of sylphon type equipment has been developed which overcomes many of these external difficulties.

Type SS Differential Pressure Regulating Valve

The new Copes Type SS differential water pressure regulating valve is an important development. This valve, Fig. 56, is designed for use in connection with any type of feed water regulator, and can be installed in either horizontal or vertical feed lines. Valve "A" controls the line from the inlet side of the Type SS valve. "B" is the line to the discharge side of the regulator valve. Sylphon bellows "C," made of 4-ply brass, actuate the control valve "F." The outside of this bellows is subjected to the water pressure at the inlet of the feed water regulator valve; the inside is subjected to the water pressure on the discharge side of the feed water regulator valve. It is subjected only to the differential water pressure, but will withstand an unbalanced pressure of more than 400 lb. per sq. in. It is unaffected by feed water temperatures of 600 deg. fahr., and has, by actual test, stood 93,000,000 reversals without failure.

The effectiveness of the Type SS valve is shown in Fig. 57. The data were taken during a 2-hr. test at the Saginaw River Steam Station of the Consumers Power Company, Zilwaukee, Mich. During the first hour the boiler was held at fairly uniform load, but during the second hour the load varied greatly. At one time when the air was shut off completely the load dropped from 128,000 to 65,000 lb. per hr. within two minutes. Two minutes later the air pressure was back to 120, and the load back to normal. Despite these severe operating conditions, the Type SS valve held the excess pressure within limits of 5 lb.

Type RG Feed Flow-Water Pressure Regulator

The Copes Type RG combined feed flow-water pressure regulator, Fig. 58, combines the differential water pressure regulating valve and the feed water regulator control valve in one compact unit which can be installed in either horizontal or vertical feed line. With a constant load on the boiler, there is a constant opening at valve "C," and no movement of valve "D" or the bellows. Increase or decrease in feed water header pressure is regulated by the bellows and valve "D" to maintain the desired differential. Fig. 59 shows the results obtained in a central station with the Type RG regulator. The steam output fluctuated 28,000 lb. per hr. and the pump pressure showed a variation of up to 55 lb. The excess pressure, as controlled by the Type RG regulator, varied within limits of 5 lb.

Type DS Governor

A new, improved Type DS pump governor, shown in Fig. 60, has been developed. As a first step in designing it, tests were made to compare the action of springs with weighted levers. The spring was abandoned because it de-

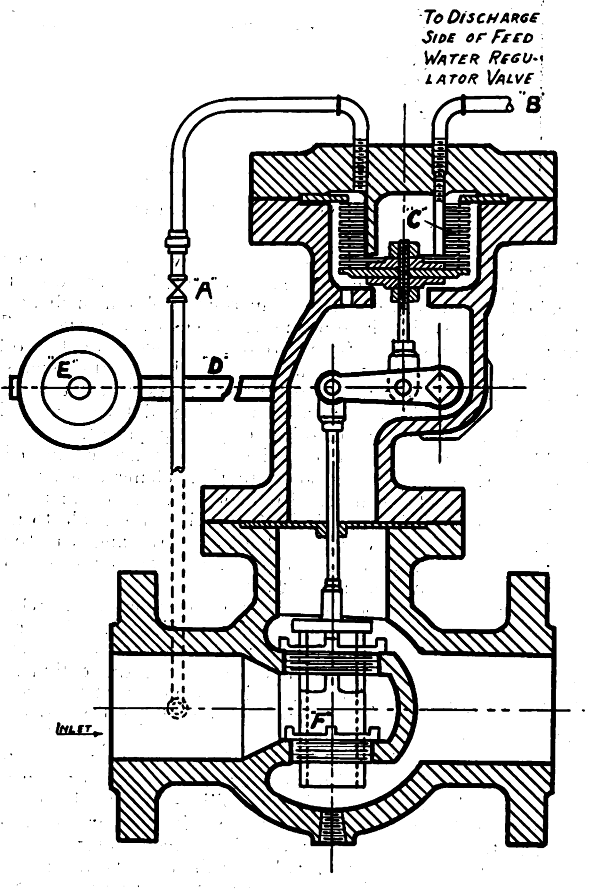


FIG. 56—TYPE SS DIFFERENTIAL PRESSURE REGULATING VALVE, NORTHERN EQUIPMENT CO.

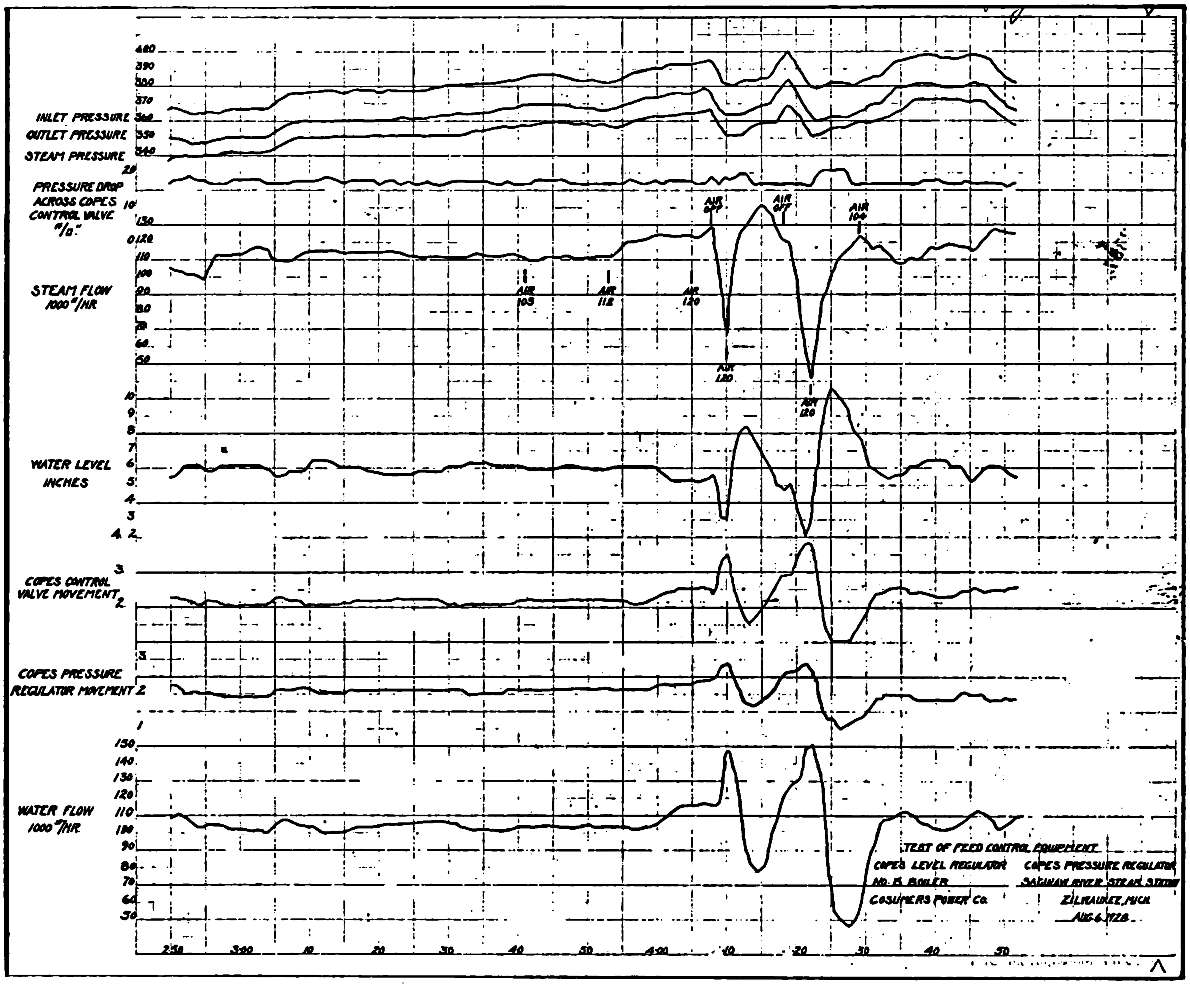


FIG. 57—TEST OF TYPE SS VALVE AT ZILWAUKEE, NORTHERN EQUIPMENT CO.

teriorated quickly, and, even when new, was less accurate than the weighted lever. The weighted lever was then studied in comparison with a mercury column such as has replaced the spring in some newer types of governors. The mercury column was found to be very accurate, but other weaknesses offset its accuracy, and the height makes it rather unwieldy for many installations. As a result of these tests it was decided to retain the weighted lever which has proved so satisfactory in other Copes equipment.

All these things were of minor importance compared to the necessity of having an actuating element which was both strong and sensitive. In theory, a diaphragm is ideal, but in practice it is not. It is practically impossible to make a diaphragm which combines both strength and sensitivity; nor will a diaphragm withstand high steam or water temperatures for any length of time.

For many years the Copes pump governor had a cylinder and piston in place of a diaphragm. This gave better all-around service over a period of years than any other actuating element used up until that time. But the cylinder required oiling. It is on the actuating element that the greatest advances have been made in the new Type DS governor. The actuating element, a brass sylphon bellows, is both strong and sensitive. It is unaffected by high steam or water temperatures, and will withstand an unbalanced pressure of more than 400 lb. It requires no oiling—practically no care of any kind. A horizontal lever shaft, similar to the one used in the control valve of the Copes feed water regulator, replaces the sliding stem valve ordinarily used. This reduces friction to a minimum, and does away with the danger of dirt being carried into the stuffing box. It can also be made much larger, thus increasing the ruggedness of the governor without affecting the balance.

The new Type DS governor is designed for installation on reciprocating, turbine or motor-driven centrifugal pumps. It is suited for differential excess pressure service for boiler feeding, constant pressure service, differential reducing valve service on motor-driven centrifugal pumps, and relief valve service on belt or gear-driven pumps.

All Copes valves, including the SS, RG and DS types for working steam pressures of more than 250 lb., are equipped with outboard ball bearings as mentioned in the 1928 report. For pressures of 1200 lb. and over, the hydraulic relay operated control valve, mentioned briefly in the 1928 report, has been tested thoroughly. The hydraulically-operated valves have operated successfully with water pressure differentials of as high as 500 lb., far higher than that normally found in central stations where the working steam pressure is from 400 to 600 lb.

Type RGF Regulator

In the 1928 report the Type L regulator, controlled by a combination of steam flow and water level movement, was described. The ideas behind this type of regulator have been carried still further by the development of the Type RGF regulator, to feed in proportion to steam flow. Thus the overloading of the boiler with water during periods of light loads, encountered with regulators actuated only by changes in water level, is eliminated.

The unit consists of the Type RGF valve, shown in Fig. 61, and the Type R thermostat designed for high-pressure

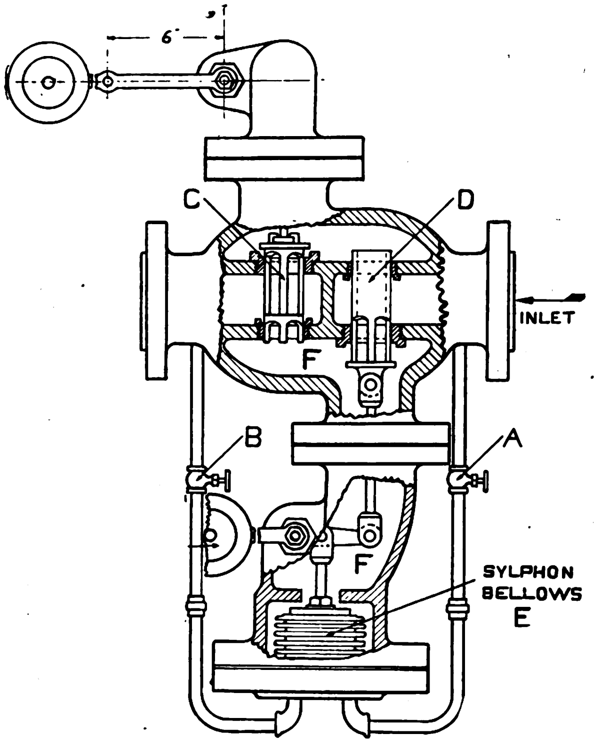

6"
C
D
INLET
F
B
A
F
SYLPHON
BELLOWS
E

FIG. 58—TYPE RG FEED FLOW-WATER PRESSURE REGULATING VALVE, NORTHERN EQUIPMENT CO.

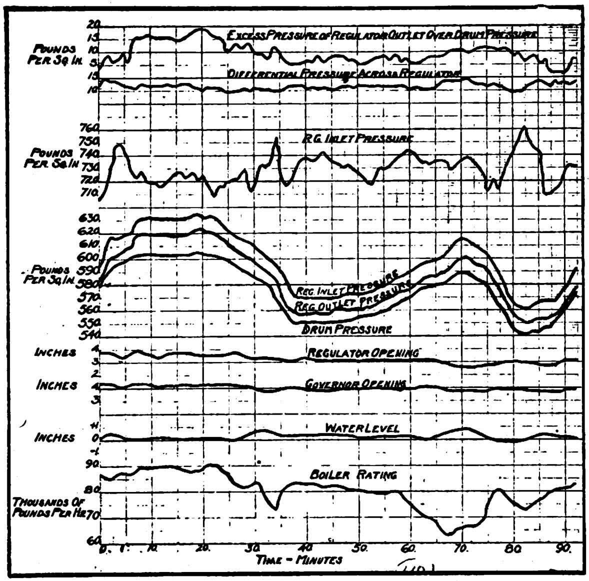


FIG. 59—TEST OF TYPE RG VALVE, NORTHERN EQUIPMENT CO.

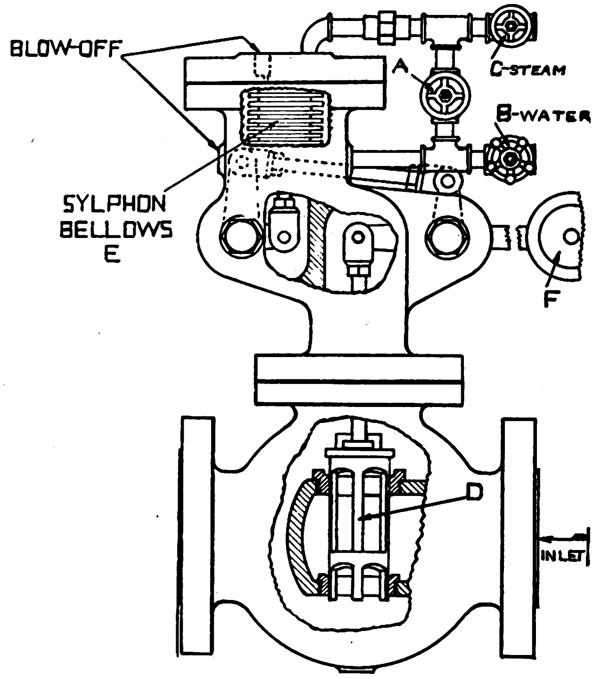

BLOW-OFF
A
C-STEAM
B-WATER
SYLPHON
BELLOWS
E
F
D
INLET

FIG. 60—TYPE DS GOVERNOR, NORTHERN EQUIPMENT CO.

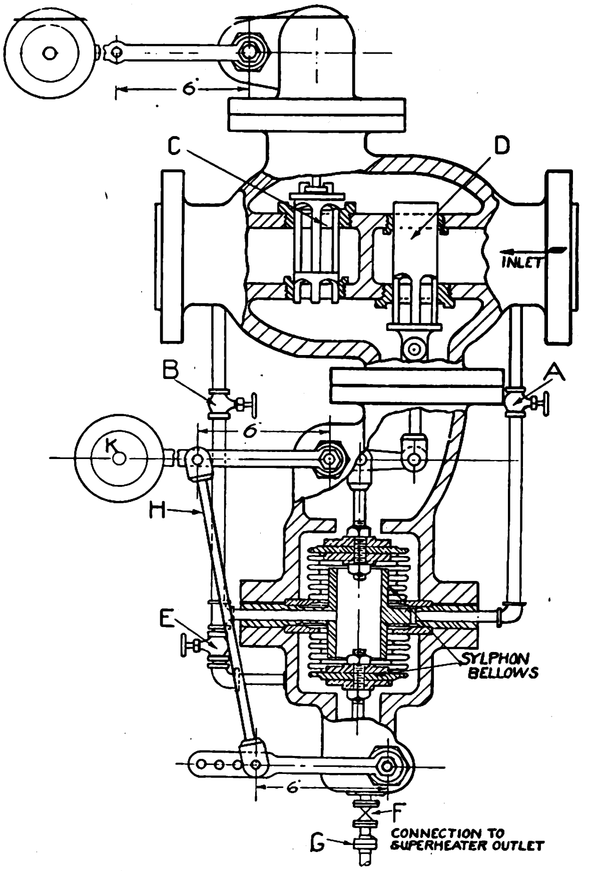

6"
C
D
INLET
B
A
6"
K
H
E
SYLPHON
BELLOWS
6"
F
G
CONNECTION TO SUPERHEATER OUTLET

FIG. 61—TYPE RGF REGULATING VALVE, NORTHERN EQUIPMENT CO.

service. The thermostat is influenced by water level to maintain fixed, safe limits of level. It functions primarily below normal load conditions in bringing boilers up to pressure and preserves a balance on the water input as influenced by variations in steam flow.

The steam flow unit consists of the lower sylphon bellows and bonnet with leverage, and is actuated by the difference in pressure between the regulator outlet and the superheater outlet, or the drop in pressure through the boiler and superheater. The inside of the steam flow bellows is subjected to the regulator discharge pressure which is common to both upper and lower sylphon bellows. The outside of the steam flow bellows is subjected to the superheater discharge pressure. As steam flow increases, the pressure on the discharge side of the regulator and on the inside of both bellows increases proportionately. Under such conditions, the superheater outlet pressure remains practically constant. Therefore, the steam flow bellows have an expanding movement which is transmitted through the levers and strut "H" to the pressure regulating valve "D," giving it a greater opening and thus increasing the differential. As steam flow decreases, the steam flow sylphon bellows contracts and the reverse action of the levers and valve "D" decreases the excess. The design of the leverage is such that it is possible to get a rise in differential equal to the drop through the boiler and superheater. In cases where the drop through the boiler drum and superheater is not sufficient to attain the desired rise in differential, an orifice plate can be installed in the superheater outlet to obtain the desired results.

The Type RGF regulator is designed primarily for high-pressure units, as units operating at low pressures rarely, if ever, produce conditions requiring this type of equipment. Performance of this new regulator has been satisfactory.

The 1928 report also mentioned the tendency to increase the ratio of water storage and liberating surface to the evaporating surface in boilers. This is particularly true on large units operating at high rates of evaporation with wide variations in load. Several of the latest installations are designed with two or more drums. This is advantageous, as storage capacity is provided on light loads to meet peak load requirements. The Copes regulator, feeding continuously, will vary the water level within fixed limits, thereby giving a feed input to meet this water storage requirement.

STATEMENT BY SMOOT ENGINEERING CORPORATION, 136 LIBERTY ST., NEW YORK, N. Y.

Boiler Feed Water Regulation

At low ratings, boiler water level tends to increase rapidly with rating increases. This ratio decreases as the ratings go to higher values, due to the greater velocity of water circulation. This relationship, commonly called "swelling effect," is greater for a given load change when steaming at 200 per cent (6.7 k-B.t.u. per sq. ft. per hr.) than when operating at 300 per cent (10 k-B.t.u. per sq. ft. per hr.) rating.

Where a regulator is set for constant level, it must constantly oppose the natural tendency of the water to change immediately its level with every shift in load. Thus, if the load suddenly drops a little, the natural "shrinking effect" of the water will immediately cause the water level to drop, which causes the feed valve to open on a constant level regulator. This increased water feed tends immediately to reduce further the steaming rate with a resulting additional decrease in water level. This double effect compounded against the constant level regulator is decidedly unstabilizing. To overcome this requires either considerable inherent stability in the regulator or an extremely slow, or unresponsive, regulating device in order that continued oscillations or hunting will not prevail.

Quite opposite to the above is the stabilizing reaction obtained in a feed water regulator by causing a function of the boiler rating to reset the level mechanism to a new value, increasing or decreasing it in proportion to the changed steaming rate of the boiler. If the full extent of this relationship were used (adjusting the regulator to compensate for the entire "swelling effect" of the water), then very little stabilizing action would be needed, because there would be no artificial reactions to correct for, inasmuch as the natural tendency of the water level to shift with load would equal the level produced by the regulator. Under such conditions the regulator on sudden load changes would not have to move immediately, but would only have to adjust the water feed valves to maintain the constant ratio of steam flow to water flow without any interference from the "swelling effect" of the water. The net result at all steaming rates would be to obtain by regulation a constant weight of water in the boiler and not a constant level of water in the boiler drums.

In modern boilers with large water wall areas, the drum capacity in proportion to the tube capacity has been reduced in some cases to a point where the "swelling effect" of the water from zero rating to maximum rating is greater in inches of water than the height of water glass provided. From this it may be concluded that from a safety standpoint it would be better to operate with considerably higher water at high loads than at low loads. As a typical example of common practice, take a large boiler with a 24-in. water glass. The "swelling effect" in this boiler would likely be 20 in. from minimum to maximum load. This means that if the boiler were steaming at its full load, with the water in the middle of the gage glass, and the load were suddenly lost, the water would go down and out of sight by 8 in. The reverse would be true if steaming at a low rate with water in the mid-position, in which case the sudden increase in load to full value would put the water over the top and cause priming.

If instead of carrying the water at a constant mid-position level it had been regulated automatically at full load near the top, then the sudden full drop in load would still have left the water in sight by 4 in. From this, the conclusion can be drawn that not only is a gradually increasing water level desirable from a regulating point of view, but is also safer from an operating standpoint. To obtain this result in a feed water regulator requires an auxiliary loading force, foreign to the regulator itself, which bears some definite relationship to boiler rating. The conventional type of feed water regulator uses some form of fixed characteristic to assist in obtaining stability, whose purpose is to change the control value of the regulator so that the water level is definitely regulated at a lower level at high load than at low load. This characteristic is similar to that inherent in all types of speed governors for controlling engines, turbines or other devices where a large time lag, capacity or inertia is encountered in the regulated response.

In every case, some movement of the regulating device is used to react on the control balance and, in the case of a feed water regulator, to give a progressive reduction in the level setting in proportion to the opening of the feed valve. This action is stabilizing, but if its sense of motion were reversed, then its reaction on the regulator would be very unstable, resulting in continuous hunting.

To obtain the desirable characteristics outlined for increasing water level with rating, it is necessary to use a suitable loading force or pressure, which is a measure of the boiler load and preferably one which follows the same law that governs the "swelling effect" of water in the drums and tubes.

The differential pressure from the boiler drum to the mud drum when plotted against rating, follows the same type of curve as does the water level corresponding to quick rating changes, previously referred to as "swelling effect." Hence, this differential may safely be used to load or adjust a sensitive water level control device inasmuch as it is of sufficiently large magnitude to be of practical use.

Another force equally as positive, and always bearing an exact relationship to rating, is the superheater differential. While this differential varies as the rating squared, it may, nevertheless, be used as a suitable variable loading. Its value is much larger, being measured in pounds where the corresponding mud drum differential is measured in inches of water.

The water level regulator to which these forces have been applied consists of a newly developed control element designed to work in conjunction with a standard Smoot regulator, power cylinder, and stabilizing device. The control element consists of two closed chambers of equal size cast together, and whose bottoms are connected with a free passage. They are partially filled with mercury which, when the casting is tipped, is free to flow from one chamber to the other. The casting is hung on rugged knife edges, centrally located between the two chambers, and the unit is statically balanced with the mercury in place. Pressure connections are taken from the top of each chamber through flexible steel tubing, terminating in a stationary block for suitable piping connections. At the end of one of the chambers, a connecting rod transmits any movement of the chamber casting to a weigh beam, which in turn actuates the regulator power mechanism.

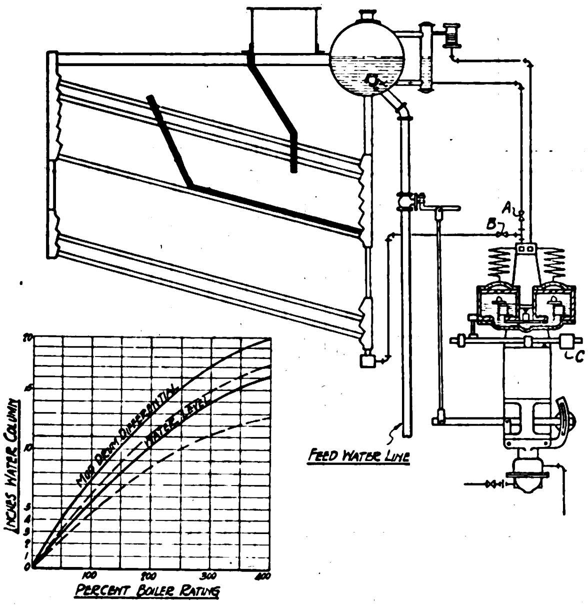


FIG. 62—FEED WATER CONTROL BASED ON MUD DRUM PRESSURE, SMOOT ENGINEERING CORP.

As shown in the diagram, Fig. 62, one of the chambers is piped to a constant level tank, the steam side of which leads to the top, or steam end, of the boiler drum water column. The other chamber connects to the water or bottom end of the water column and thus the two chambers act as a large "U" tube measuring in inches of mercury the differential in water level from the constant level tank to the water level in the boiler drum. Hence, a difference in weight of mercury from one chamber to the other will vary directly with the head of water in the boiler, and this difference in weight is used as a control force to actuate the regulator movement. The weight of mercury is balanced against the weight on the weigh beam. Shifting from one chamber to another in response to changes in water level, the weight of mercury will cause the regulator to respond, giving a controlled water level of constant value. Suitable stop valves of the float needle valve type are provided in each chamber to prevent loss of mercury in the event an excessively high differential is accidentally encountered. One of the outstanding features of this device is the absence of friction in the moving parts as no packings or pressure tight bearings are used. This permits sensitiveness; the degree is not affected in any way by the amount of boiler pressure, as is the case in the diaphragm type of control. This is an important feature when considering the pressures used in modern boilers.

Fig. 62 shows the application of this regulator to a boiler, together with the necessary connections to obtain graduated increasing level with rating when actuated by the mud drum pressure. The two curves show actual test results on a 600 sq. ft. cross-drum Springfield boiler burning powdered fuel. With valve A open and valve B closed, the regulator would control for constant level of water, the level being adjusted by the amount of weight C. With valve B slightly open and valve A open, there would be a flow of water through the valves toward the more negative pressure at the mud drum. As this flow increases, the pressure on the left-hand pressure chamber becomes more negative, causing the regulator feed valve to open and restore the pressure balance in the chambers to its former weight balance. This is accomplished, but in so doing, the water in the drum must necessarily be higher because of the pressure drop due to flow from the regulator chamber to the bottom of the water column through valve A. By adjusting the relative openings of valve A to B, a gradual variation in the magnitude of the opening force and its effect on the water level with rating changes may be had. The effect of such adjustment is illustrated by the dotted curves in Fig. 62.

Fig. 63 shows graphically the difference between water level control based on the ordinary position-level stabilizing characteristic, as shown by curve "B," and control using the new Smoot method above described and illustrated by curve "A."

Starting at light load on curve "A," a given sudden rating change "C" would cause the water level to rise along the dot-and-dash line to approximately 11½ in., and if the rating be then maintained at the full increased value, the water level, due to the regulator action, would check back to the base curve "A" at 10 in.

If the rating is then suddenly reduced by like amount "C," the level would immediately fall to about 4½ in., and then gradually return to the starting point of 6 in. on the base curve "A."

The total maximum water level swing due to the sudden up and down rating change "C" would be the value "a," while if an exactly like load change be traced out on the dotted lines, starting and finishing from the conventional base line "B," the resulting maximum level change would be the value "b," which is nearly double the value "a."

With both methods the sudden swelling effect must be the same. However, with the Smoot method, using a lower level at low load than at high load, the drum capacity for water storage would be used to its full value.

When sudden load changes occur, any given boiler drum capacity in effect is increased over the corresponding effective capacity when the usual method of holding a high level of water at light load and a low level of water at heavy load, is used.

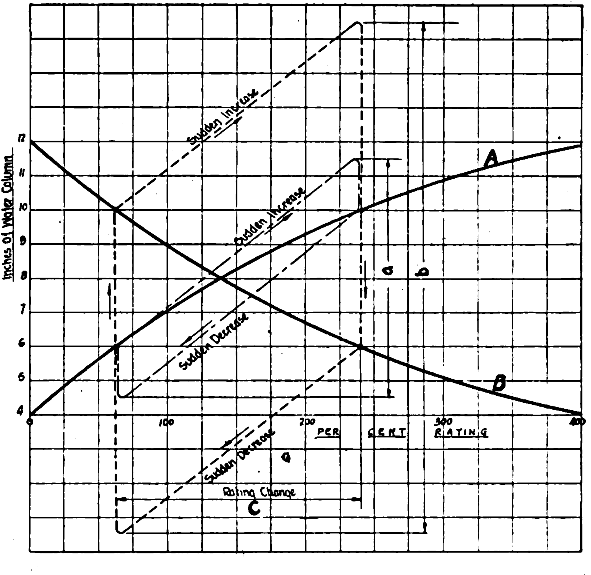


FIG. 63—COMPARATIVE CURVES SHOWING SMOOT WATER LEVEL CONTROL AND ORDINARY LEVEL REGULATION, SMOOT ENGINEERING CORP.

Fig. 64 shows an installation of a regulator of the type described above.

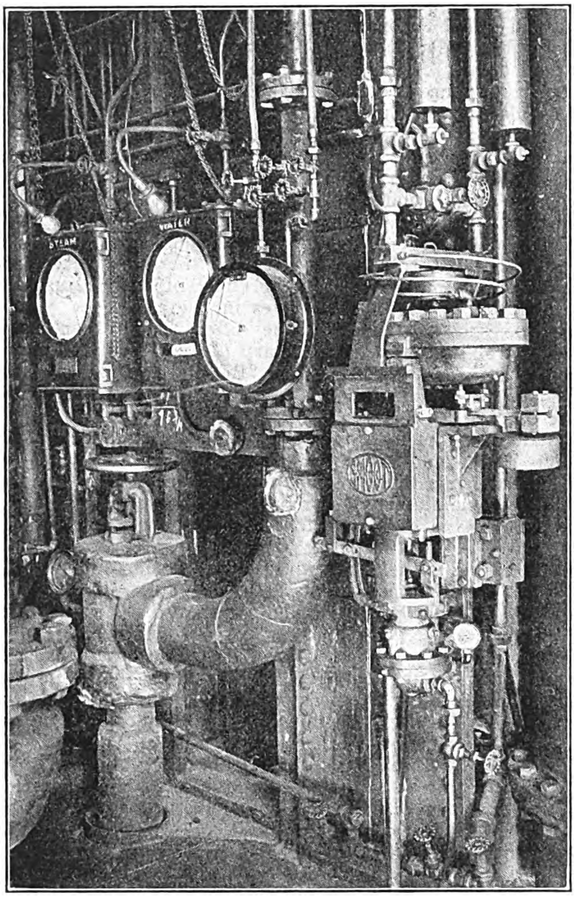


FIG. 64—Feed Water Regulator, Smoot Engineering Corp.

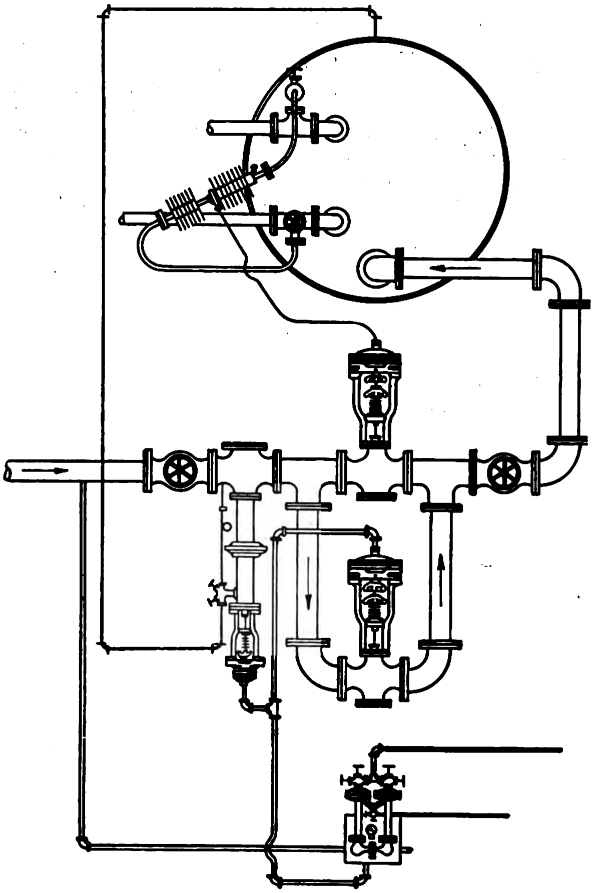


FIG. 65—Water Level and Steam-Flow Feed Water Regulator, The Swartwout Co.

STATEMENT BY THE SWARTWOUT CO., CLEVELAND, OHIO

The feed water regulator has been improved by employing a restricted disk that gives a gradual opening particularly at low ratings, together with a new design of diaphragm that will allow the long travel necessary to secure full opening of the restricted disk. This provides much closer regulation and tends to prevent the hunting action that sometimes occurs in high rating boilers.

Combination Water Level and Steam Flow Regulators

High rating boilers which are subject to sudden load changes are very difficult to regulate from the water line, because a sudden increase in load is accompanied usually by a rise in the water level which closes off the regulators. Thus the boiler is deprived of water at a time when it is needed. Also, when the load is suddenly dropped, the water level drops and the regulators open wide, thereby feeding more water than the boiler is evaporating.

To handle this situation, the Swartwout Co. has developed the system shown in Fig. 65. It consists of a standard regulator operated from the water line, an auxiliary regulator operated from the steam flow and a variable pressure differential valve also operated from the steam flow. These last two valves are controlled by a differential pressure Master Control connected to the inlet and outlet of the superheater. As the rating increases, the pressure drop across the superheater increases. This pressure drop actuates the Master Control and opens the auxiliary regulator, at the same time increasing the differential pressure, both in proportion to the steam flow. The capacity of this auxiliary regulator will be below the boiler capacity so that the water level will gradually drop until the water level regulator comes into action and maintains it at the proper level.

When the load decreases, the auxiliary valve closes and the differential pressure is reduced so that when the drop in boiler water level occurs, even if the main regulator should open wide, the differential pressure will be so low that an excess amount of water will not be fed.

Economizer Protection

To protect the economizer from excess water pressure, the Swartwout Company has developed an excess pressure

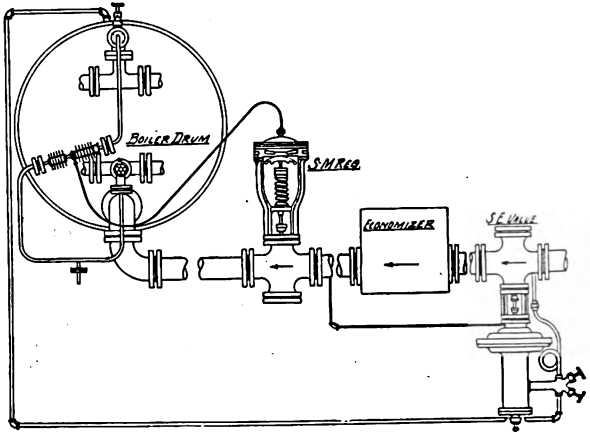


FIG. 66—Excess Pressure Regulator for Economizer Protection, The Swartwout Co.

valve, to be installed ahead of the economizer, that will pass just enough pressure to maintain the required pressure drop across the regulator. This is known as the Type S-E Valve and is illustrated in Fig. 66. The variable excess feature may also be applied to this valve as well as to the steam flow control.

WATER COLUMNS AND WATER GAGES

STATEMENT BY THE BABCOCK & WILCOX CO., 85 LIBERTY ST., NEW YORK, N. Y.

High-Pressure Water Gages

As pressures increased, experience indicated that satisfactory service could not be obtained from tubular water gage glasses, and that with boilers operating at pressures over 350 lb., the life of such glasses was from but a few hours to six weeks.

Pure feed water at a pressure of 350 lb. and upward has a chemical action on the glass, and even were the strength unimpaired, it is quite difficult to avoid breaking the glasses when packing them for pressures of 600 lb. and upward. Flat, plain or fluted gage glasses are better for such high pressures, but deterioration from the action of the water and difficulty in packing render them unsatisfactory.

Double flat glass protected on the water side by mica was then tried successfully under pressures up to about 600 lb., but with higher pressures it was impracticable to pack the glass steam-tight without breaking it.

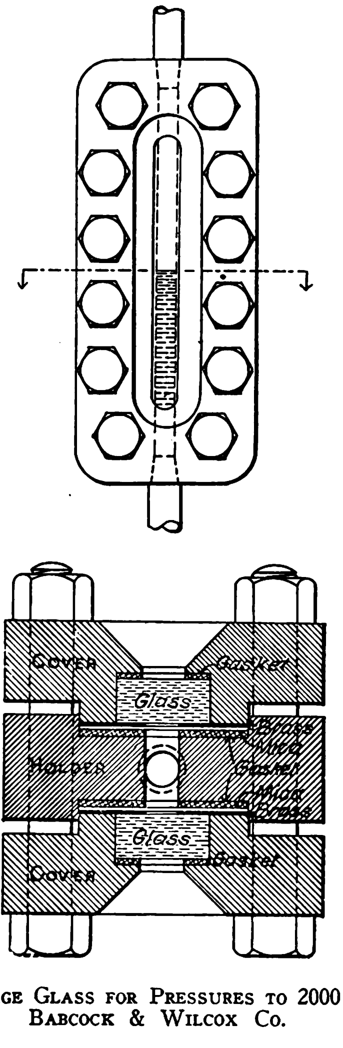


FIG. 67—GAGE GLASS FOR PRESSURES TO 2000 LB., THE BABCOCK & WILCOX CO.

To meet these high-temperature conditions the fitting illustrated in Fig. 67 was developed, which has given satisfactory service under pressures up to 2000 lb., the highest under which it has been tested.

The body comprises a central holder and two covers, each slotted vertically. In the recess in each face of the holder is first placed a gasket, then a sheet of mica and on that a thin brass gasket. In the recess of each cover is placed first a gasket and then a bar of glass about 0.7 in. thick. When the parts are bolted together only the boiler pressure can come on the glass, which is protected from chemical action by the mica. The thin brass gasket seals the edge of the joint between the cover and the glass. In service the glass lasts indefinitely, but the gaskets and mica need renewal in four to six weeks. Two fittings at different elevations are used on the same column when considerable differences in water levels must be indicated.

STATEMENT BY THE NATIONAL CO., INC., MALDEN, MASS.

Flat Gage Glass Illuminators

The present trend toward higher boiler pressures has resulted in the widespread use of the flat type gage glass in order to withstand pressures of 400 lb. and over. The general type of gage consists of a thick glass plate on either side of the gage, held in place by steel face-plates and gasketed with mica.

The illumination of this type of gage depends upon several factors: thickness of glass, collection of dirt and rust by mica gasket, distance of gage from operator, angle of visibility of gage from operating floor, elimination of reflected light from glass surface, establishing a distinct meniscus, amount of rust carried by water, and intensity of illumination.

This company has achieved success in the illumination of this type of gage by using the principle of reflecting light from the meniscus or water level down to the operator. In the Type "D" illuminator, Fig. 68, light is directed upward at such an angle that the light will penetrate the glass and water. That portion of light which strikes the meniscus is reflected down at a similar angle, so that again it penetrates the water and glass and emerges into the air, continuing down to the operator. Other light which does not strike the meniscus continues upward and is dissipated. The result is a bright spot at the meniscus in distinct contrast to the remainder of the gage, which is dark. If the direction of light is at too sharp an angle to the glass, very little light penetrates the glass, and then after reflection very little light emerges. Again, if a light source is placed near the bottom of the gage glass, but no provision made for directing light upward, the result is a lighting up of the bottom part of the glass decreasing to darkness at the upper part of the glass. This gives a contrast between meniscus and glass in the upper portion, but if the water level is low there is no contrast between meniscus and glass in the lower portion. In the Type "D" illuminator, a hood is used to help direct light upward and to confine stray light.

A recent development in flat type gage illumination is the louvre type illuminator, Fig. 69. Using the same principle of reflecting light from the meniscus, this illuminator has several new features. A gain in intensity of light at the top of the gage is obtained by using a larger light bulb in conjunction with a chromium plated mirror of such shape that it directs light upward at the proper angle for penetration of the gage and reflection from meniscus to operator. Metal louvres set at this angle prevent stray light from striking the gage glass at improper angles. The result is a very strong contrast between the dark gage glass and the bright meniscus, regardless of water level. Several mechanical features of note are: the interchangeability of the light bulb so that it may be inserted either right or left hand; pivoting of the metal louvres so that an explosion automatically closes them, thus protecting the light, reflector and glass dust plate; incorporation of a glass dust plate

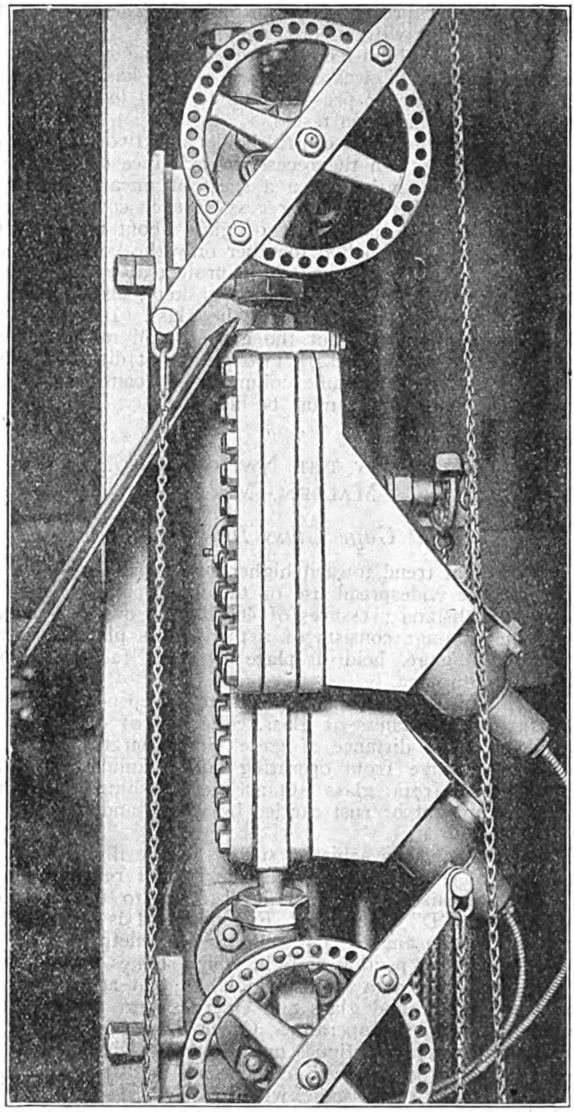


FIG. 68—TYPE D WATER GAGE ILLUMINATOR, NATIONAL CO., INC.

just beyond the louvres to seal the illuminator from dust; easy removal of the louvre unit for the occasional cleaning of the dust glass.

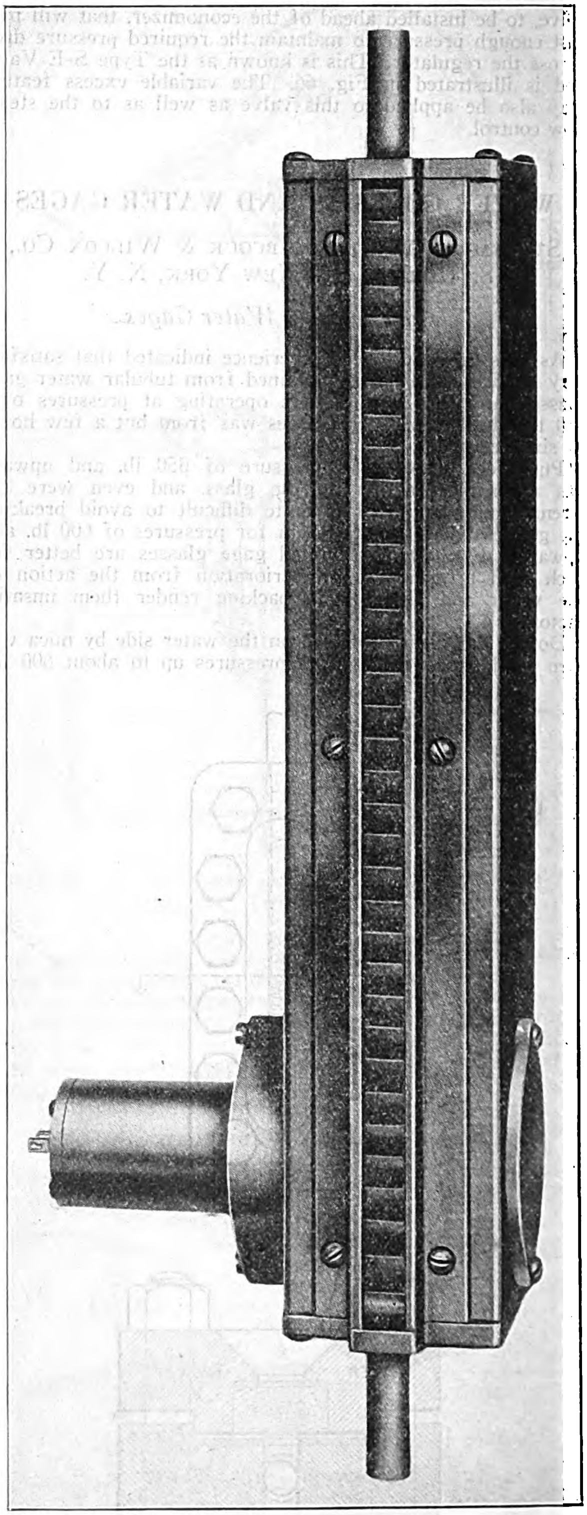


FIG. 69—LOUVRE TYPE WATER GAGE ILLUMINATOR, NATIONAL CO., INC.

STATEMENT BY THE RELIANCE GAUGE COLUMN CO., CLEVELAND, OHIO

Considerable development has been made in the manufacture of floats, although for several years they have ceased to be the limiting factor as regards pressure or temperature. Either the deposited nickel or the drawn monel floats are today the most dependable part of the water column. During the past year the use of copper floats has been discontinued, except on low-pressure work and a few odd sizes. Columns for pressures up to 250 lb. are now equipped with drawn monel metal floats, Fig. 70, reinforced at the center by a steel truss ring; the two sections are fused together on a special machine without the addition of any material. Monel floats stand 200 lb. higher pressure than copper floats of the same weight, are not affected by temperature, stand more abuse and have greatly increased reliability. They are also used in forged steel columns up to 450 lb. For forged steel columns up to 750 lb., a spherical deposited nickel float is used. These floats are regularly tested to 1200 lb.

The Reliance gage cock for pressures up to 450 lb. has been improved to its present design, Fig. 71. The use of a spring as the closing force has been completely justified, and since the adoption of the monel metal spring four years ago no spring failures can be reported. They are not af-

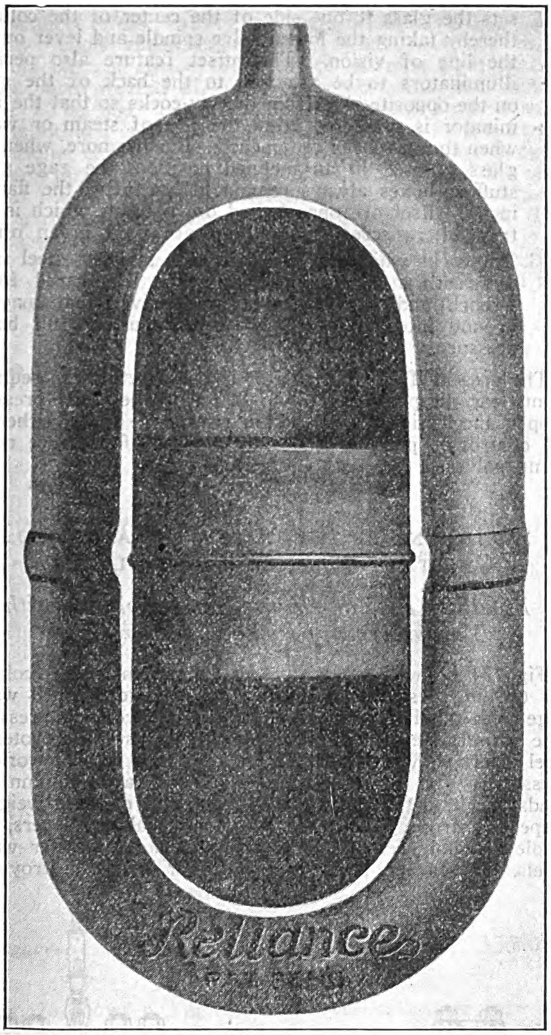


FIG. 70—DRAWN MONEL FLOAT FOR PRESSURES TO 250 LB. PER SQ. IN., THE RELIANCE GAUGE COLUMN CO.

fected by temperature, never corrode and do not lose strength. The new design has a renewable monel seat and a renewable chrome silicon cone valve disk. These parts are readily removed and so designed that the renewed parts are always installed in perfect alignment independent of the threaded portions. For pressures above 450 lb. the design shown in last year's report is used.

Fig. 72 shows the Reliance Tiltview water gage, which consists of a standard water gage with an adapter for inclining it. The adapter consists of bronze angle fittings; the extension piece at the top is a seamless tube which in the flanged type is welded to steel flanges. The horizontal column connections are readily accessible for cleaning by removing plugs.

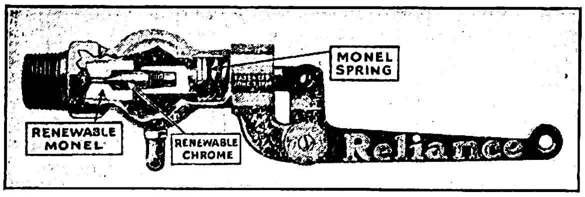


FIG. 71—GAGE COCK FOR PRESSURES TO 450 LB. PER SQ. IN., THE RELIANCE GAUGE COLUMN CO.

The upper and lower fittings are held in alignment by means of a steel tie plate, which also acts as a background to make reading of the level more easy. The alignment is perfected in the shop, and there are no adjustments to make or change at installation. These Tiltview gages are made for pressures up to 750 lb. with flat glasses; the tubular glasses only being recommended up to 400 lb.

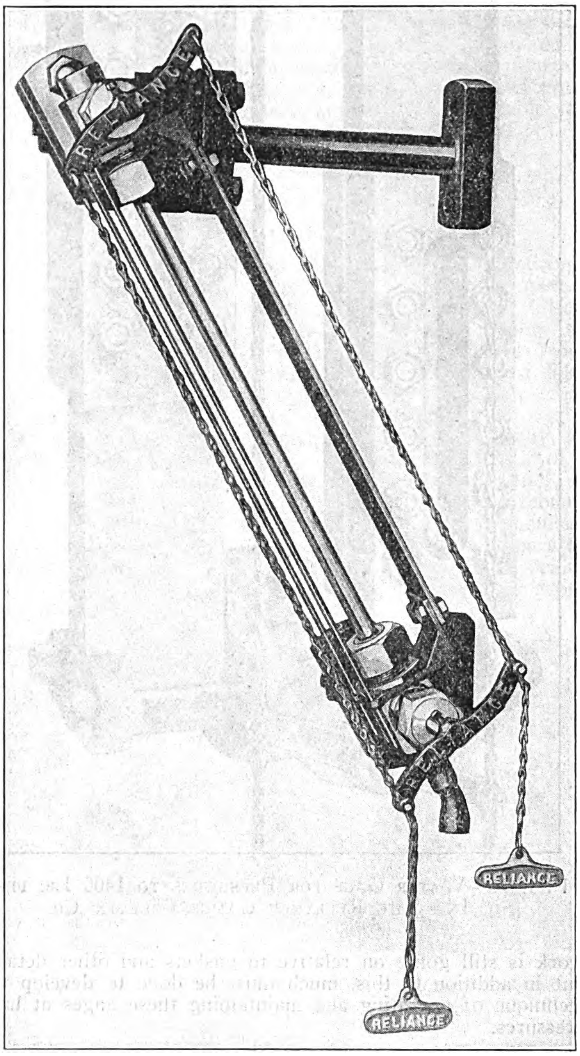


FIG. 72—TILTVIEW WATER GAGE FOR PRESSURES TO 400 LB. PER SQ. IN., THE RELIANCE GAUGE COLUMN CO.

Reliance has water columns equipped with gage cocks and water gages in operation up to 1400 lb. pressure. The water gage, Fig. 73, has flat glasses protected from the action of the steam and water by sheets of mica. Operation has developed certain requirements differing from ordinary water gages. The design must be heavy, so that there is no warping due to pressure, temperature or installation. The workmanship must be of a very high order. The design must be such that in case of replacement an entire glass housing can be removed and a spare put on. This permits careful assembly of the glass, mica and gaskets on a bench in a horizontal position. The assembly should then be steam-tested on the bench and the gaskets followed up when hot. This requires a high grade, careful mechanic, and even such a man cannot get uniform results unless the housing is removed from the column and proper facilities are provided to make a good assembly. Attempting to change a glass on the column is generally unsuccessful. Experimental

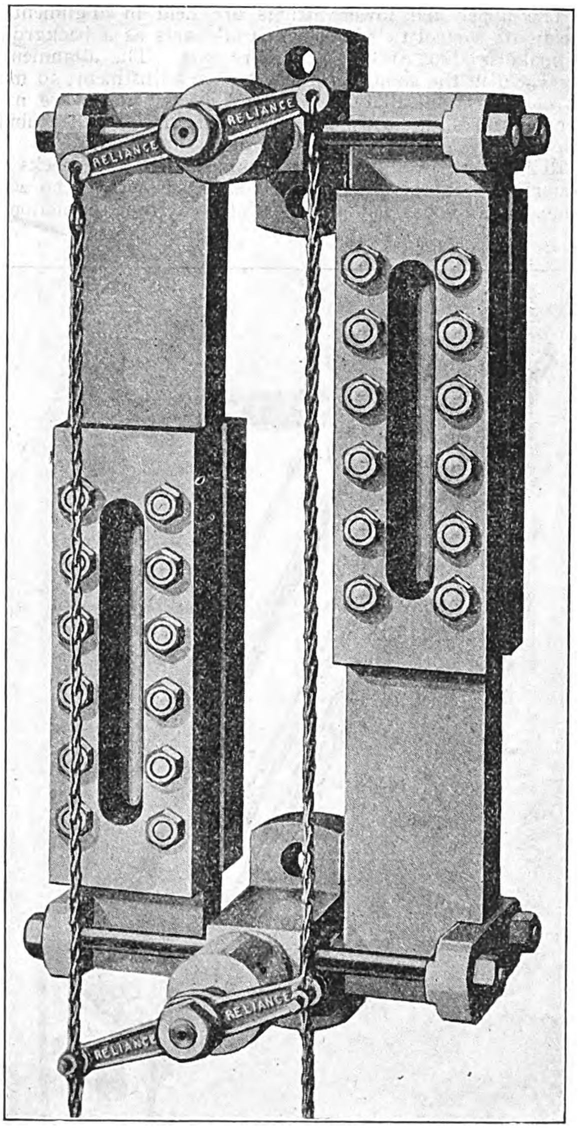


FIG. 73—WATER GAGE FOR PRESSURES TO 1400 LB. PER SQ. IN., THE RELIANCE GAUGE COLUMN CO.

work is still going on relative to gaskets and other details, but in addition to this, much must be done to develop the technique of operating and maintaining these gages at high pressures.

STATEMENT BY THE STETS CO., 141 MILK ST., BOSTON, MASS.

Experience with bronze water gage fittings and try-cocks since pressures of 300 lb. and over have come into use has shown conclusively that bronze is unsuitable for higher temperatures. The metal tends to become brittle, and the threads on the spindles and in the valve bodies break. The use of bronze or brass for water gage valves and try-cocks has been superseded by forged steel with stainless steel trim, either heat-treated or hardened by the Nitralloy Process. In addition to being a 100 per cent wrought and forged steel column, it has three outstanding features:

1. Open, water-filled, non-collapsible floats of large displacement and excess power for operating the whistle valve.
2. A bolted flanged offset in the water gage valves which sets the glass to one side of the center of the column, thereby taking the lower valve spindle and lever out of the line of vision. The offset feature also permits illuminators to be attached to the back of the glass on the opposite side from the try-cocks so that the illuminator is protected from the jets of steam or water when the try-cocks are opened. Furthermore, when the glass is used in an inclined position, the gage glass stuffing boxes always remain in line after the flanges in the offset are once bolted down tight, which is not true where screwed couplings are used in an offset.
3. Try-cocks which are provided with stainless steel spindles with a protruding end, which is squared for a wrench and slotted for a screwdriver that may be ground into the seat with column under full boiler pressure.

The present Type E regulator is still meeting the requirements for all pressures up to 800 lb., where the pressure drop is mechanically held within reasonable limits either by the control of pump speed or by the use of pressure regulating valves.

STATEMENT BY THE YARNALL-WARING CO., CHESTNUT HILL, PHILADELPHIA, PA.

Floatless Hi-Lo Alarm Water Column with Yarway-Sesure Inclined Water Gage

Fig. 74 shows a Yarway Hi-Lo alarm water column for 600 lb. pressure, with a Yarway-Sesure inclined water gage with tubular glass, good for 400 lb. working pressure. The same gage, when using the flat glass mica protected steel insert shown on the left, is good for 600 lb. working pressure. The Floatless Hi-Lo alarm water column depends for its action upon the displacement of solid weights, suspended from opposite ends of two balance levers, the whole assembly being in equilibrium at normal boiler water levels. Whenever high or low water levels destroy the

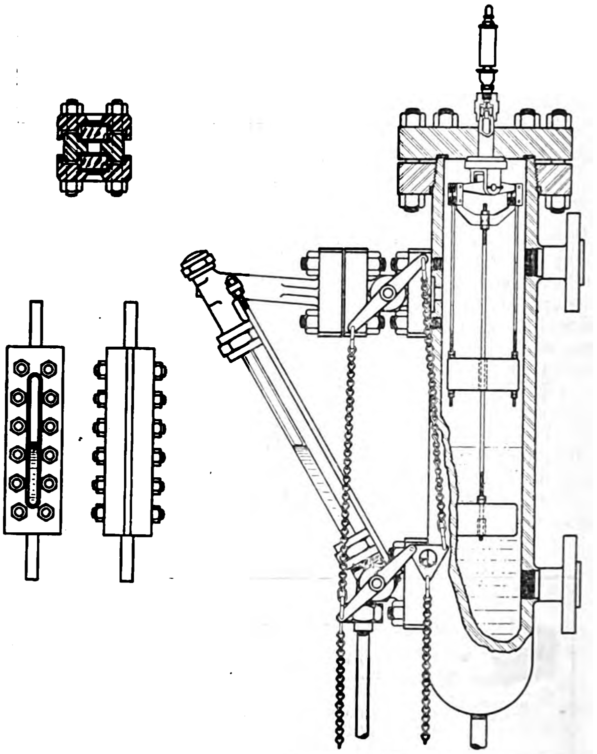


FIG. 74—WATER COLUMN FOR 600 LB. PRESSURE WITH TUBULAR GLASS FOR 400 LB. AND FLAT GLASS FOR 600 LB., YARNALL-WARING CO.

equilibrium of the weights, a rocking motion is imparted to the balance levers, causing a single whistle valve of extremely simple construction to be opened. If desired, a Mercoid electric switch connected to warning light or bell may be used instead of, or in connection with, the whistle alarm. The body of the column is forged from a solid steel billet, and is fitted with two forged steel flanges at the top. Boiler connections for the higher pressures are flanged, shoulder threaded and arc-welded. The studs for the support of the water gage are welded to the shell. The whistle valve parts are of stainless steel, hardened and ground. The tubular glass water gage shown attached to the column is of heavy bronze construction and is good for 400 lb. working boiler pressure; the same gage mountings with the steel flat glass mica protected insert are good for 600 lb.

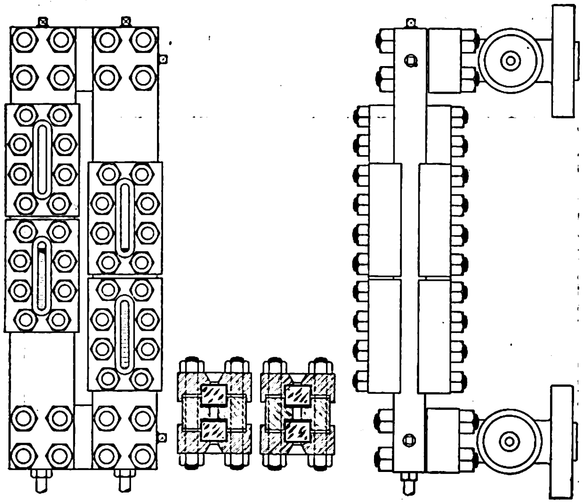


FIG. 75—YARWAY-SESURE GAGE FOR 1350 LB. PRESSURE, YARNALL-WARING CO.

Yarway-Sesure Vertical Water Gage for 1350 Lb. Pressure

Fig. 75 shows a Yarway-Sesure vertical water gage for 1350 lb. This gage is built of forged steel throughout; short flat ground glasses are used, with mica protected inner surfaces. The gage is arranged so that straight through vision is provided, which makes it possible to observe conveniently the water level. Because of the necessarily increased gasket pressure required to prevent leakage, it has been found advisable to shorten the length of the glass units. Four such glasses are shown, conveniently arranged on interchangeable water legs. Round boiler connecting flanges with 4 bolts are recommended for rigid support of these gages. This particular gage is of the vertical form, but can be built of the inclined form.

STEAM PURIFIERS

STATEMENT BY ANDREWS-BRADSHAW CO., DIVISION OF BLAW-KNOX CO., PITTSBURGH, PA.

One outstanding principle which has been determined to an even fuller extent than previously is that complete steam purification can be effected only by reducing the steam and entrained moisture velocity below that point at which atomization of the water particles takes place; i.e., re-entrainment in the steam stream must be prevented.

The outstanding development in the past year has been the adaptation of the Tracyfier principle to line use. In addition, the larger capacity drum-type Tracyfier has been developed and many installations made. The drum-type Tracyfier is put into the steam line at a predetermined point, exactly the same as a valve or separator. It can be placed directly above the boiler steam drum with outlet to superheater or to steam line, or it can be placed almost anywhere in the line. The drum-type Tracyfier carries the definite guarantee of the delivery of "Standard Specification Steam," which is defined as follows:

> "Steam shall be free from all solids, both soluble and insoluble. Samples of condensed steam shall not show more than nine parts total solids per million, which is the tolerance to cover dissolved copper and iron from the test condenser, unavoidable dust contamination during the collection of the sample and its evaporation, and unavoidable errors in the laboratory determination of total solids.
>
> "Steam shall be free from all moisture. Throttling calorimeter tests shall at all times show 100 per cent dry steam, plus or minus not more than two-tenths of 1 per cent, based on the determined normal of the calorimeter. The permitted variation of plus or minus two-tenths of 1 per cent is the tolerance for unavoidable variations in radiation and thermodynamic changes."

STATEMENT BY THE COCHRANE CORP., PHILADELPHIA, PA.

One of the installations of 1928 was the steam purifier installed on a Combustion Engineering Corp. steam generator at the Calumet Station of the Commonwealth Edison Co. The steam generator is fed with a good quality of feed water, the make-up being but 4 to 5 per cent from the Calumet River, the analysis approaching that of lake water. The steam generator operates at 325 lb. The steam purifiers are installed between the saturated outlet of the boiler and the superheater inlet, and have a capacity of 150,000 lb. per hr.

Because of the good quality of the feed water and the fact that moisture in the steam is principally due to mechanical entrainment rather than priming caused by chemical salts, it was found advisable to return the water separated from the steam back to the boiler. This method of draining has been successful because of the low-pressure drops through the purifier.

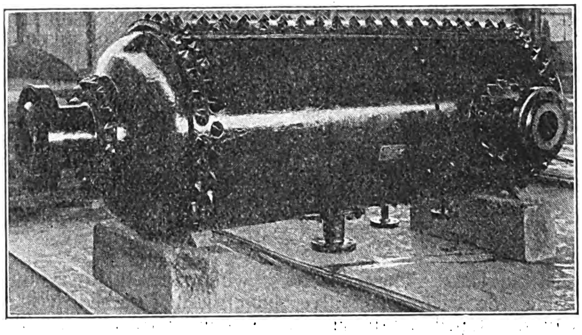


FIG. 76—STEAM PURIFIER FOR 650 LB. PRESSURE, COCHRANE CORP.

The Waldorf Paper Products Co. of St. Paul, Minn., has installed two steam purifiers on its single pass Edge Moor boilers. These purifiers each have a capacity of 250,000 lb. per hr. at 650 lb. Cochrane forged steel dischargers were furnished for draining the steam purifiers. Fig. 76 illustrates the construction of Cochrane steam purifiers for this pressure.

VALVES

STATEMENT BY THE CONSOLIDATED ASHCROFT HANCOCK CO., INC., BRIDGEPORT, CONN.

Safety Valves

In offering an improved line of high-pressure safety valves, it was realized that positive control of blow-down is the

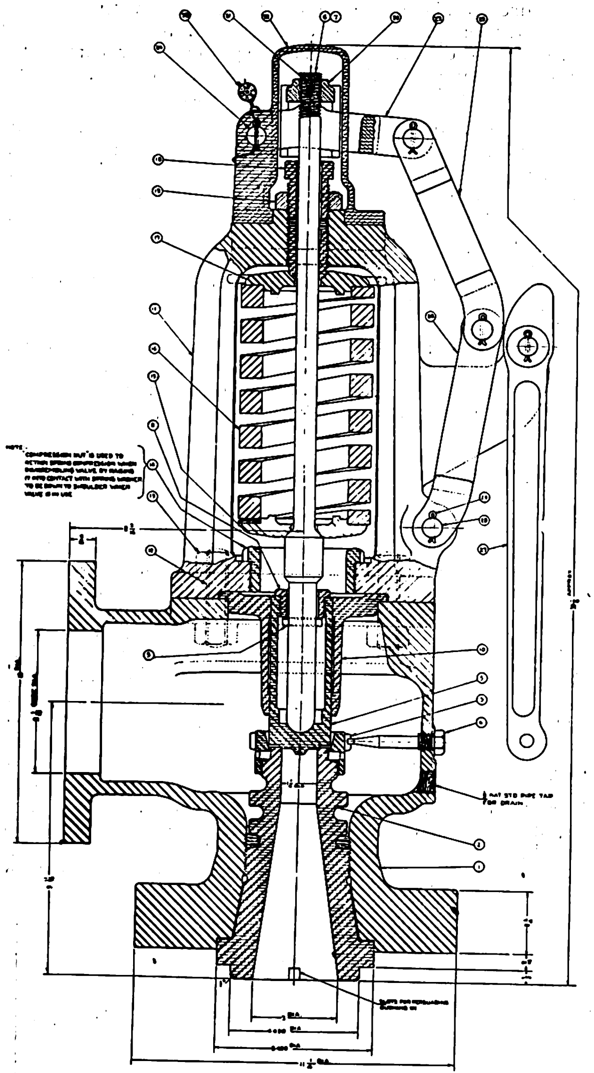

NOTE: COMPRESSION NUT IS USED TO RETAIN SPRING COMPRESSION WHEN DISASSEMBLING VALVE BY RAISING IT INTO CONTACT WITH SPRING WASHER TO BE DOWN TO SHOULDER WHEN VALVE IS IN USE

FIG. 77—SAFETY VALVE FOR 700 LB. TO 1500 LB. PRESSURES, CONSOLIDATED ASHCROFT-HANCOCK CO., INC.

prime requisite. The capacities, which are the maximum possible for each size valve, have been obtained with a newly developed single ring blow-down adjustment. The cut of this new model in its highest pressure range is shown in the Type 1557 valve, Fig. 77, for pressures from 700 to 1500 lb. This shows the adjusting ring to be similar in shape and general design to previous Consolidated rings, except for the addition of a steam vent or passage from the huddling chamber downward through an open annular ring and holes drilled in the side. This vent is too small to affect materially the pop action and lift of the valve, but at the reduced pressure of valve closing it removes enough support from the disk to permit its closing more quickly and sharply for a shorter blow-down.

The anti-distortion seat bushing is an improved development (patented May, 1928) of the original reinforced bushing (patented June, 1915), which the company has furnished in marine valves and in all high-pressure power valves. This bushing has a fluted exterior shape, presenting alternate yielding and unyielding sections, adapted to prevent transmission of distortion from the valve body to the valve seat. The improvement consists in lowering the point of attachment of this bushing to the valve case to a point where the case distortion to be absorbed in the bushing is less, i.e., to the bottom surface of the valve inlet flange.

In addition to these anti-distortion features of the seat bushing, all steam pressure beneath the valve is contained within the forged or high nickel alloy bushing and does not reach the body casting of the valve, which is exposed only to exhaust pressure at periods when the valve is blowing.

Other new features are the guiding of the disk from above, which removes all obstructions to the flow of steam through the throat of the valve; the use of a compression nut, 14, at the bottom of the spring, which permits retaining the set spring compression when disassembling the valve; the cover studs, 12, are now through studs with nuts on both ends and no threading in the flanges, eliminating the possibility of studs breaking off in the flange; the method of guiding the disk practically eliminates all escape of steam from the case while the valve is blowing. Regular Consolidated high-pressure construction is followed throughout, such as in the toggle lifting gear, the full ball-bearing spring mountings, the long length disk guiding and the substantial lock-up.

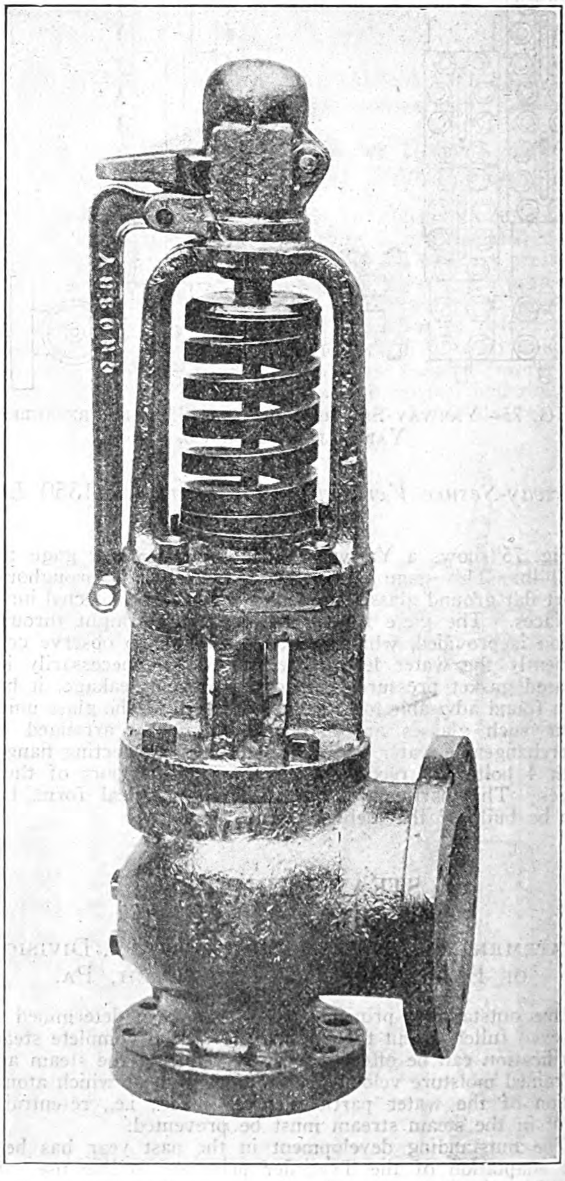


FIG. 78—SAFETY VALVE SHOWING SPOOL INSERTED TO PREVENT HEATING OF SPRING, CROSBY STEAM GAGE & VALVE CO.

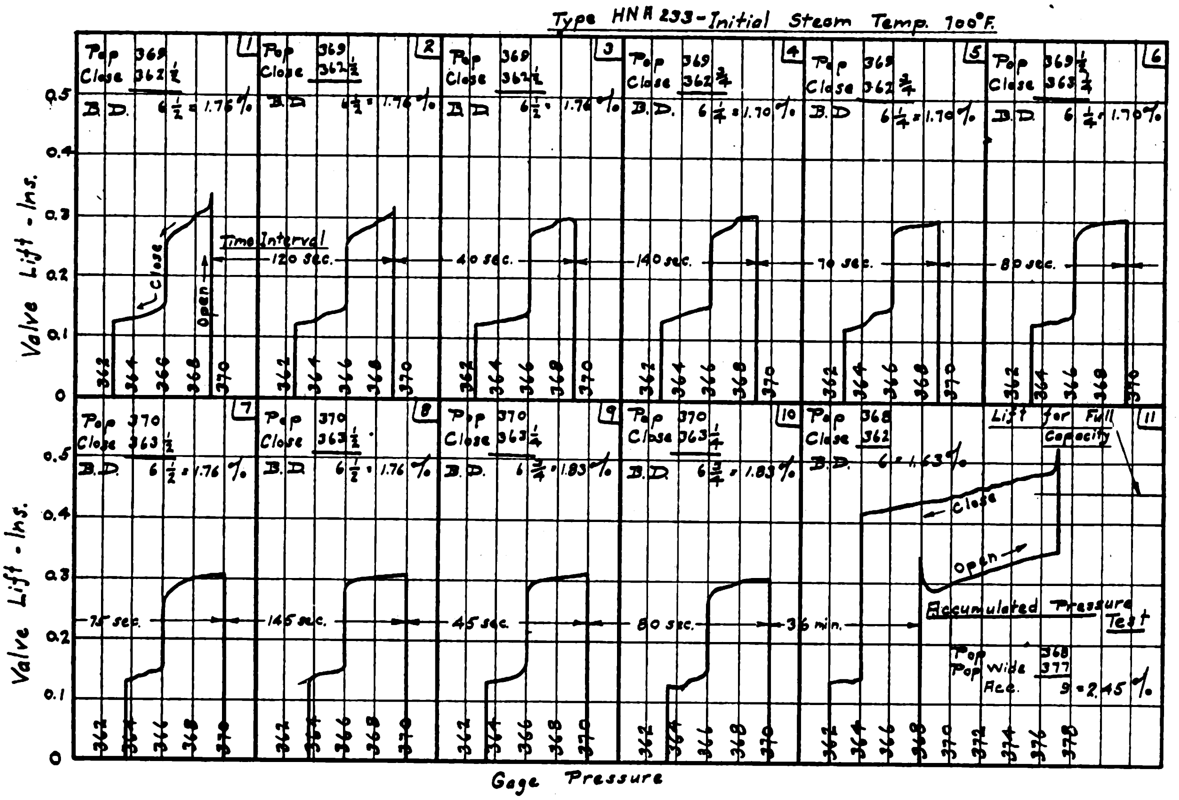


FIG. 79—TYPE HNA SAFETY VALVE CLOSING DIAGRAMS, CROSBY STEAM GAGE & VALVE CO.

STATEMENT BY THE CROSBY STEAM GAGE & VALVE CO., 10 ROLAND ST., BOSTON, MASS.

Safety Valves

The 1926 and 1927 reports contained statements covering the development of the Crosby nozzle type safety valve and the application of the general design to safety valves for all services up to 1500 lb. pressure at 750 deg. fahr. Practical experience with this style of valve now covers a period of over five years, during which no essential changes of design have been found necessary, while at the same time many important refinements have been included, such as closer regulation of blow-down to 2 per cent instead of 4 per cent, as permitted by the Boiler Code. Actual experience has demonstrated that the nozzle type design effects very real economies. Its high discharge capacity permits the use of fewer valves per boiler; the stiff conical nozzle with its seat completely removed from the effects of possible body distortion, and the small symmetrical disk (both parts being high alloy steel forgings), together with the 90 deg. knife edge seats, have reduced leakage troubles to a point formerly thought impossible, thus reducing maintenance costs to a minimum.

During the past year particular attention has been paid to safety valves for service on superheater outlets. In order to protect the superheaters these valves are usually set to blow before the valves on the boiler drum, and so do most of the work under average service conditions. All safety valves must be permitted a proper blow-down to insure proper operation, and this blow-down is always allowed for in determining the set pressure for the superheater safety valves. Having determined the set pressure, however, it is important that the valve pop consistently at this pressure, and close at the pressure corresponding to normal blow-down below it. Any decrease of popping or closing pressures may interfere with station operation.

During the intervals between pops, a safety valve forms a dead end and, even when mounted on a superheater outlet, the valve body and other parts cool down considerably below the temperature which they attain when the valve pops. The closer the spring to the valve body, the more is it subject to these changes of temperature. It is a fact, confirmed by many experimenters, that the modulus of elasticity of any steel, and hence the load which any spring will carry at a given deflection, fall off fairly rapidly with quite moderate increases of temperature, returning to their original values when the original temperature is re-established. This condition cannot be prevented; it is entirely distinct from any question of spring "set," which results from exceeding the elastic limit of the material. As a result, a safety valve will pop and close at lower pressures if the spring is warm than if the spring is cool; to avoid such changes of popping and closing pressures, the temperature of the spring must be kept as nearly uniform as possible.

In the regular Crosby nozzle type HN valves, the spring is entirely above the valve body. This arrangement, while showing a marked improvement over other arrangements, has not been found adequate to prevent all heating of the spring when the valve is relieving high-temperature superheated steam.

To remove entirely the spring from the valve body and to keep it as cool as possible, an extra "spool" has been inserted between the body and the spring yoke or valve bonnet, as shown in Fig. 78. This spool is designed to provide as little metal for conduction of heat from the body to the yoke as is consistent with adequate strength, together with as great a surface as possible for air cooling. This spool can be applied to any regular HN type valve, a longer spindle and a small collar being the only other parts required.

Fig. 79 shows actual tests on a type HNA valve fitted with this cooling spool, mounted on the superheater outlet. The valve was set to pop at 369 lb., the steam temperature being approximately 700 deg. fahr. The diagrams have been carefully traced from the originals, made by means of a lift indicating device, and show the relation of valve lift to pressure. Ten consecutive pops were made, as closely following each other as the pressure could be manipulated. For the ten blows neither the popping nor closing pressures varied more than 1 lb., the blow-down throughout being slightly under 2 per cent. After a wait of about half an hour, a test was run in which the pressure was built up above the popping pressure, to establish the maximum lift and discharge capacity according to A. S. M. E. rating (the A. S. M. E. Boiler Code states that the rated discharge capacity of a safety valve shall be determined at a pressure 3 per cent in excess of that at which the valve is set to blow). Here also the pop and blow-down pressures did not vary more than 1 lb. from those of test No. 1.

These tests not only demonstrate the accurate operation of the valve under this severe temperature, but show the action clearly. As will be noted, the pop is clean and sharp to a lift of about 5/16 in. Closing takes place in two steps, the final drop being from a lift of about ⅛ in. If the pressure increases above the popping pressure, the valve jumps to a lift greater than that necessary to develop "full-bore" capacity of the nozzle, well within the 3 per cent accumulation limit set by the A. S. M. E. Code. With reduction of pressure, closing takes place in two steps, the final drop being as before from a lift of about ⅛ in. These tests show clearly that the valve disk closes on a steam cushion, and thereby eliminates danger of producing a hammer blow.

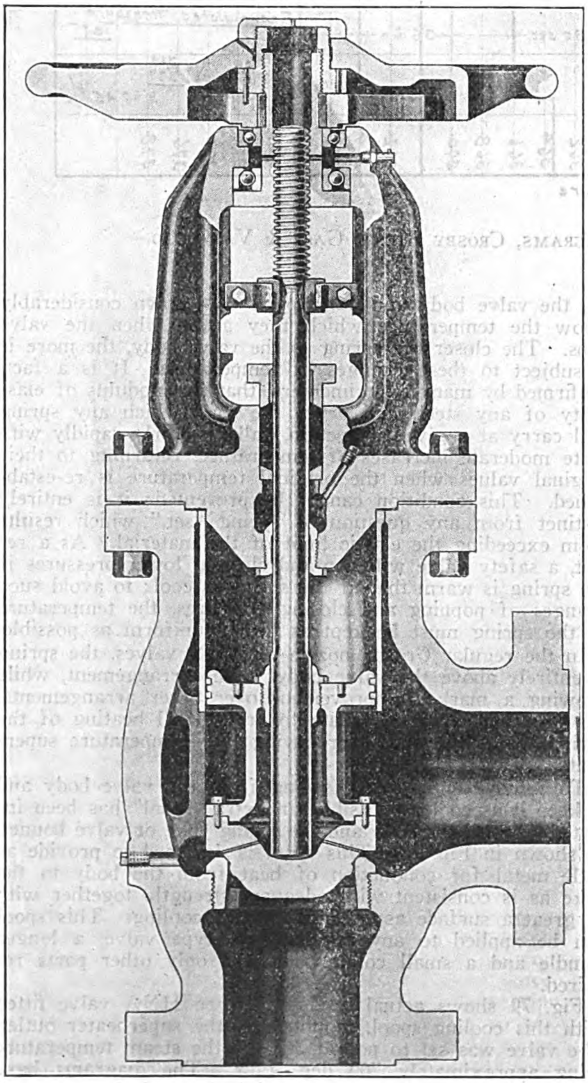


FIG. 80—NON-RETURN VALVE FOR 1350 IB. PRESSURE, THE EDWARD VALVE & MANUFACTURING CO.

STATEMENT BY THE EDWARD VALVE & MFG. CO., 1200 W. 145TH ST., EAST CHICAGO, IND.

Outstanding developments of recent months in connection with design of Edward valves for high-pressure, high-temperature service include:

1. New designs in non-return, blow-off and forged steel stop valves for 1350 lb., 750 deg. fahr. total temperature, conforming to A. S. A. standards. Fig. 80 shows a non-return valve with integrally machined dashpot liner of monel metal, cast steel piston with forged stainless steel disk and seat, stainless steel piston rings, yoke bushings with two combination radial and end thrust ball bearings, and an accessible type of stem key retainer sliding between ribs cast in the bonnet legs.

2. Impactor type handwheel (indicated in cut of non-return valve) for closing against high boiler test pressures. Two heavy hammer weights are cast in the handwheel contacting with a cast steel tee handle keyed to the revolving yoke bushing. This device permits equally distributed application of sufficient force to both ends of the tee handle to enable one man to seat the valve tightly against any required pressure.

3. "Separated" type drumhead stop-check valve, Fig. 81, in which an angle stop valve and a horizontal check valve are incorporated in a single body, the check valve being easily accessible for regrinding through a removable cover. As the stem is in a horizontal position, this type lends itself readily to sprocket wheel and chain operation. With the addition of a single stop valve, this combination meets the minimum boiler code requirements for feed pipe valves. This valve has been manufactured in pressures up to and including 1350 lb.

4. More frequent use of spur gear trains for manual operation of stop valves in connection with higher pressures.

5. Noticeable increase in the use of bleeder line non-return valves.

6. Redesign of blow-off valves for 250 lb. pressure, A. S. A. standards, embodying such features as reversible seats and disks and a compression spring to compensate for thermal expansion and contraction.

STATEMENT BY THE YARNALL-WARING CO., CHESTNUT HILL, PHILADELPHIA, PA.

Yarway Seatless Blow-Off Valve for 1350 Lb.

Fig. 82 shows a Yarway seatless blow-off valve which has recently been built for 1350 lb. boiler pressure. The body and yoke of these valves are steel forgings; the plunger, upper and lower follower rings are of Everbrite; the stem is of steel, and the packing of regular Vulcabeston asbestos fiber material, compressed into a solid yet resilient mass. The lower packing is further protected by armored nickel alloy rings. The valves are fitted with ball thrust bearings and are provided with planetary gear operation when the service demands it.

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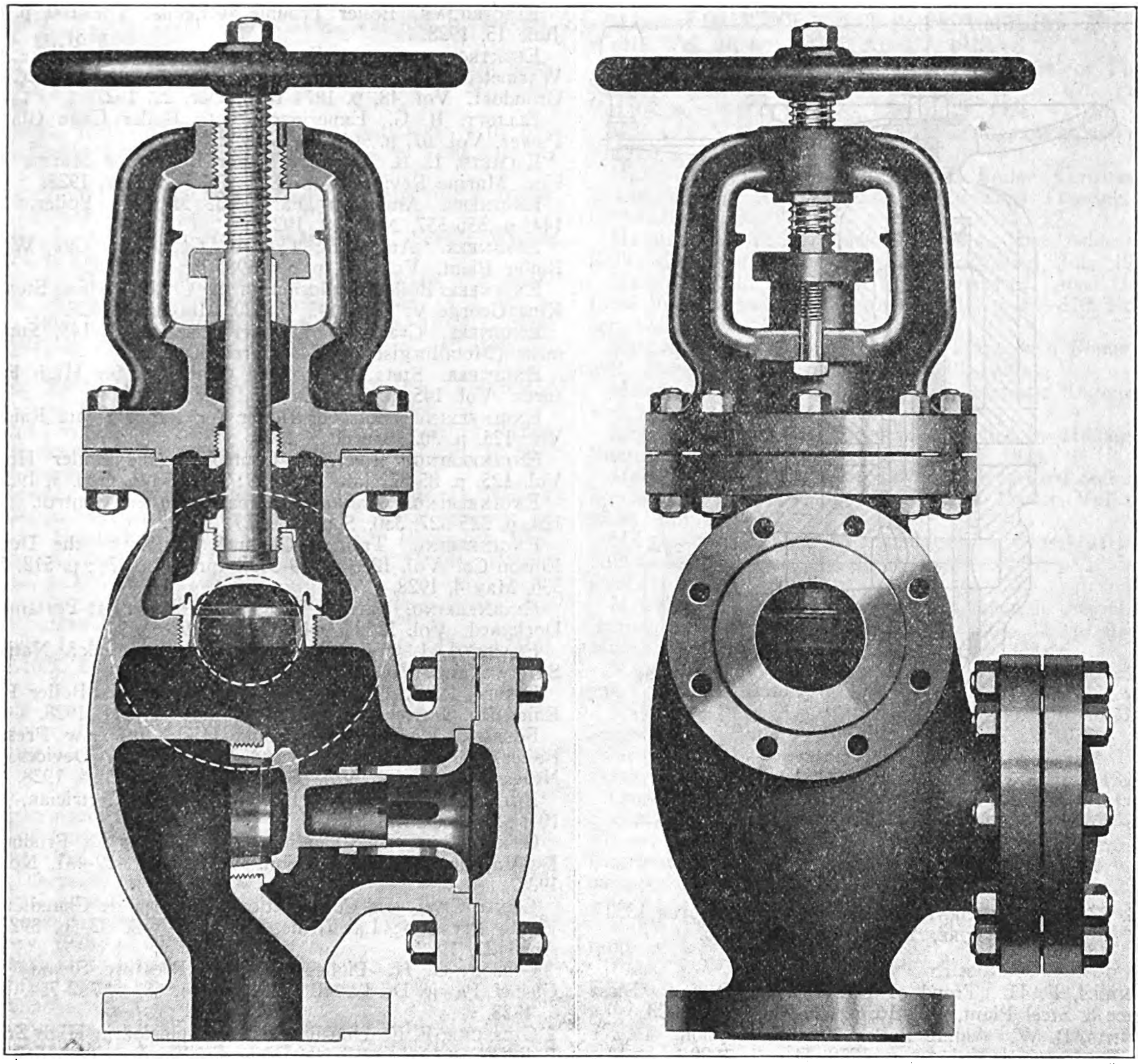

FIG. 81—Stop-Check Valve for 400 Lb. Pressure, Side View and Cross Section, The Edward Valve & Manufacturing Co.

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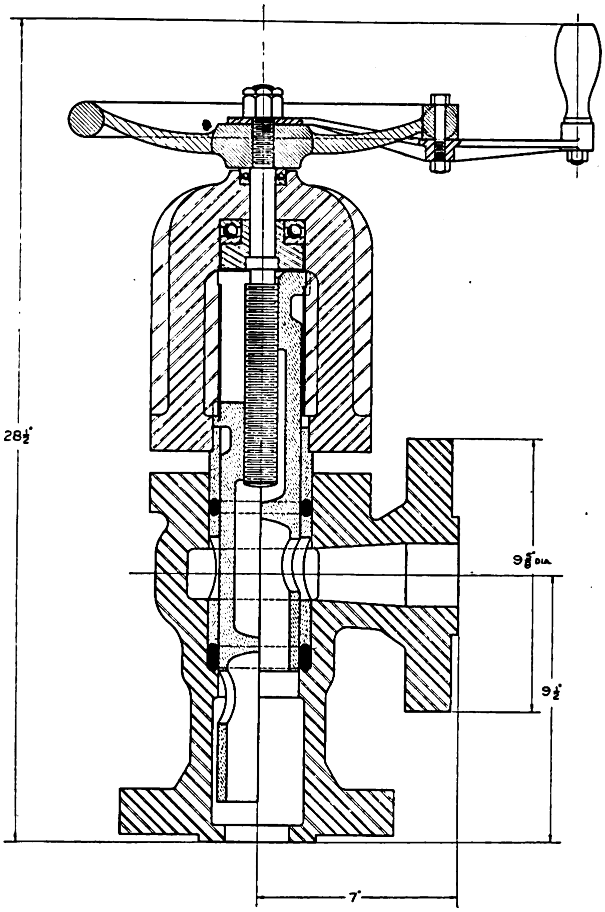

FIG. 82—YARWAY SEATLESS BLOW-OFF VALVE FOR 1350 LB. PRESSURE, YARNALL-WARING CO.

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TURBINES

Abstract

The 1927 report presented the detail operating record for turbines of 20,000-kw. capacity and larger for the year 1925. The present report presents a summary of the 1926 record of 153 turbines, 1927 record of 186 turbines and the detail 1928 record of 207 turbines. The 1928 record shows an increase in the per cent of total time units were available for service and when compared with the 1925 record the unit outage shows a reduction of approximately 25 per cent.

An investigation of the turbine operating methods disclosed that there is no consistency in the time in which cold machines of equal capacity are brought up to speed and loaded. Neither was there found any definite relation between major turbine troubles and the machine operating methods.

Troubles incident to turbine blading form the greatest single cause of turbine outage. This presents a problem that requires most careful attention to details in design, manufacture and operation. In this connection troubles due to deposits in turbine blading were reviewed. Although no method of cleaning blading which would be universally applicable was evolved, information presented should be helpful in suggesting a method of approach when these troubles are encountered.

The majority of operating companies inspect turbines annually. However, a tendency to increase the period between inspections is apparent.

Tests on turbo-generator units ranging in capacity from 6000 to 60,000 kw. are included. In previous years the tests reported were made with the unit operating straight condensing. In this report tests are presented for some units operating on the regenerative cycle with detail data included on the performance of the extraction heaters. The effect of varying exhaust vacua and evaporator operation, on economy when the unit is operated with bleeding; also data for the same unit operated straight condensing and on the regenerative cycle, are included.

The report contains statements by operating companies on new installations, special tests and unusual operating experiences. Also manufacturers' statements on turbine blading, large steam turbines and turbines used for auxiliary drive.

A bibliography concludes the report.

COMMITTEE STATEMENT

Review of Present Trend in Turbine Design and Operation

The survey made by the Committee and upon which this report is based, appears to indicate that since the last report, in 1927, the trend in the industry has been toward the use of higher steam pressures, increased capacity per unit installed, a reduction in the ratio of average yearly installed capacity to system demand, a reduction in the average outage of units reported, automatic control of frequency, and more care in station operation particularly with regard to the starting and stopping of large units.

There were many developments in design and manufacture of turbines such as the more extensive use of steel castings, greater use of non-corrosive blade material, more efficient and rugged blade or bucket fastening as exemplified by the general use of the outside dovetail by the General Electric Company and the serrated type of fastening by the Westinghouse Electric & Manufacturing Company, improvement in blade finish eliminating sharp edges and surface marks thereby reducing the tendency for cracks to develop, and improvement in provision for freedom of expansion particularly at the high-pressure end.

The present capacity limit for turbines to be installed is 75,000 kw. for single cylinder, 160,000 kw. for tandem compound and 208,000 kw. for cross compound units. Machines of a capacity up to 165,000 kw. are being built for operation at 600 lb. per sq. in. and up to 55,000 kw. capacity for operation at 1200 lb. per sq. in. steam pressure.

The mercury turbine now seems to have been developed to a favorable degree. It is estimated that a combined steam and mercury plant can be built to produce a kw-hr. from 10,500 B.t.u. and at a cost worthy of its consideration.

The Westinghouse Electric & Manufacturing Company adopted the so-called hydraulic type of governor for large units. Governors of this type had been in use for many years on small turbines. Favorable reports were received from operating companies on the performance of this new type of speed control equipment on large machines.

There is at present no apparent trouble on units

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reported that is of a general nature. Some isolated cases have proved very stubborn of correction.

There seems to be little, if any, improvement in the average availability of turbines during the first year of service. This is probably due in a large measure to the impossibility of operating large turbines under power station conditions in the manufacturers' shops. A considerable amount of development and correction of defects of design and manufacture must be done in the field.

It is believed that the manufacturers are seeking diligently to hold such field development to a minimum. Perhaps a standardization by our industry on sizes, types and operating conditions would do more to improve steam turbine operation than may be accomplished in any other manner.

RECENT LARGE TURBINE ORDERS AND INSTALLATIONS

The average capacity of turbo-generator units installed by operating companies increased very rapidly in recent years. During 1928, turbines were placed in operation that for the first time exceeded a unit capacity of 100,000 kw. The largest unit now in service is the 165,000-kw. triple cross compound unit at the Philo Station. The 208,000-kw. triple cross compound unit for the State Line Generating Co. will soon be in operation.

Units now on order establish new capacity records for machines of their particular type and include two units rated above 100,000 kw. The maximum capacity of the single-cylinder type of turbine increased from the 65,000-kw. unit at the Edgar Station to the 75,000-kw., 1800-r.p.m. unit for the Cahokia Station. The multi-cylinder, tandem-type of turbine increased in capacity from the 94,000-kw. unit at Long Beach Station No. 3 to a 160,000-kw. unit on order for the East River Station.

There is a greater use of steam at higher pressures as evidenced by the machines on order or recently installed. The 10,000-kw., 1200-lb. per sq. in. turbines at the Edgar and Northeast Stations represent the highest capacity of this type of machine now in operation. Deepwater and Holland Stations have on order 1200-lb. per sq. in. turbines that will operate as high pressure elements of cross compound machines rated respectively at 53,000 and 55,000-kw. capacity.

Table I shows the large or special turbines that were recently placed in operation. Table II presents similar data for turbines on order or under construction.

TURBINE OPERATING DATA

1926 and 1927

The performance of 153 machines for the year 1926 and 186 machines for the year 1927 was analyzed. Operating data for these years, presented in Table VIII, are used in determining the general trend of unit performance over a period of years.

1928

The operating data of 207 units, ranging in capacity from 20,000 to 110,000 kw. were compiled for the year 1928. The operating factors and the causes of outage are presented in detail to show the trend in the performance of these machines.

The operating records for each of the 207 machines, for the year 1928, are graphically presented in Table III. In this table the units are classified according to their first service year and the per cent turbine capacity used. The annual period of 8784 hours is divided into the time the machine was operated, the time it was in reserve and the time during which it was unavailable to carry load because of an outage of the turbine, generator, condenser or because of other conditions not attributable to the unit.

The capacity of the unit and the identification number, the same as that used in the 1927 report, are shown at the left margin of Table III. The letters A, B, C and D, at the right margin of this table, refer to the manufacturer of the turbine. The letters S., T. C., and C. C. refer respectively to single cylinder, to tandem compound and to cross compound types of turbines.

A summary of the operating record is shown in Table IV. In Table V the operating and outage factors are tabulated with respect to the first service year of the machines included in the 1928 operating record.

The 207 turbo-generators are classified in Table V according to the character of service to show the system demand for the machines. The relation between the demand and the availability of these units is presented in greater detail in Table VI, where the machines are classified according to the service demand factors. A service hour classification of machines is presented in Table VII to show the relation between operating and outage time with the units grouped according to their first service year.

The 1928 service record of each machine is graphically presented in Fig. 1. In this figure are shown the total outage hours, the service hours and the reserve hours in per cent of total period hours for every unit reported and the general distribution of outage for all units. The machines with high service hour factors are not the machines that show a high total outage. Turbo-generators that are normally in continuous service and operate more than 80 per cent of the time show a total outage of only 5.77 per cent. The total outage increases with a decrease in operating time until service hour factors are

TABLE I

TURBO-GENERATOR UNITS—LARGE OR SPECIAL TURBINES RECENTLY PLACED IN OPERATION.

Capacity Kw.	*Manufacturer	Operating Company	Station	**Type	Speed R.P.M.	Volts	Steam Conditions - Remarks
165,000	G.E.	Ohio Power Co., Philo, Ohio.	Philo	C.C.	1800	11,000	600 lb. - reheating. Highest capacity unit in operation.
160,000	Brown-Boveri	United Electric Light & Power Co., New York, N.Y.	Hell Gate	C.C.	1800 1200	13,800	275 lb., 610 °F. Highest capacity double C.C. unit in operation
110,000	West.	Brooklyn Edison Co., New York, N.Y.	Hudson Avenue	C.C.	1800	13,800	400 lb., 706 °F.
104,000	West.	Commonwealth Edison Co., Chicago, Ill.	Crawford Avenue	C.C.	1800	12,800	550 lb. - reheating.
94,000	G.E.	Southern California Edison Co., Los Angeles, Calif.	Long Beach No. 3	T.C.	1500	16,500	400 lb., 725 °F. Highest capacity single shaft turbine and largest generator in operation.
91,500	G.E.	Commonwealth Edison Co., Chicago, Ill.	Crawford Avenue	C.C.	1800 1200	12,000	550 lb. - reheating.
75,000	G.E.	Buffalo General Electric Co., Buffalo, N.Y.	Chas. R. Huntley	S.	1500	12,000	250 lb., 660 °F. Highest capacity single cylinder type of turbine in operation.
65,000	G.E.	Edison Electric Illuminating Co., Boston, Mass.	Edgar	S.	1800	14,000	350 lb., 725 °F.
60,000	West.	Milwaukee Electric Railways & Light Co., Milwaukee, Wis.	Lakeside	S.	1800	13,800	290 lb., 700 °F.
55,000	G.E.	Super Power Company of Illinois, Pekin, Ill.	Pekin	T.C.	1800	22,000	600 lb. - reheating. First 22,000 volt generator in operation.
50,000	Allis-Chalmers	Public Service Company of Northern Illinois, Waukegan, Ill.	Waukegan	T.C.	1800	12,000	600 lb., 725 °F.
50,000	G.E.	Detroit Edison Co., Detroit, Mich.	Delray Trenton Channel	S.	1200	12,200	375 lb., 700 °F. Five units.
50,000	G.E.	United Electric Light & Power Co., St. Louis, Mo.	Cahokia	S.	1800	13,800	315 lb., 725 °F.
50,000	G.E.	Exeter Power Co., Pittston, Pa.	Stanton	S.	1800	11,000	600 lb. - reheating.
10,000	West.	Kansas City Power & Light Co., Kansas City, Mo.	Northeast	S.	1800	13,200	1200 lb., exhausting against 365 lb. back pressure.
10,000	G.E.	Edison Electric Illuminating Co., Boston, Mass.	Edgar	S.	3600	14,000	1200 lb., exhausting to 350 lb. station header.
10,000	G.E.	Hartford Electric Light Co., Hartford, Conn.	South Meadow	S.	720	-	Mercury vapor at turbine, 72 lb., 884 °F.
7,700	G.E.	Milwaukee Electric Railways & Light Co., Milwaukee, Wis.	Lakeside	S	3600	-	Operated in compound with 300 lb. condensing turbine.

*G.E. - General Electric Co.
West.- Westinghouse Electric & Manufacturing Co.

**S. - Single Cylinder
T.C. - Tandem Compound
C.C. - Cross Compound

TABLE II

TURBO-GENERATOR UNITS—LARGE OR SPECIAL TURBINES ON ORDER OR IN COURSE OF CONSTRUCTION.

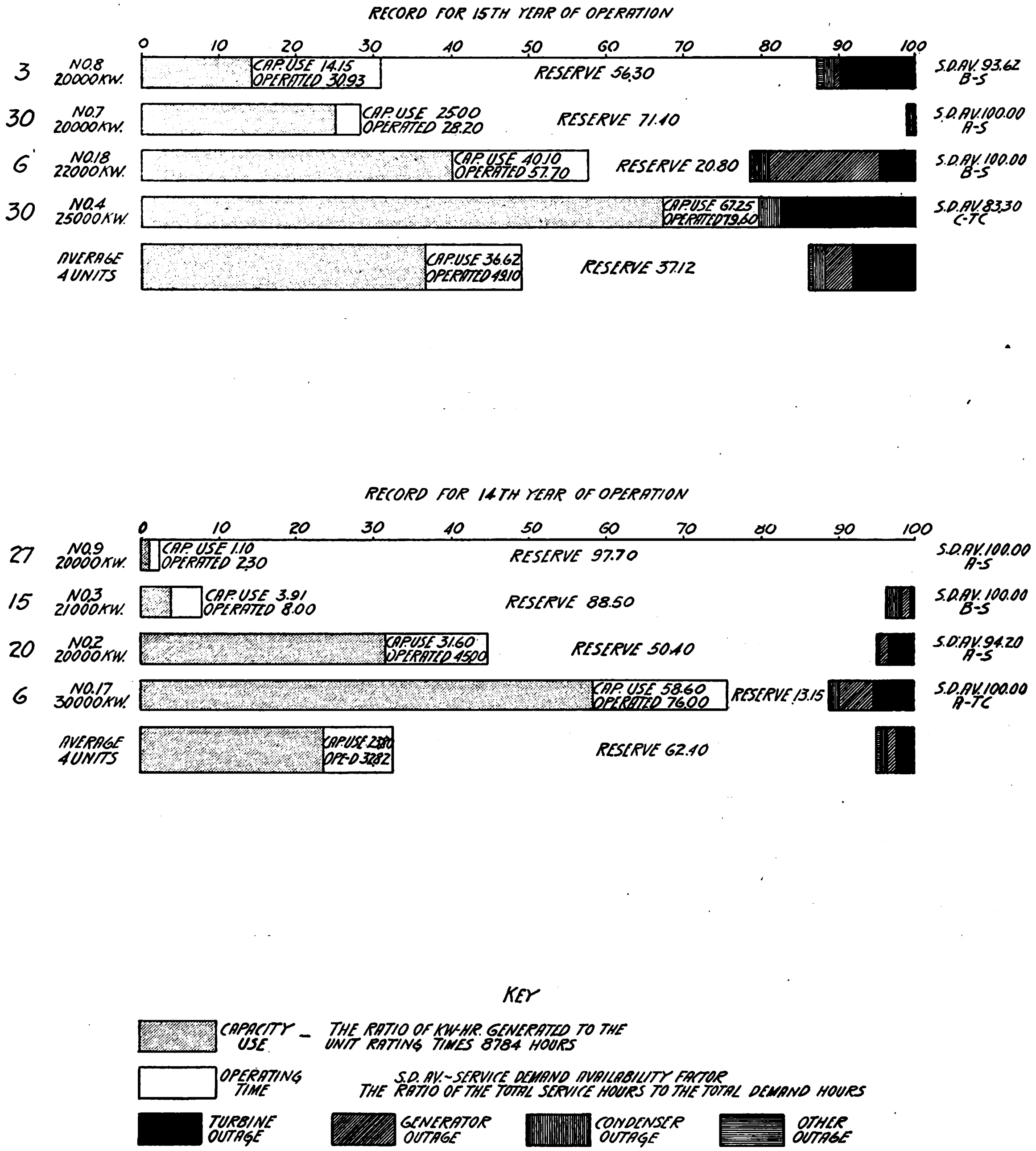
Capacity Kw.	*Manufacturer	Company	Station	**Type	Speed R.P.M.	Volts	Steam Conditions - Remarks
208,000	G.E.	State Line Generating Co., Chicago, Ill.	State Line	C.C.	1800	22,000	600 lb. - reheating Highest capacity unit under construction.
165,000	West.	United Electric Light & Power Co., New York, N.Y.	Hell Gate	C.C.	1800 1200	13,800	265 lb., 700 °F.
160,000	G.E.	New York Edison Co., New York, N.Y.	East River	T.C.	1500	11,400	275 lb., 700 °F. Highest capacity single shaft turbine under construction. Generator has two separate windings - each of 80,000 kw. capacity.
94,000	G.E.	Southern California Edison Co., Los Angeles, Calif.	Long Beach No. 3	T.C.	1500	16,500	400 lb., 725 °F. Similar to unit recently placed in operation at this station.
75,000	G.E.	Union Electric Light & Power Co., St. Louis, Mo.	Cahokia	S.	1800	13,800	315 lb., 725 °F. Largest 1800 r.p.m. single cylinder turbine under construction.
64,000	West.	Northern Indiana Public Service Co., Michigan City, Ind.	Michigan	S.	1800	22,000	650 lb., 750 °F.
63,000	G.E.	Columbia Power Co., Cincinnati, Ohio.	Columbia	T.C.	1800	13,200	600 lb. - reheating. Rebuilding the 45,000 kw. unit.
60,000	West.	Duquesne Light Co., Pittsburgh, Pa.	James H. Reed	S.	1800	11,500	375 lb., 725 °F.
60,000	G.E.	Alabama Power Co., Birmingham, Ala.	Gorgas	S.	1800	13,800	400 lb., 725 °F.
55,000	G.E.	Super Power Company of Illinois Pekin, Ill.	Pekin	T.C.	1800	22,000	600 lb. - reheating Similar to unit recently installed at this station.
55,000	West.	Duke Power Co., Spencer, N.C.	River Bend	S.	1800	13,200	425 lb., 725 °F. Two turbines on order.
55,000	G.E.	New Jersey Power & Light Co., Dover, N.J.	Holland	C.C.	3600 1800	13,800	1200 lb. - reheating. Condensing.
53,000	G.E.	American Gas & Electric Co., New York, N.Y.	Deepwater (N.J.)	C.C.	3600 1800	11,000	1200 lb. - reheating. Condensing.
53,000	G.E.	American Power Corp., Philadelphia, Pa.	Deepwater (N.J.)	C.C.	3600 1800	11,000	1200 lb. - reheating. Condensing.
12.500	G.E.	American Gas & Electric Co., New York, N.Y.	Deepwater (N.J.)	S.	3600	11,000	1200 lb. - exhausted at 450 lb. Exhaust used for process work.
3,700	Brown-Boveri	- - -	- - -	S.	3600	-	1400 lb. - exhausting at 360 lb.

*G.E. - General Electric Co.
West.- Westinghouse Electric & Manufacturing Co.

**S. - Single Cylinder
T.C. - Tandem Compound
C.C. - Cross Compound

TABLE III

1928 OPERATING RECORD FOR 207 LARGE TURBINES
PER CENT OF 8784 HOURS (ONE YEAR)



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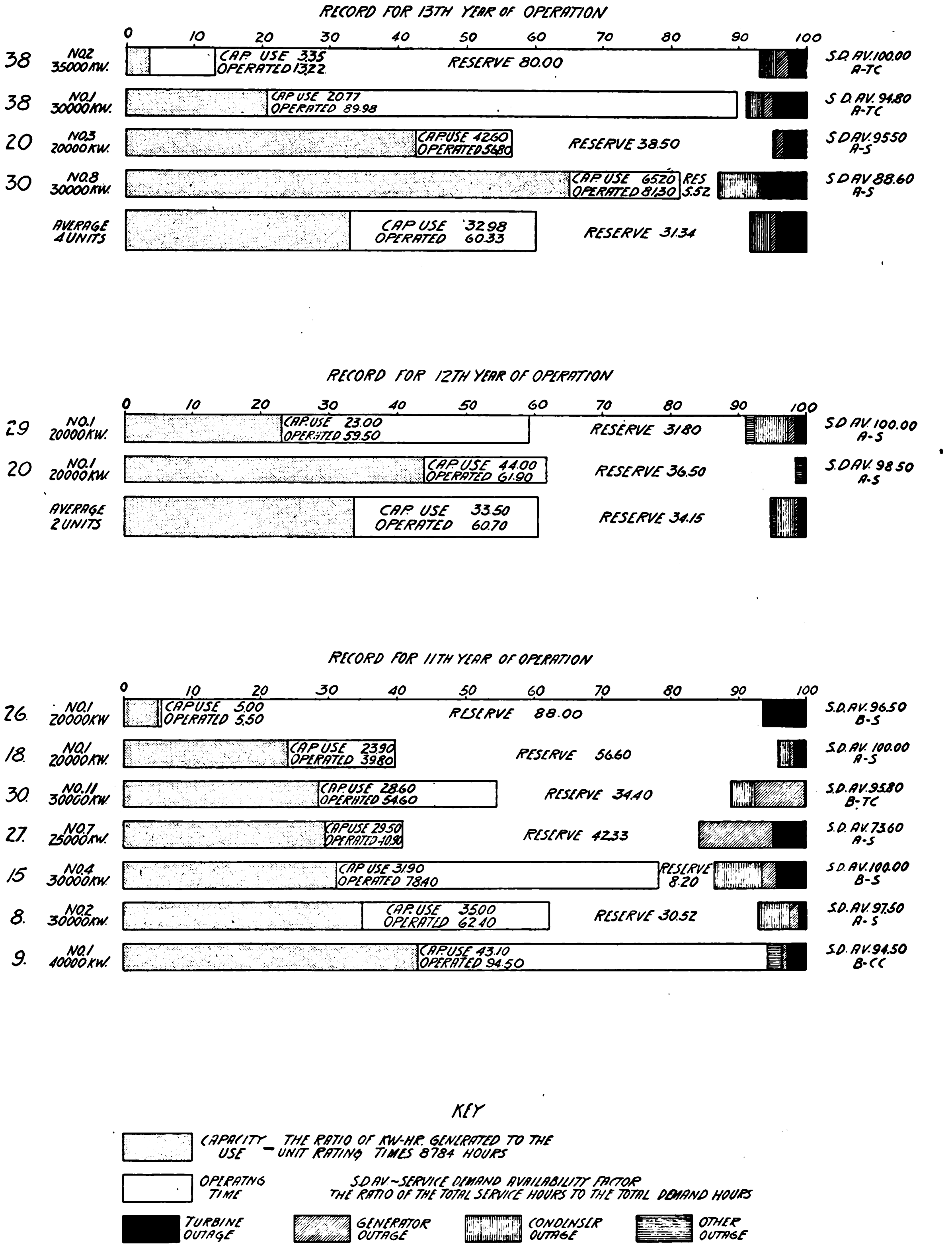

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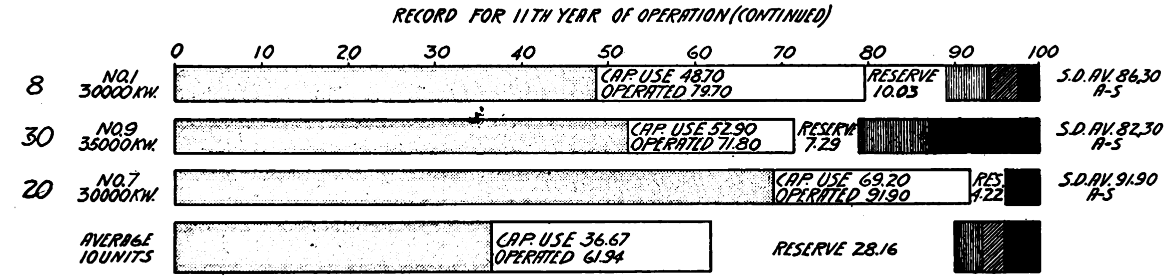
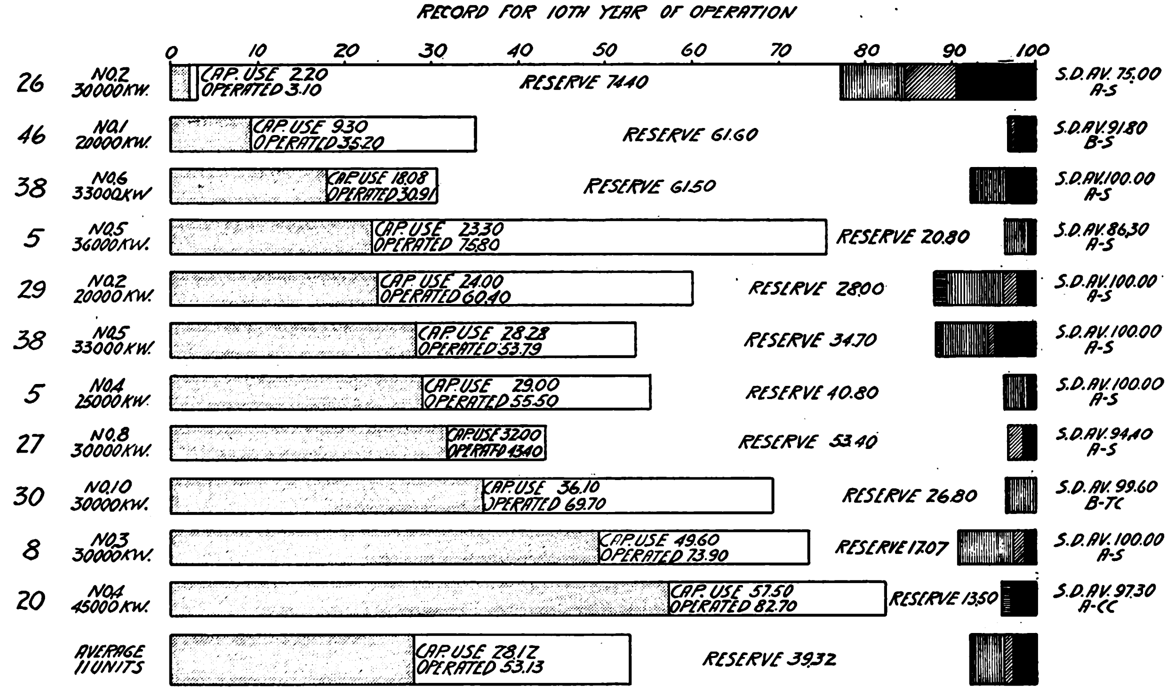




KEY

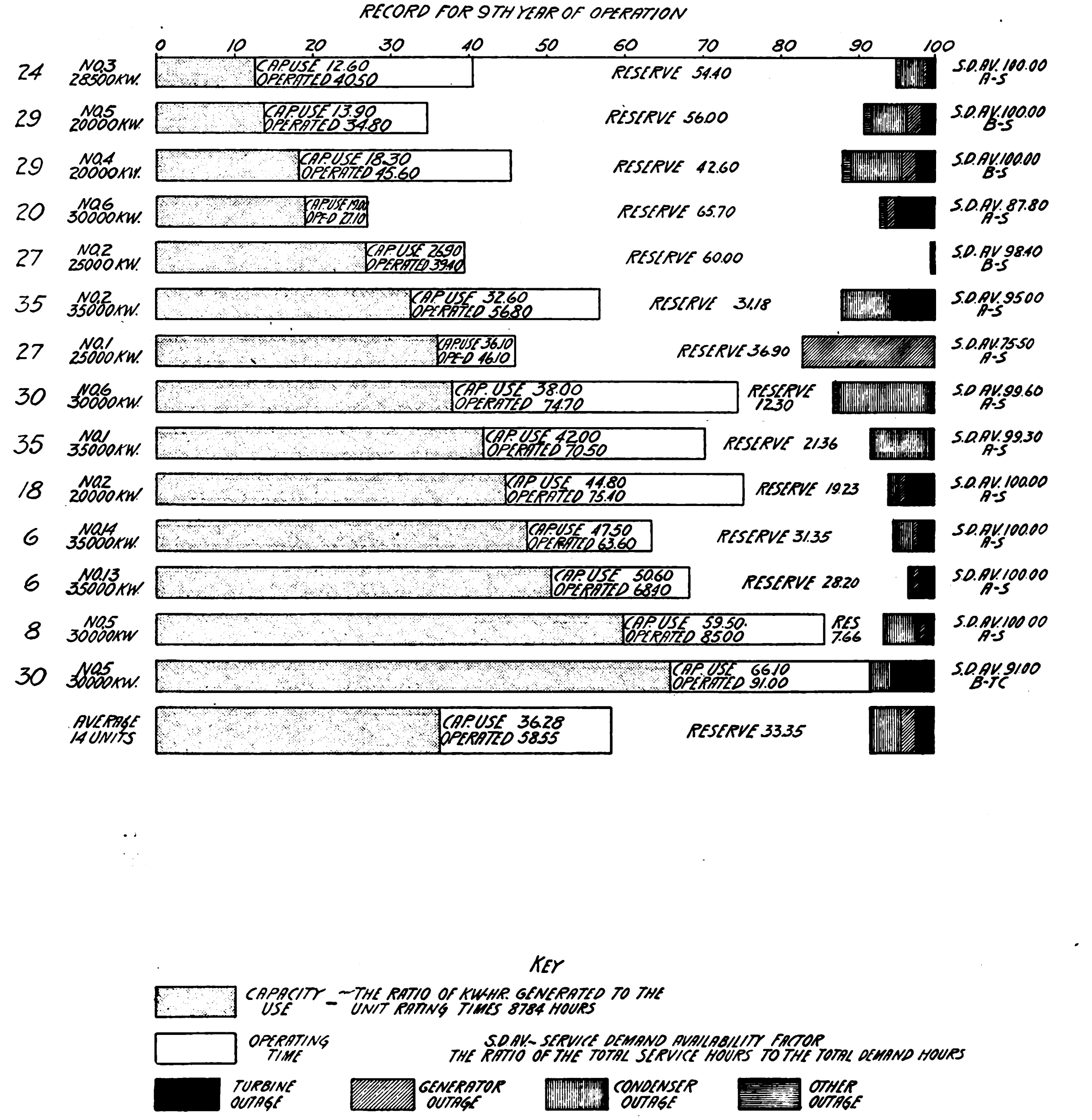
▒ CAPACITY USE – THE RATIO OF KW-HR. GENERATED TO THE UNIT RATING TIMES 8784 HOURS

☐ OPERATING TIME

S.D. AV. - SERVICE DEMAND AVAILABILITY FACTOR
THE RATIO OF THE TOTAL SERVICE HOURS TO THE TOTAL DEMAND HOURS

■ TURBINE OUTAGE ▨ GENERATOR OUTAGE ▥ CONDENSER OUTAGE ▤ OTHER OUTAGE

TABLE III—(*Continued*)



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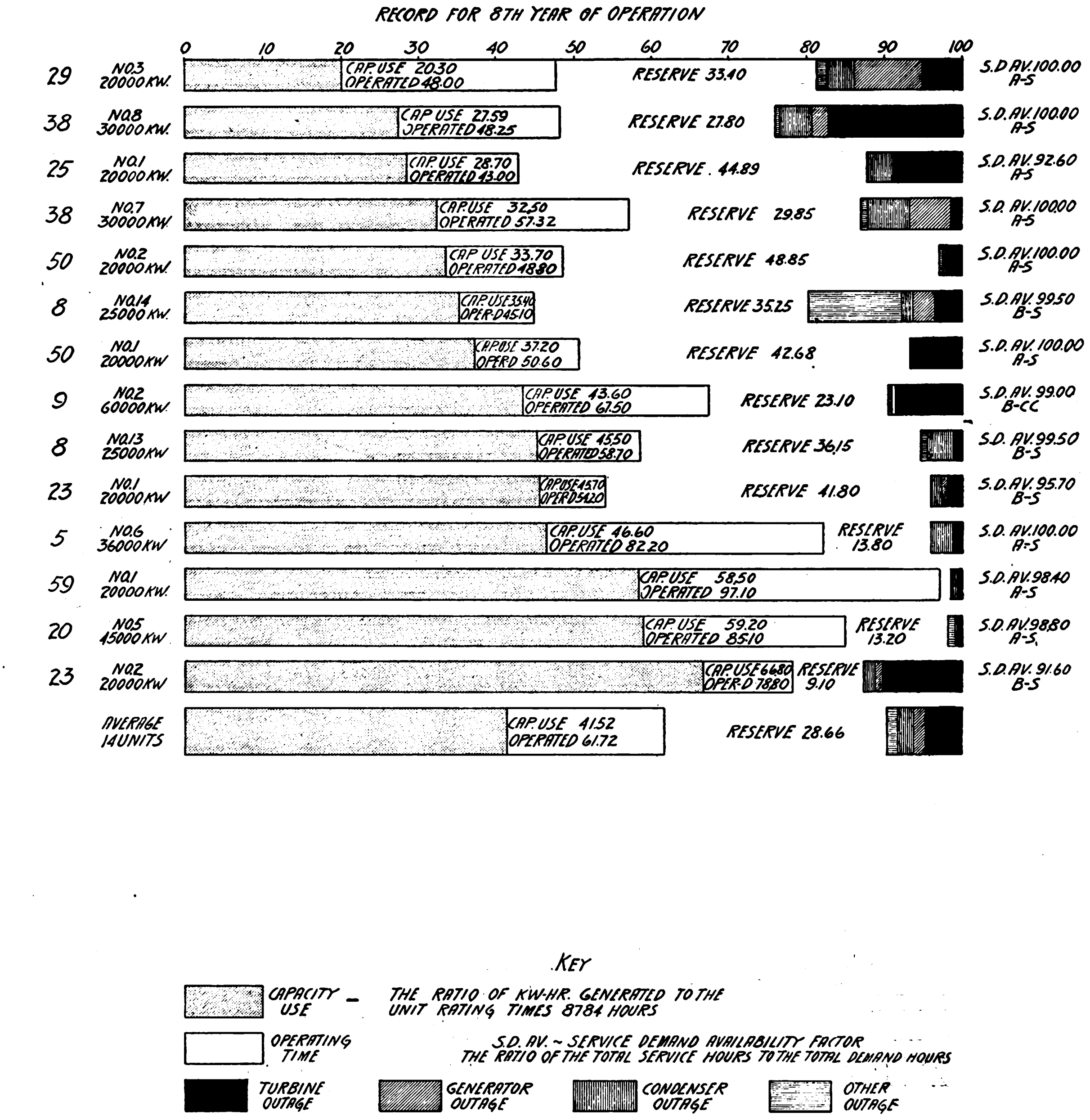

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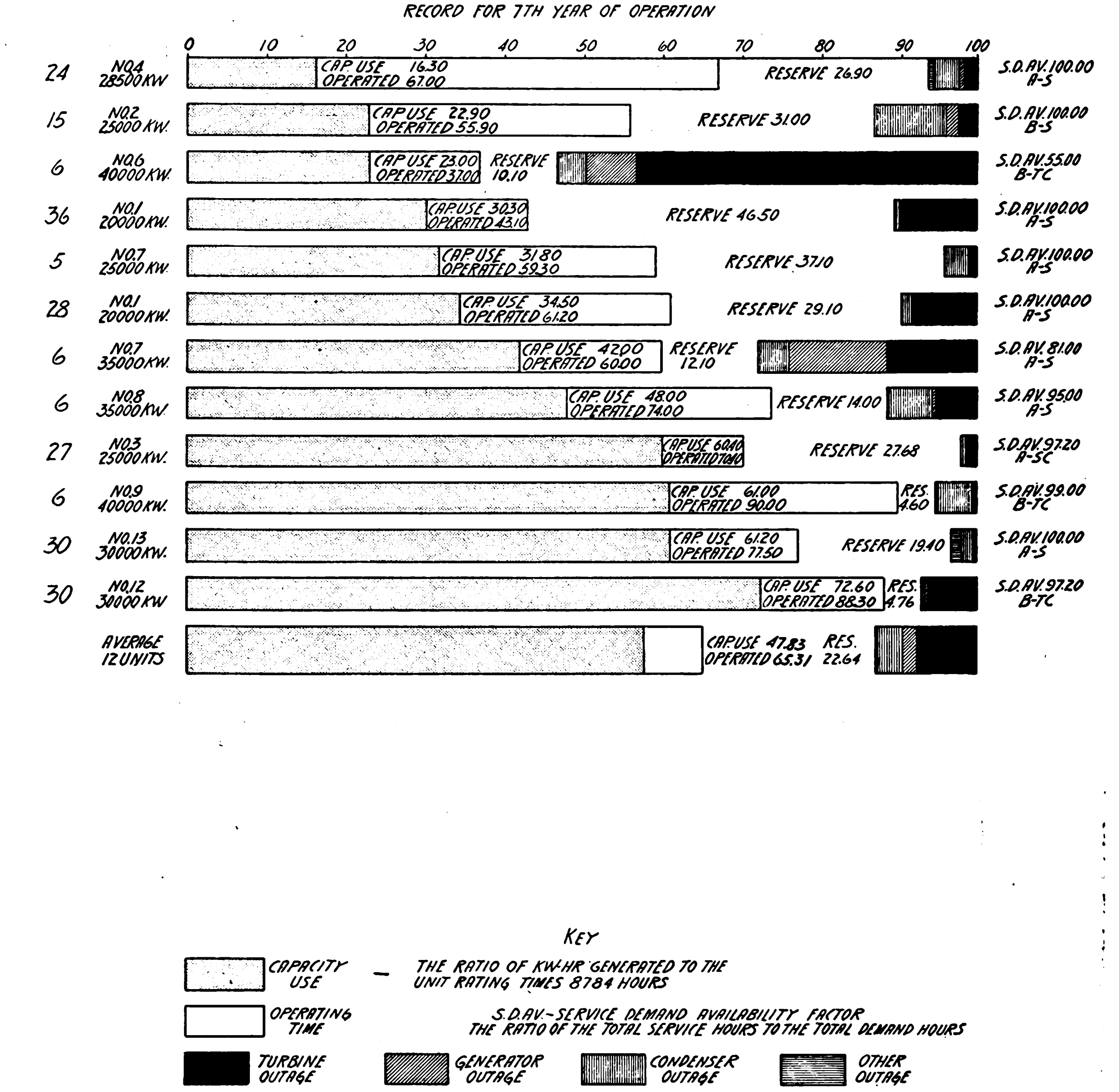

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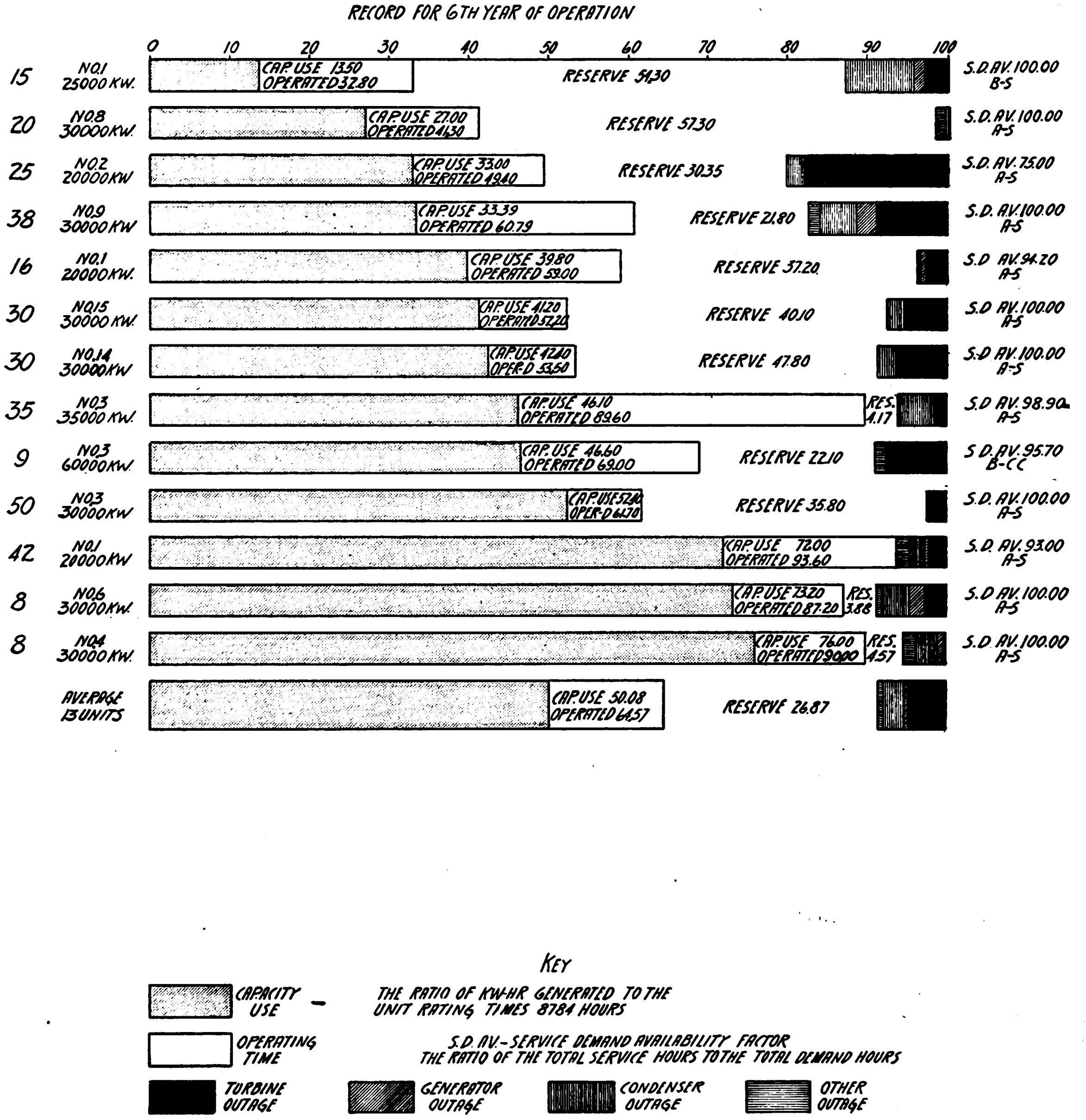

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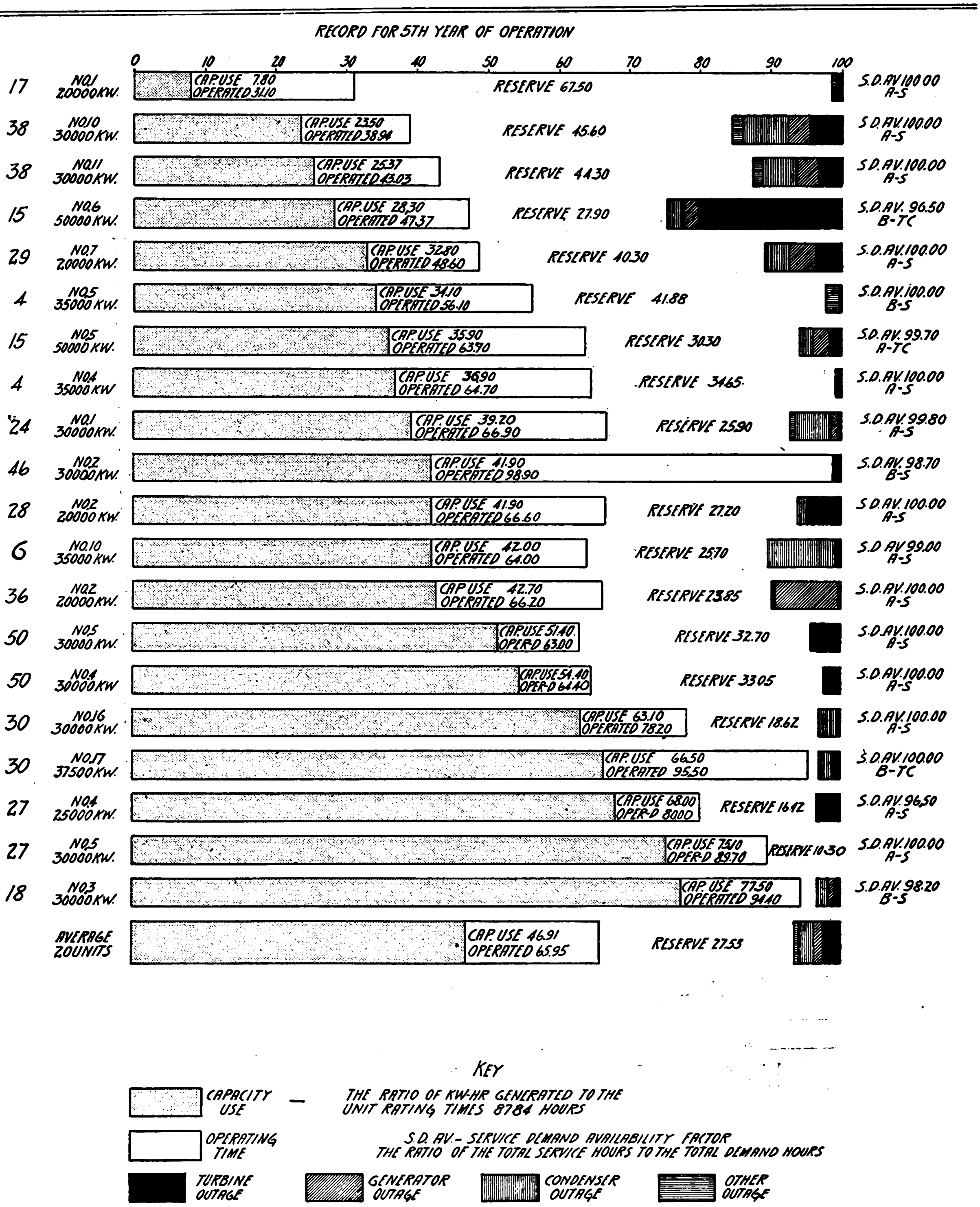

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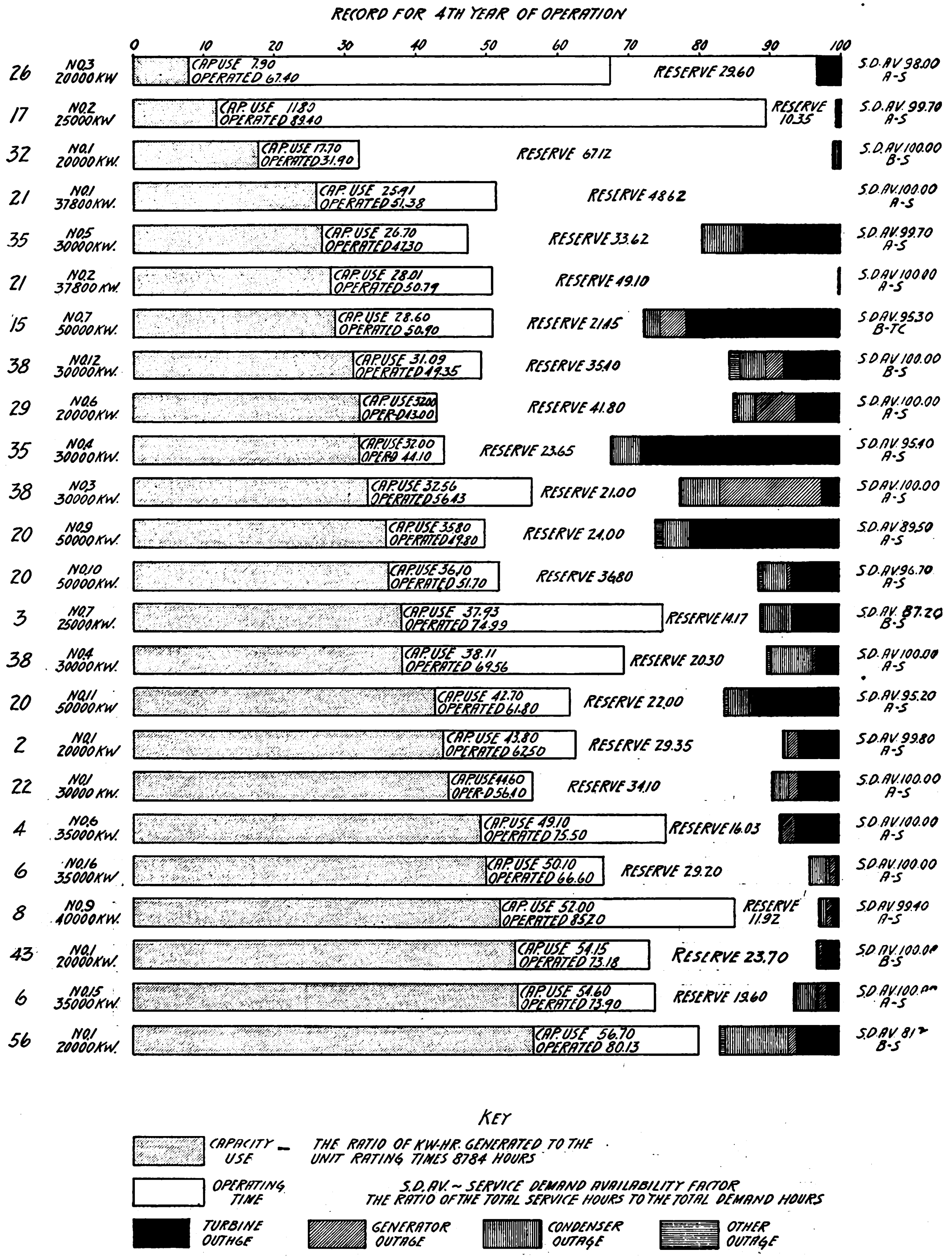

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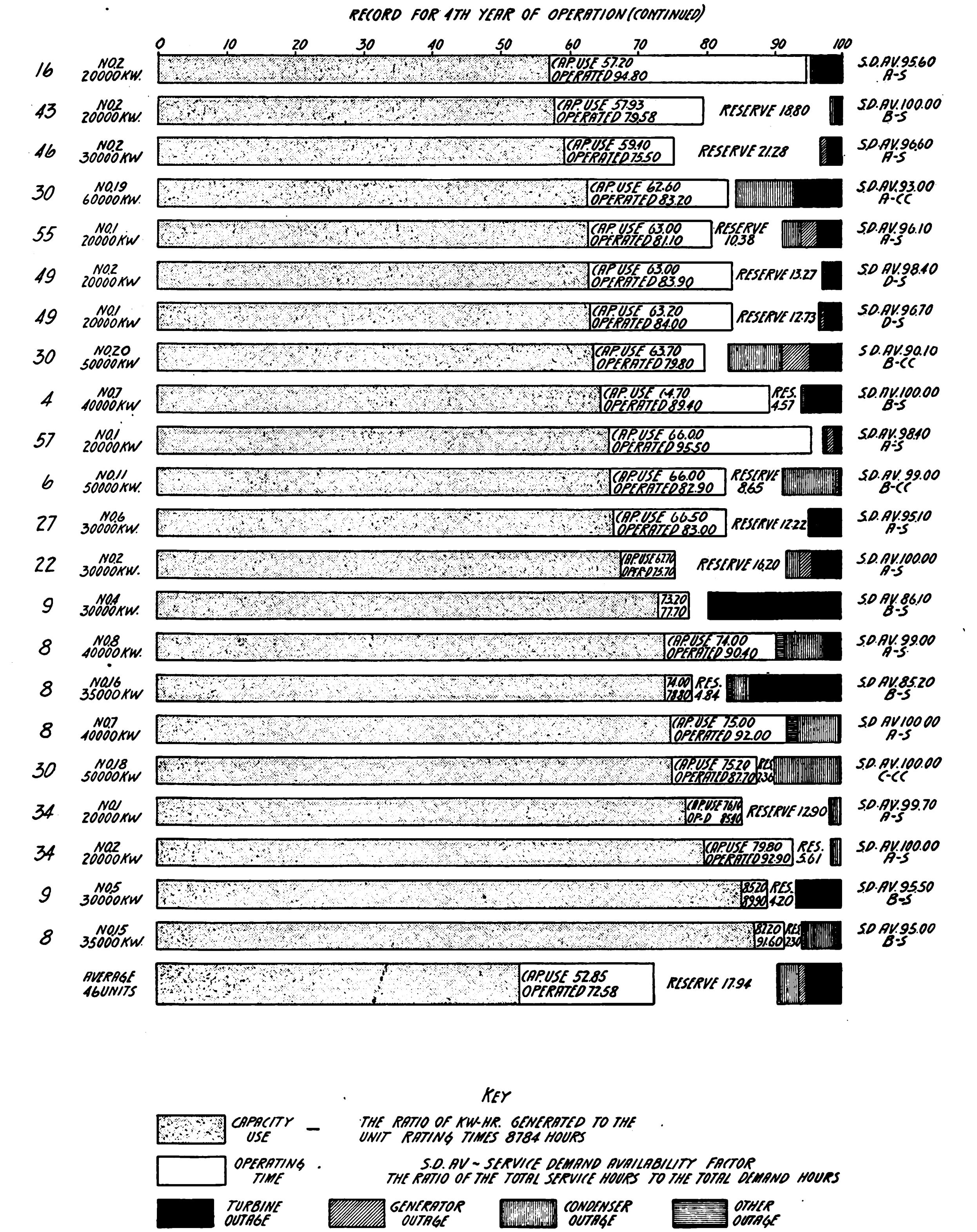

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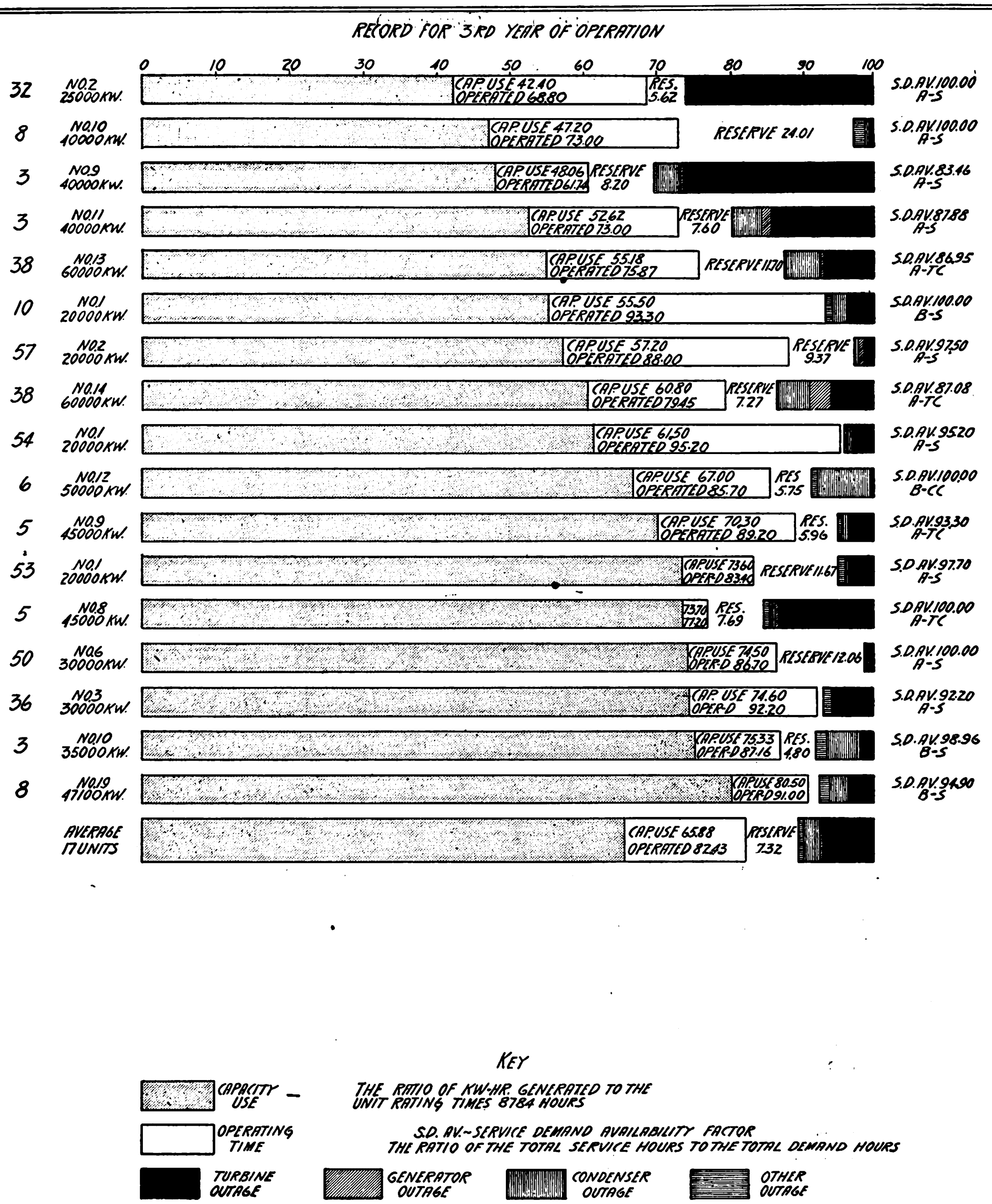

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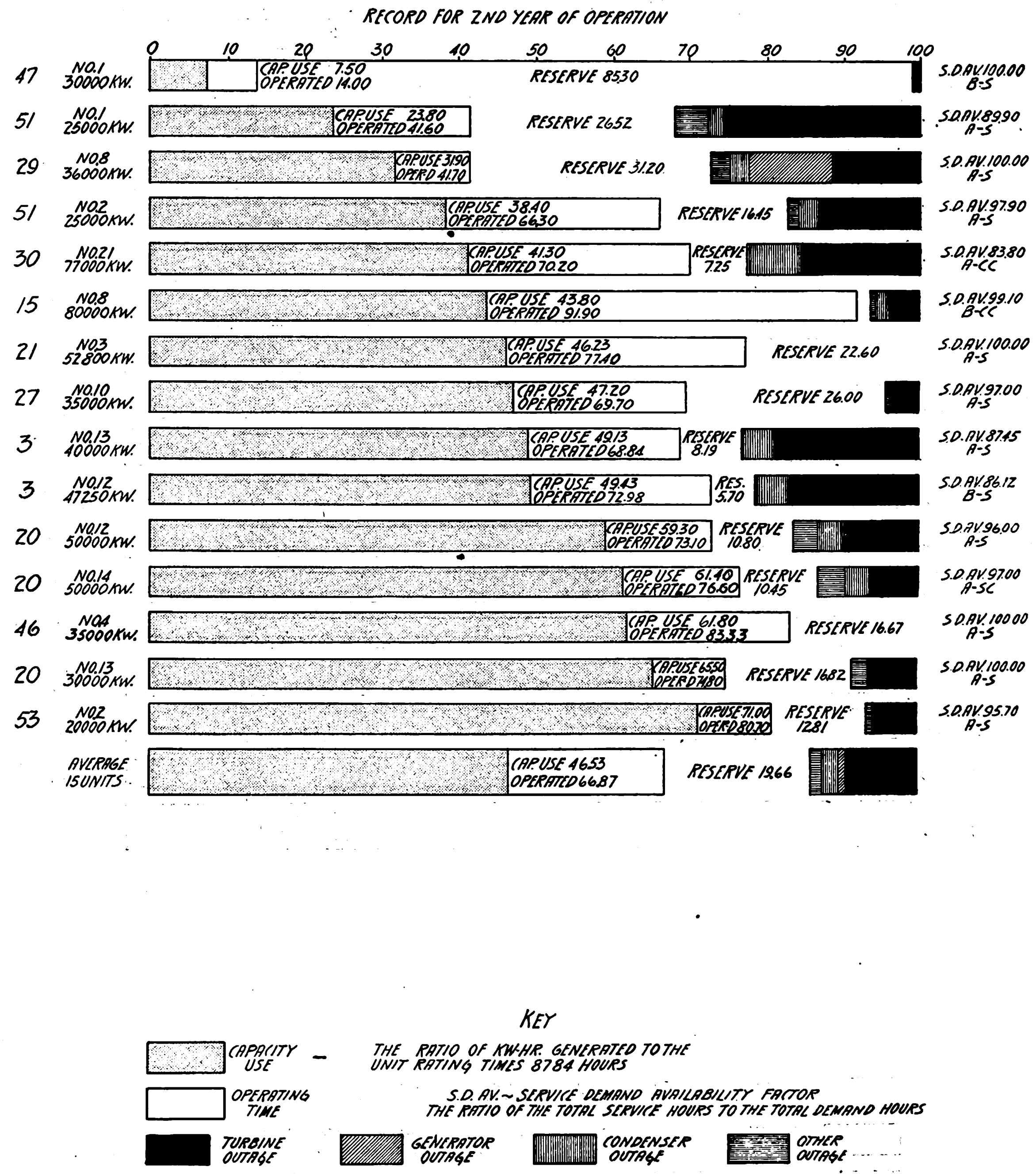

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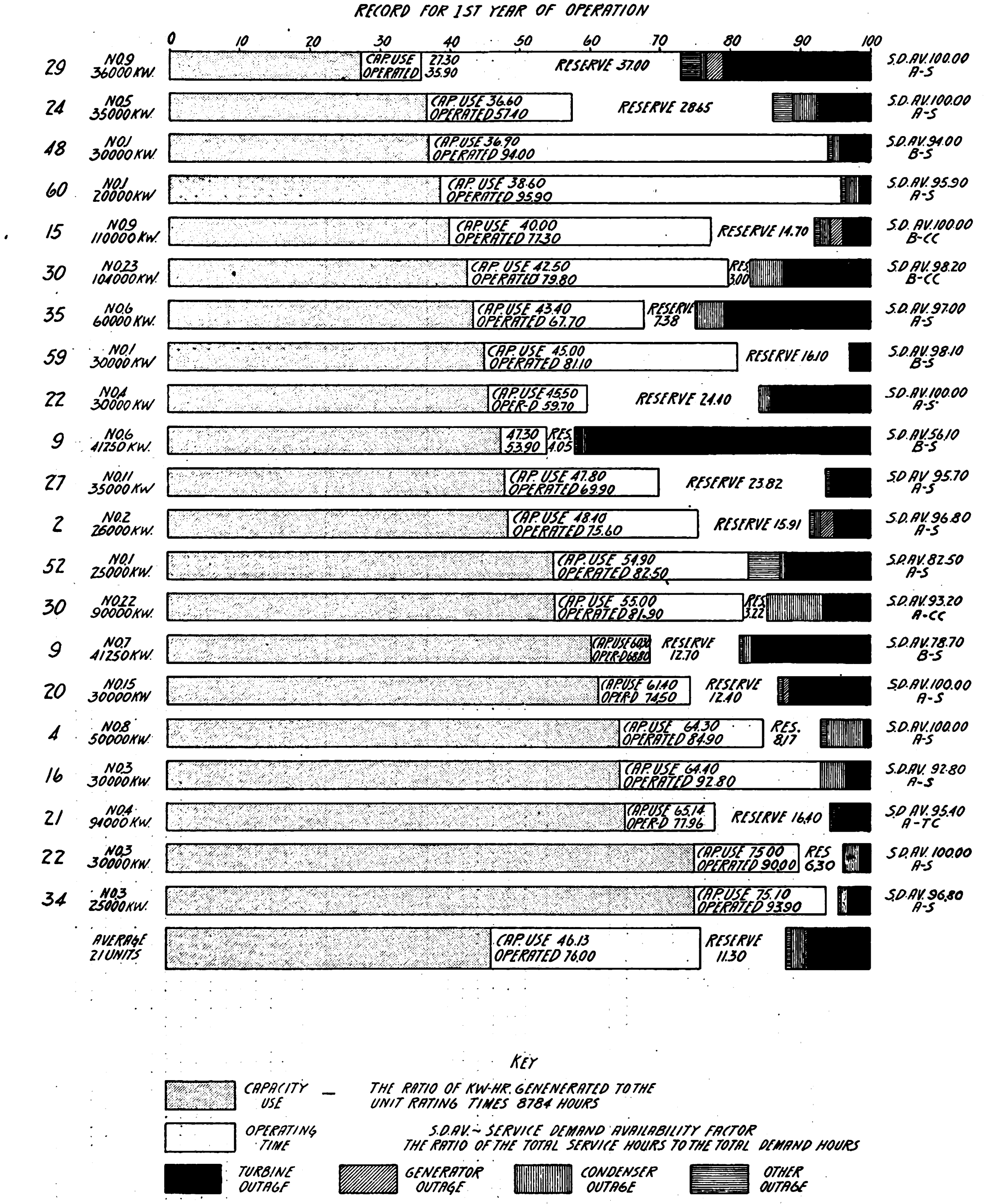

TABLE IV

SUMMARY OF OPERATING RECORD—1928—207 TURBINE UNITS

		Per Cent of Period Hours
Number of turbine units reviewed	207	
Total rated capacity of units reviewed	6,772,750	
Total period hours reviewed	1,769,947	100.00
Total kw-hr. generated	26,997,978,670	
Total hours the units were in demand	1,232,239	69.62
Total hours the units operated	1,183,685	66.88
Total hours the units were idle	586,262	33.12
Hours idle due to steam turbine	96,262	5.44
Hours idle due to generator	21,422	1.21
Hours idle due to condenser	43,767	2.47
Hours idle due to other causes	10,113	.57
Total hours the units were in reserve	414,698	23.43
Number of unit idle periods	22,004	

Factors

Unit service demand	69.62
Unit service demand availability	96.06
Unit capacity	46.62
Unit output	69.71
Unit service	66.88
Maximum possible unit service	90.31

Analysis of Steam Turbine Outage Hours

	Demand Hours	No-Demand Hours	Total	Per Cent	Number of Machines Affected
Steam casing	522	1,092	1,614	1.68	41
Governors	392	633	1,025	1.06	69
Control gear	705	2,242	2,947	3.06	74
Shaft packing	1,353	4,005	5,358	5.57	54
Nozzles and diaphragms	1,738	1,602	3,340	3.47	19
Shaft	526	252	778	.81	11
Wheels or spindle	2,831	2,491	5,322	5.53	31
Buckets or blades	10,480	7,530	18,010	18.71	41
Vibration	1,668	1,343	3,011	3.13	25
Bearings	420	2,123	2,543	2.64	55
Lubrication system	411	757	1,168	1.21	79
Cleaning oil system	407	1,908	2,315	2.40	86
Annual inspection and adjustment	15,234	29,930	45,164	46.93	113
Miscellaneous	1,270	1,045	2,315	2.40	32
Unclassified	250	1,102	1,352	1.40	29
Total for repair and maintenance	38,207	58,055	96,262	100.00	

TABLE IV—(*Continued*)

Analysis of Generator Outage Hours

	Demand Hours	No Demand Hours	Total	Per Cent	Number of Machines Affected
Vibration	0	55	55	.26	4
Oil leakage	4	148	152	.71	9
Armature core	10	0	10	.05	1
Armature windings	2,713	791	3,504	16.36	18
Field windings	1,069	3,720	4,789	22.36	31
Exciter	235	1,275	1,510	7.05	47
Annual inspection and cleaning	711	5,494	6,205	28.97	42
Miscellaneous	677	3,464	4,141	19.33	41
Unclassified	349	707	1,056	4.91	23
Total for repair and maintenance	5,768	15,654	21,422	100.00	

Analysis of Condenser Outage Hours

	Demand Hours	No Demand Hours	Total	Per Cent	Number of Machines Affected
Leakage	623	1,401	2,024	4.62	68
Cleaning	3,955	31,304	35,259	80.57	142
Tubes	154	2,183	2,337	5.34	49
Shell	105	241	346	.79	21
Circulating pumps	348	1,446	1,794	4.10	51
Condensate pumps	45	346	391	.89	27
Air pumps	191	301	492	1.12	40
Miscellaneous	186	347	533	1.22	19
Unclassified	30	561	591	1.35	12
Total for repair and maintenance	5,637	38,130	43,767	100.00	

Analysis of Outage Due to Other Causes

	Demand Hours	No Demand Hours	Total	Per Cent	Number of Machines Affected
General piping	631	3,022	3,653	36.12	113
Boiler room	737	695	1,432	14.16	27
Plant electrical	914	2,085	2,999	29.67	73
Outside electrical	46	122	168	1.66	14
Miscellaneous	228	1,590	1,818	17.97	27
Unclassified	12	31	43	.42	9
Total for repair and maintenance	2,568	7,545	10,113	100.00	

TABLE V

HISTORY OF 207 LARGE TURBINES FOR CALENDAR YEAR 1928

			Class of Service of Units			Factors - Per Cent							
						Outage							
First Service Year	Number of Units	Average Capacity of Units	Class I	Class II	Class III	Turbine	Generator	Condenser	Other Causes	Reserve	Service Hours	Possible Service Hours	Capacity
1914	4	21,700	1	2	1	9.02	3.65	1.61	.42	37.12	49.10	86.24	36.62
1915	4	22,750	-	4	-	2.20	1.35	.83	.31	62.40	32.82	94.97	23.80
1916	4	28,750	1	2	1	4.65	.91	2.51	.22	31.34	60.33	91.93	32.98
1917	2	20,000	-	2	-	1.05	.55	2.39	1.18	34.15	60.70	94.85	33.50
1918	10	29,000	1	5	4	4.06	2.70	2.92	.30	28.16	61.94	89.81	36.67
1919	11	29,700	4	7	-	2.59	1.15	3.51	.30	39.32	53.13	92.38	28.12
1920	14	28,300	-	13	1	2.32	1.86	3.61	.28	33.35	58.55	91.91	36.28
1921	14	27,900	1	10	3	4.92	1.54	2.01	1.26	28.66	61.72	90.42	41.52
1922	12	29,600	1	9	2	7.62	1.87	3.09	.21	22.63	65.31	87.22	47.93
1923	13	30,000	-	7	6	4.78	.68	2.45	.60	26.87	64.57	92.39	50.08
1924	20	30,900	2	15	3	2.65	1.31	2.03	.49	26.28	65.85	92.47	46.91
1925	46	32,200	2	27	17	5.12	1.11	2.58	.33	17.94	72.58	90.53	52.85
1926	17	36,800	-	7	10	6.90	.48	2.14	.78	7.32	82.43	89.01	65.88
1927	15	42,200	1	8	6	9.11	.85	2.07	1.35	19.66	66.87	83.41	46.53
1928	21	46,200	-	8	13	8.89	.42	1.78	.85	12.06	76.00	91.50	46.13
Total No. of Units	207		14	126	67								
Average		32,700				5.44	1.21	2.47	.57	23.43	66.88	90.16	46.62

Class I Service - Peak loads only, on reserve for other generating units.
Class II Service - Average central station load demands of daily peak type
Class III Service - Base load requirements of system.

TABLE VI

TURBO-GENERATOR OPERATING RECORD FOR 1928—TURBINES CLASSIFIED ACCORDING TO SERVICE DEMAND.

Service Demand Factor Class	Number of Units	Service Demand Factor %	Service Demand Availability Factor %	Total Outage Factor %	Units With No Demand Hour Outage Number	Units With No Demand Hour Outage %
90-100	42	95.7	93.0	8.33	5	12.2
80-90	39	85.8	95.3	8.72	10	25.7
70-80	33	75.2	97.3	8.71	17	51.5
60-70	28	65.4	95.7	12.62	16	57.0
50-60	26	55.7	97.8	10.93	17	65.2
40-50	22	45.2	97.7	13.23	12	55.5
30-40	10	34.8	98.1	8.48	8	80.0
Below 30	7	10.9	96.0	5.82	5	71.4
Total	207				90	
Av. all Units		69.6	96.1	9.69		43.7

reached, when the machines are no longer needed to meet daily peak load or operating reserve capacity requirements. The high outage between service hour factors of 40 and 80 per cent seems to indicate that starting and stopping turbines influences the availability of machines.

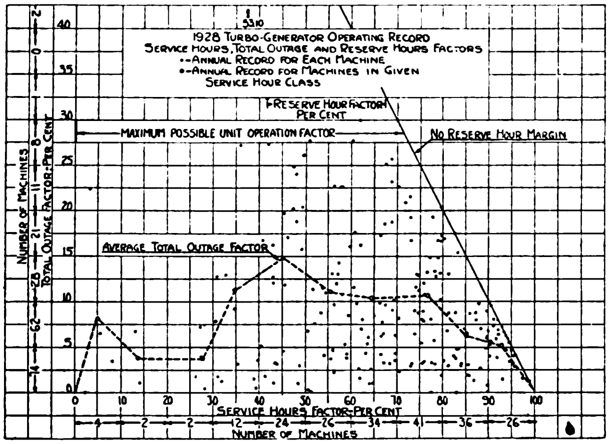

FIG. 1—OPERATING AND OUTAGE FACTORS FOR ALL TURBINES IN 1928 OPERATING RECORD.

It is apparent from Fig. 1 that machines with a high outage factor, with less than approximately 10 per cent reserve factor, are machines of the base load type that would have operated practically continuously had no forced idleness been encountered.

The relation between the time the machines operated and the per cent of the operating time the machines were out of service for repairs is shown in Fig. 2. Although the total outage decreases with service hour factors below 40 per cent, the ratio between total outage and operating time increases.

Comparison with Year 1925

The data summarized in Table V are graphically presented in Fig. 3, 4, 5 and 6, where data from the 1925 operating record are also shown. It is significant that a fairly consistent relation existed between the service year and the number of turbine reports received for respective service years. This also held true when the units were segregated with respect to class of service as shown in Table V. This consistency in the class of service and the number and age of turbines reported adds to the reliability of conclusions that might be drawn when the performances of these units, during 1925 and 1928, are compared.

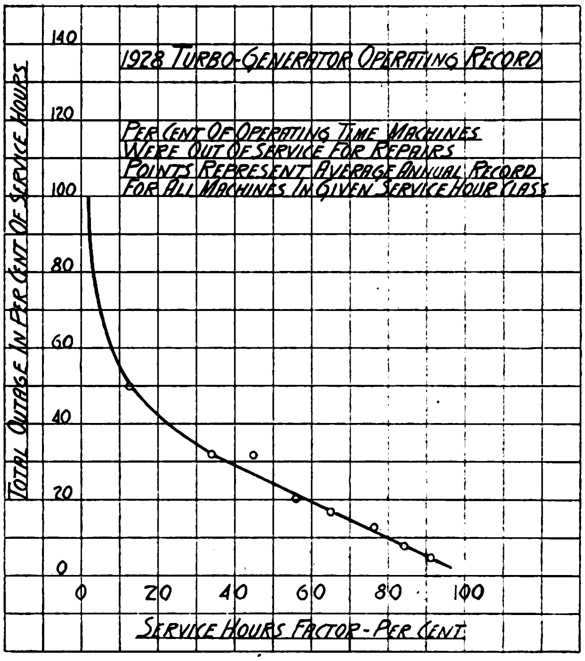

FIG. 2—PER CENT OF OPERATING TIME MACHINES WERE UNAVAILABLE, 1928 OPERATING RECORD.

An improvement in the availability of units is apparent when operating records for years 1928 and 1925 are compared. An inspection of Fig. 4 discloses that the outages caused by the turbine for machines installed the same year show an appreciable reduction. The generator and the condenser show a smaller per cent reduction in caused idleness. However, the per cent improvement in both of these cases exceeds that effected by the turbine. Fig. 3 indicates that the service hours factor remained practically unchanged, the reduction in outage manifesting itself in the form of increased reserve capacity. The reserve hours factor curve indicates, as would be expected, a decreasing trend as the more recently installed machines are reviewed.

TABLE VII

HISTORY OF 207 LARGE TURBINES FOR CALENDAR YEAR 1928—TURBINES CLASSIFIED ACCORDING TO HOURS IN SERVICE.

	Class															
	A				B				C				D			
			Total Outage				Total Outage				Total Outage				Total Outage	
First Service Year	No. of Units	Service Hours Factor %	Per Cent of Period Hr. %	Per Cent of Service Hr. %	No. of Units	Service Hours Factor %	Per Cent of Period Hr. %	Per Cent of Service Hr. %	No. of Units	Service Hours Factor %	Per Cent of Period Hr. %	Per Cent of Service Hr. %	No. of Units	Service Hours Factor %	Per Cent of Period Hr. %	Per Cent of Service Hr. %
1914	2	29.56	6.58	22.3	1	57.70	22.50	39.0	1	79.60	20.40	25.6	-	-	-	-
1915	2	5.15	1.75	34.0	1	46.00	4.60	10.2	1	76.00	10.85	14.2	-	-	-	-
1916	1	13.22	6.78	51.0	1	56.80	4.70	8.2	-	-	-	-	2	85.64	11.09	12.8
1917	-	-	-	-	1	59.50	8.70	14.6	1	61.90	1.60	25.9	-	-	-	-
1918	2	22.65	5.05	22.3	2	47.75	13.88	28.0	4	70.57	12.91	18.3	2	93.20	4.69	5.0
1919	3	23.07	11.10	48.3	3	50.89	6.14	12.0	4	69.95	6.88	9.7	1	82.70	3.80	4.6
1920	3	33.77	5.66	16.8	4	47.25	11.48	24.3	5	70.52	7.03	9.9	2	88.00	7.35	8.3
1921	-	-	-	-	9	50.44	11.88	23.5	2	73.15	11.22	15.3	3	88.10	2.55	2.9
1922	1	37.00	53.10	14.4	3	52.76	6.15	11.6	6	68.35	10.19	14.9	2	89.15	6.20	6.9
1923	1	32.80	12.90	39.2	5	51.08	8.50	16.7	3	63.83	9.30	14.5	4	90.10	6.60	7.3
1924	2	35.02	1.64	4.6	4	48.77	10.19	20.7	9	66.41	4.67	7.0	5	91.70	2.26	2.4
1925	1	31.90	1.20	3.9	11	50.40	16.51	32.7	15	72.60	9.10	12.5	19	87.40	6.42	7.3
1926	-	-	-	-	-	-	-	-	7	72.72	16.86	23.2	10	89.18	5.55	6.2
1927	1	14.10	1.10	7.7	2	41.65	29.80	71.8	9	72.21	14.22	19.7	3	85.30	4.36	5.1
1928	1	35.90	27.20	75.5	3	57.00	26.20	45.9	8	73.94	12.92	17.6	9	88.22	7.59	8.6
Total	20				50				75				62			
Average		26.00	9.13	35.1		50.49	13.10	25.9		71.22	10.52	14.7		88.35	5.77	6.5

Class A - Turbines Operating 0 to 40 Per Cent of Period Hours
Class B - Turbines Operating 40 to 60 Per Cent of Period Hours
Class C - Turbines Operating 60 to 80 Per Cent of Period Hours
Class D - Turbines Operating 80 to 100 Per Cent of Period Hours

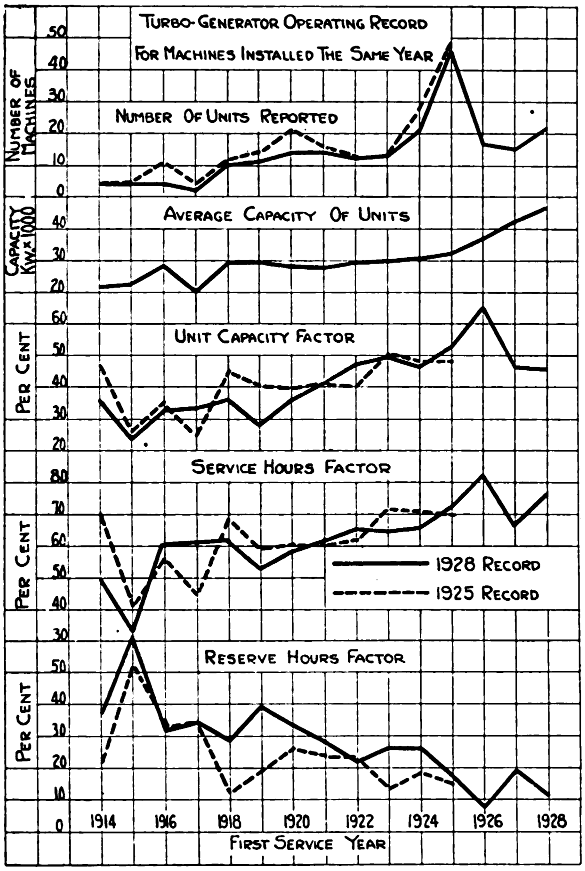

FIG. 3—OPERATING FACTORS FOR TURBO-GENERATORS INSTALLED THE SAME YEAR.

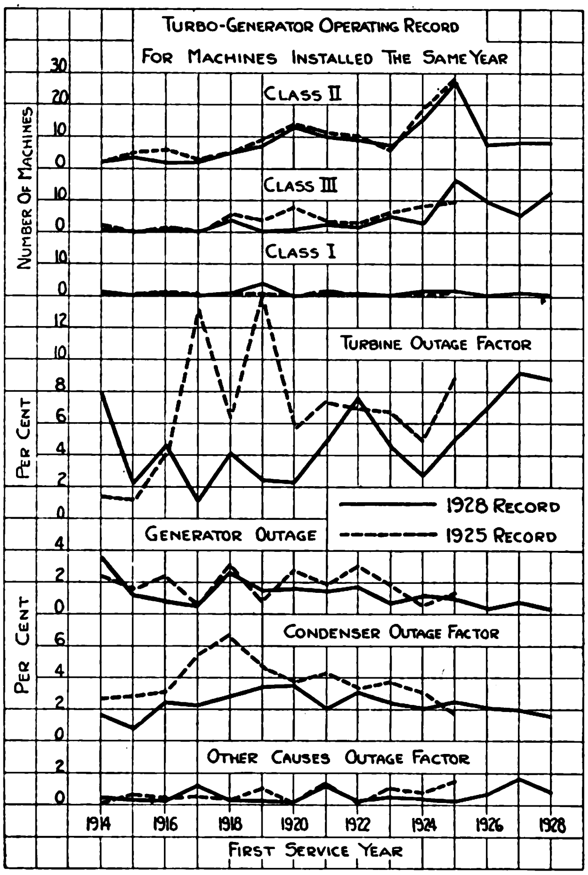

FIG. 4—OUTAGE FACTORS FOR TURBO-GENERATORS INSTALLED THE SAME YEAR.

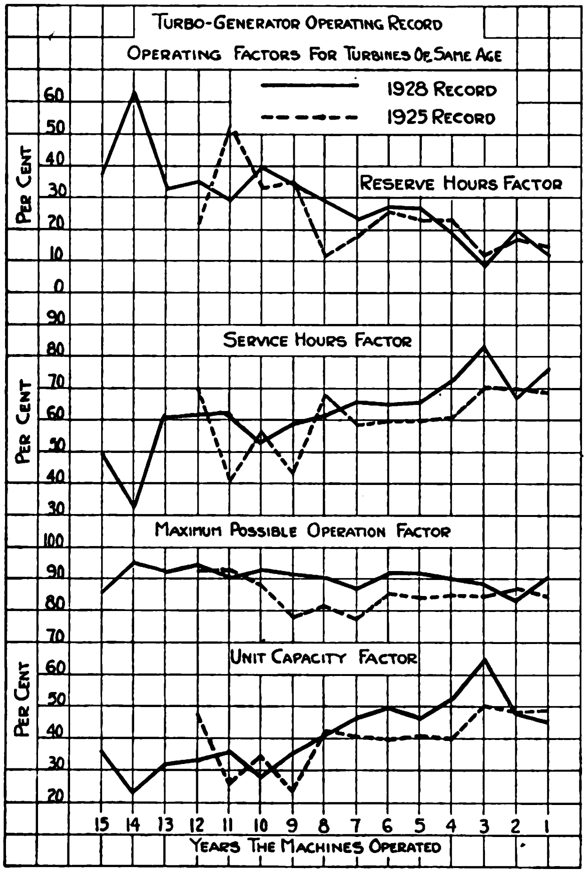

FIG. 5—OPERATING FACTORS FOR TURBO-GENERATORS OF SAME AGE.

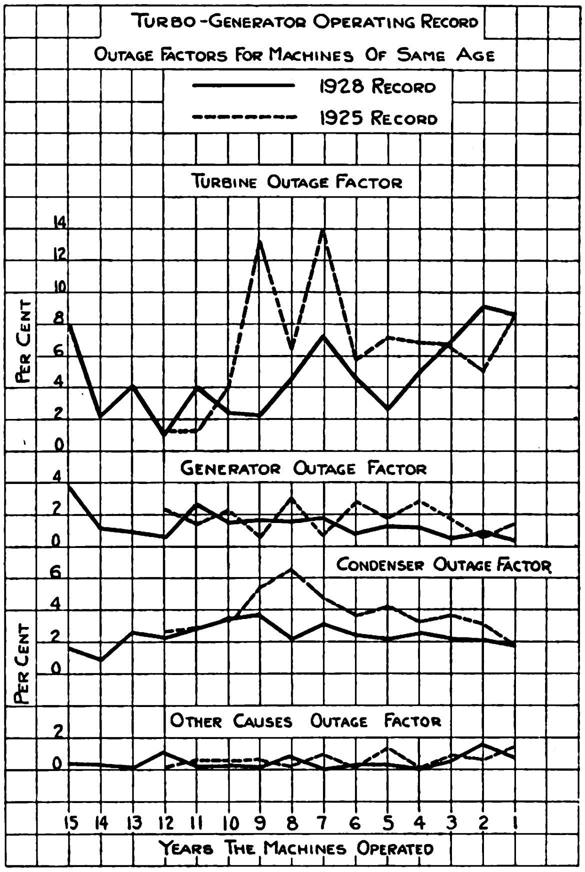

FIG. 6—OUTAGE FACTORS FOR TURBO-GENERATORS OF SAME AGE.

The service year 1925 showed an unusually rapid increase in the generating capacity installed by the companies from which reports were received. The increase in capacity installed during the service year 1928 was only 65 per cent of that reported for 1925.

When the operating factors shown in Fig. 5 are compared on a basis of the number of years the machines operated, it is seen that the reserve hours factor remained the same, but the service hours factor and the capacity factor are higher for 1928 than for 1925.

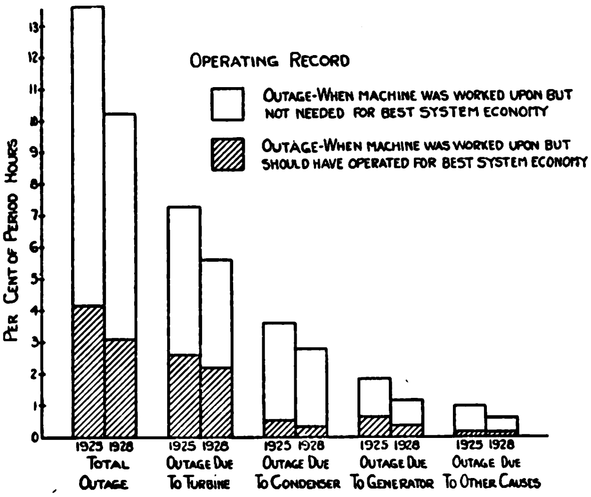

FIG. 7—TOTAL AND DEMAND HOUR OUTAGE OF TURBO-GENERATOR UNITS.

Fig. 7 graphically distributes the total and the segregated outage between the demand and no demand period in per cent of total period hours for the years 1925 and 1928. The 1928 outage, both total and over the demand period, is approximately 25 per cent less than for 1925.

The outage during demand periods is of primary interest. Reduction in idleness during the demand hours is of greater importance than reduction in total outage in which the demand hour idleness has not

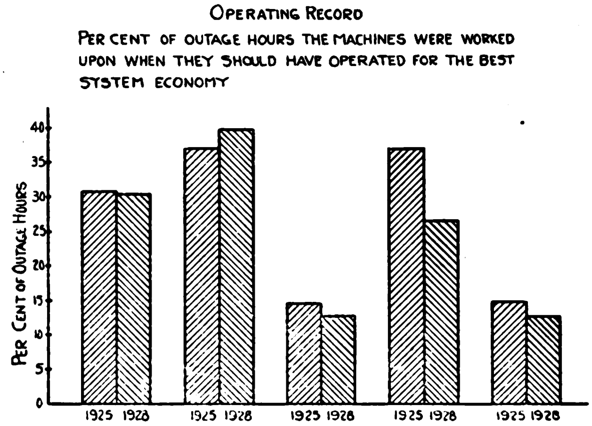

FIG. 8—PER CENT OF OUTAGE DURING THE DEMAND PERIOD.

TABLE VIII

WEIGHTED AVERAGE PERFORMANCE OF UNITS 20,000-KW. CAPACITY AND LARGER.

Period Analyzed	1914-1921 Inclusive	1922	1923	1925	1926	1927	1928
Turbine units reviewed	78	74	87	191	153	186	207
Service demand factor, %	77.80	74.80	78.40	68.80	70.55	71.11	72.09
Service demand availability factor, %	85.50	71.00	92.30	94.60	92.16	94.62	96.01
Unit capacity factor, %	43.80	48.10	51.60	44.40	49.20	46.13	48.15
Unit output factor, %	66.00	70.60	71.30	68.20	64.44	66.89	69.44
Service hours factor, %	66.50	68.10	72.40	65.10	67.06	67.14	68.58
Turbine outage factor, %	6.93	7.90	7.33	7.29	6.28	6.36	5.73
Generator outage factor, %	2.56	3.10	1.74	1.85	1.70	1.68	1.13
Condenser outage factor, %	1.20	2.50	3.18	3.51	2.65	2.75	2.77
Other causes outage factor, %	.66	1.80	.66	.98	.57	1.06	.57
Reserve hours factor, %	22.05	16.60	14.69	21.25	21.74	21.04	21.22

been reduced. It is appreciated, however, that maintenance during no-demand hours may forestall a future demand-hour outage.

Fig. 8 shows the per cent of outage due to turbine, generator, condenser or other miscellaneous causes that took place at a time when the machines were in demand. All causes of idleness except the turbine show a decrease in demand outage, expressed as a per cent of total outage.

Comparison with Preceding Years

The weighted average annual operating and outage factors for turbines of 20,000-kw. capacity and above without regard to date of installation for the years 1921 to 1928 inclusive are shown in Table VIII. Significant improvements were made in the outage factors for the most recent years.

Increased capacity of the systems very appreciably reduced the annual service hours factor, the unit capacity factor and service demand factor for the year 1925 and increased the capacity of machines held in reserve. For the years 1926, 1927 and 1928 the capacity of units installed apparently increased at a rate more nearly conforming to the load increases of the systems of the reporting companies. The reserve hours factor, however, showed little change as the reduction in the outage factors of the units approximately corresponded to the increase in the service hour factor.

Outage Due to Turbine

An inspection of the turbine outage factor chart, Fig. 4, reveals that the 1928 record appears better than the 1925 record, but it must not be inferred that this was due to improvement in recently installed machines. The 1925 record for the first year of operation is the same as the 1928 record for the first year of operation. The average outage becomes less as the machines become older. From this it is evident that there has been no reduction in the field work on new machines during the last three years. The turbine outage factor during the first two years of operation exceeds 8 per cent, whereas in the later years it is reduced to about 4 per cent.

High turbine outage for machines in their first operating year in 1922 is due to an abnormal turbine outage for one machine in that group. If this machine with a turbine outage factor of 43.20 per cent were excluded from this group the average for 1922 would decrease from 7.62 per cent to 4.0 per cent, which is approximately equal to the average for the preceding and succeeding years. For machines with their first operating year in 1927 and 1928 the outage is not sufficiently localized in one unit to produce an appreciable reduction in outage if it were excluded from the averages reported.

When outages caused by turbine troubles are reviewed, it is found that barring the period of annual inspection, the major causes are buckets or blades. The number of machines affected by bucket or blade trouble increased from 19 during the year 1925 to 41 during 1928, and the outage during machine demand hours increased by more than 300 per cent. This brings to our attention a condition which is most important and one which demands the most strenuous efforts for correction. Present developments indicate a possible reduction in outage due to these causes but it may be several years before the condition becomes more satisfactory.

Outage Due to Condenser

In connection with the condenser 80 per cent of the outage is due to cleaning, with 13 per cent of the cleaning outage hours charged against the unit at a time when the machine should have operated for best station economy.

Operating Records for High Capacity Turbines

The average capacity of units installed by operating companies is showing a consistent increase. Referring again to Fig. 3, it is seen that on a basis of the years when the turbines were first operated the capacity changed very slowly. The average capacity increased from approximately 29,000 kw. in 1918 to 31,000 kw. in 1924. From 1924 to 1928 the average capacity of the turbines reported increased from 31,000 kw. to 46,000 kw. As the general trend is upward, the operating record for units of a capacity of 50,000 kw. and above may be of interest and is presented in Table IX. These data indicate that the turbine caused idleness is greater for these machines than for machines below 50,000-kw. capacity.

TABLE IX

OPERATING RECORDS FOR HIGH-PRESSURE AND HIGH-CAPACITY MACHINES FOR YEAR 1928

	Pressure 550 lb. ga. or above	Capacity 50,000 kw. or above
Turbine units reviewed	12	26
Average capacity of units, kw	56,700	62,200
Service demand factor, %	86.70	76.50
Service demand availability factor, %	94.90	95.20
Unit capacity factor, %	65.50	50.30
Unit output factor, %	73.90	68.60
Service hours factor, %	82.40	72.60
Turbine outage factor, %	5.60	8.05
Generator outage factor, %	.54	.78
Condenser outage factor, %	5.02	3.47
Other causes outage factor, %	.57	1.16
Reserve hours factor, %	5.87	13.80

Operating Records for High Pressure Turbines

Operating and outage factors for 12 turbo-generator units operating with 550 to 600 lb. per sq. in. gage steam pressure are shown in Table IX. These units, although operating 25 per cent more hours than the average of all other machines, show turbine outage factors that favorably approach the average obtained for all units for 1928. When compared with 1925 record of machines of the same class the outage factors show a decline from 14.75 per cent to the present 5.6 per cent. The improvement can be accounted for by the fact that the 1925 record represented turbines in their first year of operation.

TURBINE OPERATING METHODS

Operation of large turbines was reviewed to determine if there was any relation between turbine operating methods and turbine troubles, other than those due to blade failure. Information is reported on the starting and stopping cycles, instruments used when turbines are placed in service and rates of turbine loading for 135 turbines of 20,000-kw. capacity and above.

Turbine Starting Cycles

The time required to bring cold turbines of the same capacity up to synchronous speed varies considerably in the different stations. In most cases, the starting cycle is scheduled by time which has been determined by machine performance during the rolling period or which has been specified by the turbine manufacturer. In the case of one 1200-lb. per sq. in. turbine reported, the rolling time is governed by the expansion of the turbine casing.

Two stations reported the use of slow turning devices for turbines. In both cases, the rolling period of the starting cycle has been eliminated and the time required to bring the units up to speed is reduced.

Table X and XI give the time required for the various periods of the starting cycles reported.

One point of difference in the starting cycles for impulse turbines is the operation of the seals. In one-third of the stations reporting the operation of impulse machines, the sealing steam for the high pressure packing is admitted previous to rolling. This is no doubt done to obtain a high starting vacuum. In the remaining two-thirds of the stations the high pressure seal steam is admitted immediately after the turbine begins to roll.

In the case of reaction turbines, the seals are applied after the turbine is rolling.

There is a difference of opinion regarding the change of the starting cycle time when the machine is considered as a hot or warm machine. In the majority of cases the starting time of a hot machine is less than that of a cold machine. Some operators do not differentiate between a hot or a cold machine using the same starting cycle for both conditions. In several cases reported, more time is taken to start a hot machine than a cold one, since the hot machine is considered to require more attention while starting due to shaft deflection.

Shaft truth indicators are used in six of the stations reporting. The length of the period of slow roll is determined by the readings of these indicators.

Shutting Down Cycles

Statements in regard to shutting down cycles indicate that in some plants the vacuum is broken immediately after the throttle is tripped or closed, while in others the vacuum is retained for some definite time or as long as it is self-sustained. In one station operating 45,000-kw. tandem compound reheating units, the vacuum is reduced to 20 in. of mercury before the turbine throttle is tripped.

The majority of stations rely upon the throttle valve to keep the steam out of the turbine casing while the machine is out of service. Several stations report that the valve at the header end of the turbine lead is also closed as a precaution against leakage, using an open ended drain between the header and throttle valves to maintain atmospheric pressure in the turbine lead.

Turbine Loading

The minimum loads carried by the various machines and the rates of loading are also presented in Table X and XI. These data indicate that for machines of 30,000-kw. capacity the general practice is to allow a minimum load of 5000 kw. As the capacity of machines increases, the minimum load limit increases, being 10,000 to 15,000 kw. for 35,000 to 60,000-kw. turbines.

The rate of loading turbines is reported as 1000 kw. per minute in most of the plants, although as indicated in Table X and XI the loading rate adopted in some plants varies from this average rate.

Instruments Used

The instruments used for turbine operation vary considerably. Six plants report the use of shaft truth indicators during the rolling periods. Turbine speed is recorded in two plants. The other stations use the hand indicating tachometer, the vibrating reed type of speed indicator, and in a few cases the electric indicating tachometer which comes into operation after the generator field is applied.

The use of recording and indicating pressure and temperature instruments is not standardized. Some stations use recording, whereas others use indicating instruments. This applies to oil pressure and temperature, seal water pressure, throttle steam pressure and temperature and to exhaust steam pressure and temperature.

TABLE X

STARTING CYCLE OF IMPULSE TURBINES.

Unit Capacity Kw.	*Type	Pressure Lb. Ga.	Temperature °F.	Stages	Vacuum At Start In. Hg.	Slow Rolling Time Min.	Slow Rolling Speed R.P.M.	Increase to Synchronous Speed Time Min.	Total Starting Time Min.	Loading Minimum Load Kw.	Loading Rate of Loading
20,000	T.C.	225	500	12	14	40	400	30	70	5,000	1,000 Kw. per Min.
20,000	S.C.	200	540	9	25	5	-	45	50	-	1,000 Kw. per Min.
20,000	S.C.	225	572	9	20	-	-	30	30	5,000	1,000 Kw. per Min.
20,000	S.C.	275	614	9	-	16	200	10	(1) 60	5,000	5,000 Kw. in 15 Min.
20,000	S.C.	325	650	9	15	-	-	40	40	5,000	-
20,000	S.C.	325	675	14	15	60	300	20	80	5,000	5,000 Kw. in 15 Min.
20,000	S.C.	285	700	21	15	15	300	15	30	5,000	-
20,000	S.C.	300	725	14	15	20	300	20	40	5,000	5,000 Kw. per Min.
20,000	S.C.	375	750	14	10	120	300	30	150	5,000	2,500 Kw. in 3 Min.
21,000	S.C.	350	700	14	-	-	-	45	45	5,000	-
25,000	S.C.	225	575	17	12	-	-	30	30	-	-
25,000	S.C.	350	635	9	15	30	300	15	45	1,000	1,000 Kw. per Min.
25,000	S.C.	330	660	14	12	45	400	10	55	3,500	Load on after 10 Min.
25,000	S.C.	325	675	14	15	60	300	20	80	6,000	6,000 Kw. in 15 Min.
25,000	S.C.	375	700	14	15	45	400-800	20	65	7,000	-
30,000	S.C.	200	588	17	20	-	-	45	45	5,000	1,000 Kw. per 1½ Min.
30,000	S.C.	230	600	17	16	-	-	60	60	5,000	5,000 Kw. per 15 Min.
30,000	S.C.	230	600	17	15	-	-	120	120	5,000	1,000 Kw. per Min.
**30,000	S.C.	230	600	17	15	-	-	40	40	-	-
30,000	S.C.	325	605	17	15	-	-	60	60	5,000	15,000 Kw. 1st Hour
30,000	S.C.	250	615	17	18	-	-	60	60	5,000	15,000 Kw. 1st Hour
30,000	S.C.	275	635	17	15	16	500	20	(2) 60	10,000	-
30,000	S.C.	350	650	17	15	-	-	60	60	-	-
30,000	S.C.	300	665	17	12	-	-	50	50	3,000	1,000 Kw. per Min.
30,000	S.C.	285	700	17	15	15	300	15	30	5,000	-
30,000	S.C.	375	700	17	15	40	500	35	75	3,000	1,000 Kw. per Min.
30,000	S.C.	350	700	17	15	90	0-800	20	110	4,500	Full Load in 45 Min.
35,000	S.C.	200	500	20	15	30	100	60	90	10,000	4,000 Kw. per 10 Min.
35,000	S.C.	390	700	13	15	60	-	30	90	3,000	1,000 Kw. per Min.
40,000	S.C.	225	550	21	15	70	200	20	90	10,000	1,000 Kw. per Min.
40,000	S.C.	325	700	17	15	60	200	30	90	1,500	-
40,000	S.C.	566	720	19 Reh	15	90	250	30	(3) 180	10,000	20,000 Kw. per Hour
40,000	S.C.	600	725	19 Reh	20	40	200	140	180	5,000	40,000 Kw. per Hour
45,000	T.C.	600	725	26 Reh	10	60	300	30	90	15,000	-
50,000	T.C.	640	725	-	15	40	200	140	180	15,000	1,000 Kw. per Min.
50,000	S.C.	375	680	21	15	40	200	80	120	11,000	1,000 Kw. per Min.
50,000	S.C.	265	610	21	-	35	100	35	70	12,000	1,000 Kw. per Min.
65,000	S.C.	350	725	17	20	90	600	30	120	10,000	65,000 Kw. per 45 Min.
60,000	S.C.	375	700	21	15	30	100	60	90	20,000	60,000 Kw. per 30 Min.
3,150	S.C.	1200	700	20	-	180	1200	10	190	-	-

*S.C. - Single Cylinder. T.C. - Tandem Compound
**Slow Turning Device

(1) Also rolled for 34 min. at 900 r.p.m.
(2) Also rolled for 24 min. at 800-1200 r.p.m.
(3) Also rolled for 60 min. at 400 r.p.m.

TABLE XI

STARTING CYCLE OF REACTION TURBINES.

Unit Capacity Kw.	*Type	Pressure Lb. Ga.	Temperature °F.	Vacuum At Start In. Hg.	Slow Rolling Time Min.	Slow Rolling Speed R.P.M.	Increase to Synchronous Speed Time Min.	Total Starting Time Min.	Loading Minimum Load Kw.	Loading Rate of Loading
20,000	S.C.	190	484	-	30	300	15	45	-	
20,000	S.C.	190	470	-	4	100	16	20	5,000	2,000 Kw. per Min.
20,000	S.C.	200	513	-	-	-	30	30	5,000	1,000 Kw. per Min.
20,000	S.C.	200	520	-	120	-	60	180	1,500	1,000 Kw. per 3 Min.
20,000	S.C.	220	500	10	-	-	40	40	5,000	-
20,000	S.C.	275	610	-	35	-	25	60	4,000	-
20,000	S.C.	350	700	-	15	-	30	45	2,000	Full Load in 15 Min.
20,000	S.C.	400	700	-	90	300	-	-	3,500	-
25,000	S.C.	190	484	-	30	300	15	45	12,000	Full Load in 15 Min.
27,200	S.C.	385	700	2	40	300	60	100	3,500	-
30,000	S.C.	265	650	-	60	300	20	80	5,000	3,000 Kw. per Min.
30,000	S.C.	375	700	-	15	-	20	35	5,000	1,000 Kw. per Min.
40,000	T.C.	265	610	5	30	200	35	65	12,000	1,000 Kw. per Min.
50,000	C.C.	265	610	-	20	200	40	60	15,000	1,000 Kw. per Min.
50,000	T.C.	265	610	-	35	100	35	70	12,000	1,000 Kw. per Min.
**60,000	C.C.	285	700	5	-	-	40	40	5,000	
80,000	C.C.	375	700	-	35	100	35	70	15,000	1,000 Kw. per Min.

*Single Cylinder - Tandem Compound - Cross Compound
**Slow Turning Device

TURBINE TROUBLES

The report on turbine troubles, other than blade failures, reviews troubles encountered in connection with machines of 20,000-kw. capacity and larger during the years 1926, 1927 and 1928. Table XII classifies the turbines, for which information was reported according to the year in which the machines were first operated.

TABLE XII

SUMMARY OF MACHINES REVIEWED IN REPORT—TURBINE TROUBLES.

Year Installed	No. of Turbines
1918 or before	18
1919	6
1920	10
1921	6
1922	6
1923	11
1924	23
1925	21
1926	18
1927	10
1928	6
Total	135

Major difficulties have been so varied that it appears there is no trouble at the present time that is general on machines installed during the past three or four years. The general troubles on machines installed prior to this time have apparently been corrected by changes in design.

Turbine Casings

A number of turbines installed prior to 1920 were constructed with cast iron high pressure casings. Operating pressures on these units were of the order of 235 lb. per sq. in. gage with temperatures not over 600 deg. fahr. The cast iron casings of six of the machines have been changed to steel due to cracking, while in two other cases the reinforcing ribs on the high pressure cast iron casings have cracked but are still in service. Only one case of cracking of an exhaust casing was reported.

Two cases of cracking of steel casings have been reported. One of these turbines was installed in 1924. After four years of operation with a steam pressure of 566 lb. per sq. in. gage and a temperature of 720 deg. fahr., a crack was found in the lower half of the high pressure casing. In the second instance, the throttle and control valves were installed below the turbine, the steam entering the turbine through a long sweep ell which had a partition in it for separating the steam to the two control valves. Due to expansion strains caused by the divided steam flow, a crack developed in the flanged neck forming an integral part of the lower half of the high pressure casing. This machine was started in 1926, the crack developing after seven months of operation. The operating steam pressure was 375 lb. per sq. in. gage and the temperature 750 deg. fahr. The crack was welded and the piping strains relieved. No further trouble has developed.

Four cases of warping of cast iron high pressure casings and one case of warping of an exhaust casing have been reported. In three of these cases the warped joints were in the vertical plane. These joints were remachined. In the other two cases the warping was in the horizontal plane, but the casing joints were pulled tight with bolts. The machines that have experienced the warped casings were installed in 1924-25.

Turbine Foundations

Statements indicate that the foundations of the turbines reported are satisfactory. Two turbines installed in 1925 were grouted with a mixture of iron borings and salammoniac. This material disintegrated and was replaced with Lumnite cement. In one station it was found that filling the steel box columns of the foundations with concrete resulted in smoother running machines. The concrete has changed the period of vibration of the columns.

Vibration was experienced on three machines installed in one station which started operation the latter part of 1925. The foundations are of steel and it was thought that the design was responsible for the turbine vibrations. Additional stiffening steel was added to one of the foundations, but did not improve operation. Changes were made in the turbines which eliminated the difficulty.

Bearings

Statements indicate that there has been no trouble with the main unit bearings.

Several cases of failures of the single plate type thrust bearing have been reported. These have in most cases been replaced with multiple plate type bearings.

Five stations reported that the generator thrust bearings have given trouble. Analysis of these failures indicates that they occurred on machines installed prior to 1921. This condition has apparently been corrected on machines of the present design.

Shafts

Three cases of sprung shafts on impulse turbines are reported. The shaft of one 25,000-kw. machine installed in 1926 had sprung 0.015 in. and was straightened. The other two cases occurred on two machines of 50,000-kw. capacity installed during 1924 and 1925. New shafts were installed in these two units.

The steel shrink links on a 40,000-kw. reaction type turbine installed in 1922 stretched causing the high pressure spindle to run out of alignment. New chrome nickel steel links were installed to correct this trouble.

Another station operating a 22,000-kw. reaction turbine, installed in 1921, reported the spindle had cracked through the balancing and equalizer holes on the governor end of the machine, making it necessary to install a new central section of the spindle.

Steam piping strains caused a spindle rub, resulting in blade failures and a bent spindle. This accident occurred in 1927 on an old reaction machine following repairs to the dummy strips.

High and Low Pressure Seals

The low-pressure seals are apparently giving satisfactory results.

In the case of the high-pressure seals, two stations reported that machine vibration was caused by steam leakage between the shaft and the rotating element of the seal causing unequal heating of the shafts. In one of these instances the seal rubbed and had to be renewed. In both cases the new seals installed had grooves cut on the inner circumference of the rotating element so that in case of steam leakage it would be distributed around the grooves, preventing unequal heating of the shaft. The machines on which this trouble occurred were of 30,000 and 35,000-kw. capacity, installed in 1926 and 1928.

In two plants the combined water and steam high-pressure seals were changed to a steam-sealed type. These two machines were installed in 1926 and 1927. In one case water from the seal was pulled into the machine and caused dishing of the first stage wheel resulting in a rub.

Two stations reported that the use of steam and water for sealing on the same bronze packing gland runners resulted in cracking and loosening of the runners. They were replaced with steel runners. In one of the above cases the use of steam for sealing has been discontinued.

Operating Governors

The operating governors have given practically no trouble. One case of a broken governor spindle has been reported.

Couplings

No difficulties have been reported with couplings.

Oil Pumps

Turbine oil pumps were reported as giving satisfactory service.

Throttle and Control Valves

Six stations report steam leakage between the seat rings and the casings of throttle valves. This trouble is apparently confined to the older units, since there were no reports of this nature on the more recently installed turbines.

One case is reported where the wrought iron studs in the bottom bonnets of the control valves on two 50,000-kw. machines installed in 1924 had crystallized. These studs were replaced with special steel studs.

In the case of an 80,000-kw. unit installed in 1926, a cap bolt in one of the main valve cages loosened due to broken binding wires and passed into the turbine, causing damage to the first stage blades and nozzles. The binding wires were replaced with lock washers bent up around two flats of the bolt head and crimped into seats.

TURBINE BLADING TROUBLES

This investigation covers 100 machines, totaling approximately 2,750,000-kw. capacity, which encountered blading failures during the years of 1926, 1927 and 1928. Most of the machines were of 20,000-kw. capacity or larger. Some of the turbines experienced repeated blade troubles over a period of years, but these additional failures have not been used in computing the totals reported. A large number of the machines had been in operation from two to four years. Care was taken in using data submitted from older machines as it was recognized that there has been an advancement in turbine blade design and material in the past five years. Many blade troubles are related to other turbine troubles, and failures which could be traced to or which accompanied other troubles such as thrust or dummy failures, etc., were not considered.

The troubles considered include in addition to blade failures proper, fractures discovered before actual failure, damage to or loss of shrouding sections, fractures of lacing wires or soldered lacing wire connections resulting in damage to blades, some root troubles and a few cases of cracked tenons under the shroud bands. Many of the blade troubles reported were discovered before actual failure had occurred. Often these discoveries were made by close inspection by the manufacturer's engineer during annual overhaul or upon special inspections made by or at their suggestion.

The Committee is not in position to make complete analyses of the causes of the failures. Such analyses can only be made by the manufacturers' turbine engineers and blading specialists with full detailed knowledge of turbine design, detailed blade design, blade loadings, allowable stresses and other details. However, from the information on hand it is possible to roughly group turbine blade failures into the two following classifications:

1. Those for which no apparent cause can be found and which apparently bear no definite relation to failures in other machines.
2. Those for which cause is discovered by inspection after the development of trouble or which apparently bear some relation to similar troubles in other machines.

A large number of failures can be grouped under the first classification. Many blade failures are discovered for the first time on opening the machine for annual inspection. Their presence was not suspected by the operating force, and apparently no indication was given or noticed, and no unusual noise heard at time of failure.

Often a number of failures may be linked together to form evidence which points to some weakness of design or other probable cause of trouble. In this group may be classed the failures of the longer blades in the lower stages of certain sizes of impulse turbines and of the shorter intermediate blades in reaction machines. It must not be assumed that the causes of failure are the same in every case.

Failures Result of Fatigue

From the evidence available, failures of the longer impulse blading cannot be attributed directly to the primary stresses due to centrifugal force, to impact, to pressure differences across the blading, or to blade loadings. Failures are rather the result of fatigue due to vibration. In a few of the cases reported the failures have been hastened by erosion and corrosion but it is believed failure would have ultimately occurred from vibration alone. The stresses caused by vibration cannot be easily analyzed mathematically. Therefore, the problem must be solved by direct research and by actual experience.

Failures in reaction machines have appeared in the intermediate sections and on blades and shapes deemed amply strong through years of service. Such failures probably result from a combination of the primary stresses rather than from vibration which would be more apt to manifest itself in the longer blades. These troubles have resulted in revision of methods of blade calculations to include factors previously deemed unimportant.

All the turbine builders have continued their study of blade design and have conducted extensive research into the problems presented by vibration. The methods used consist in general of testing to destruction many shapes of blading under the influence of various forms of vibration. This research includes the effect of position and shape of lacing wires and their fastenings and also the materials of blading.

Improvement Over Old Materials

The use of Ascoloy, stainless steel or chrome iron alloy is increasing for replacement as well as new blades. The data submitted were not sufficient to definitely determine the comparative resistance with respect to steel and other alloys against erosion, corrosion and similar troubles. The few reports received indicate considerable improvement over the old materials, and this checks with manufacturers' shop experience. It has been pointed out that stronger materials are available, but of the blading materials thus far developed chrome iron alloys apparently best combine the requirements of strength, resistance to erosion and corrosion, reasonable ease of working by ordinary shop methods, possibility of soldering without alteration of structure and resonable cost.

The use of lacing wires upon replacement of the longer blades is continued. In an effort to stiffen blading some applications of binding wires were made to blade shapes which have shown a tendency to fail through vibration. The application of tie wires to blades which are not primarily designed for their use must be regarded as somewhat experimental and while it may clear up the existing situation it does not completely eliminate the causes.

Improved blade roots and fastenings and better fitting of roots have also reduced blade vibration. With these and the use of much heavier and stiffer blades with well-rounded edges and large radius fillets, future troubles from vibration should decrease.

Some blade troubles may arise from the use of higher steam temperatures, particularly in the larger sized machines, which call for more skill and care in handling during the starting and stopping periods. Manufacturers of large turbines are fully aware of the seriousness of blade failures. They are carrying on extensive research in the hope of improving present designs and materials. It is not possible to simulate in a laboratory actual operating conditions. Therefore, at present, it appears that much of their information must be gained from operation in the field.

An attempt was made to ascertain the benefits of corrective measures which have been applied but sufficient data are not available to give definite conclusions. It seems that initially manufacturers applied lacing or tie wires to existing blades in an attempt to stiffen them. In one or two instances these were not entirely successful and later troubles were corrected by complete replacement. The use of silver solder to build up eroded edges has been successful in most instances, except where probably a good bond was not obtained.

Manufacturers' statements on turbine blading supplement the Turbine Blading Trouble section of this report.

MANUFACTURERS' STATEMENTS ON BLADING

The Prime Movers' Committee Does Not Accept Responsibility for any Manufacturer's Statement

STATEMENT BY THE ALLIS-CHALMERS MANUFACTURING COMPANY, MILWAUKEE, WIS.

Steam turbines manufactured by the Allis-Chalmers Co., 20.000 kw. and larger in capacity, are in service in five power plants in the Middle West, with a total of eight units.

The only blading renewals were as follows:

Two rows of moving and stationary blading in a 25,000 kw. unit.

One row of moving and stationary blading in a 25,000 kw. unit.

These two machines are located in the East Peoria Power Plant of the Illinois Electric Power Co., Peoria, Ill. They have both practically completed their fourth year of continuous operation. The replacements were of relatively small blading in the intermediate section of the turbines and were made during the regular inspection periods. There were no shut-downs of any of the eight machines because of blading failure.

The blading material in all of these machines has been of nickel-copper and nickel-chrome alloys that are corrosion resisting and in this company's judgment, more resistant to corrosion than stainless iron. For twenty-five years this company has not used a material for blading that is not of the non-corrosive type of metal.

The nickel-copper alloys used have been of two types, cupro-nickel and Monel metal. For the larger machines a limited amount of cupro-nickel is used for stationary blading in the intermediate and lower pressure stages. All of the moving blading is made of either Monel metal or the nickel-chrome alloy mentioned; this last alloy containing approximately 20 per cent nickel and 7 per cent chrome.

The blading research, as conducted by this company, covered the subject of blading vibration, strength of material at all temperatures, erosion, and fatigue strength of the material in round bar form and also in actual blade shapes and at different temperatures.

The work of this company in connection with the effect of vibration on turbine blading has been generally in the direction of making a structure or assembly of blading having a relatively high natural frequency.

This company tests the relative resistance of blading material to erosion on turbines in the power plant at their factory. Tests are continuous and are conducted over a period of years. They are performed by installing, in the same row of blading in a turbine, blades made of different material.

Research in the fatigue of blading material has been conducted for this company by the University of Illinois Experiment Station. The results of the tests of material submitted by this company for fatigue strength at room and high temperatures have appeared in publications of the university. The most recent publication on turbine blade material used by this company is contained in University of Illinois Bulletin No. 183. The material furnished the university was taken from stock shelves without any additional or special finish on the surface or on the edges. The knowledge made available by such tests is most valuable in determining the limiting load to be applied to an actual turbine blade.

STATEMENT BY THE GENERAL ELECTRIC COMPANY, SCHENECTADY, N. Y.

Present Situation

During 1928 improvement was made in the bucket situation, especially as regards the so-called light last stage buckets initially placed in service in 1924 and of which the first failure was reported during 1927. The use of this type was discontinued immediately when the failures were reported and their gradual elimination from machines in service has been attended with a corresponding improvement in service record.

This company has never lost any buckets due to primary or centrifugal stresses either in the body of the buckets or in the dovetail connections. All failures have been due to the presence of vibration as is evidenced by the fractures displayed. But no one single disease is common to all cases. It is necessary to take account of the particular type of vibration involved and also the strength or special points of weakness of the bucket in question, the stimulus present, the maximum value of which bears a definite relation to the load, the margin from resonance, and the ability to resist the development of stress as well as the strength of the dovetail connection and of the materials involved.

Investigations

Systematic tests are being carried on in reference to all the above factors. These tests involve shop experiments which range all the way from observation of the special behavior of a bucket under actual operating conditions of speed, load and steam conditions to analytic determinations by means of thousands of test samples of the properties of materials to withstand fatigue under actual operating conditions in regard to steam pressure and temperature.

Analysis of Service

The ultimate test of success with which all results must eventually be compared is the test of service in the machine. On this account, complete and careful service records of all buckets in all machines are kept and thorough analyses are made as to the success of the various designs. The results of these analyses, verified by shop tests, show that there is an apparent relationship between the load carried by a bucket or the total steam passed by it and the tendency to vibrate and the corresponding degree of fatigue suffered. Below a certain loading, there is apparent freedom from trouble, from which this company concludes at the present time that the corresponding fatigue, whenever present, is always within limits while for greater loadings the trouble percentages increase according to a fairly regular rule.

Out of the above relationships and with the aid of numerous production tests to determine coefficients, this company developed methods which enable it to proportion buckets with confidence that such fatigue stresses as may occur are well within the allowable limits. This company is of the opinion that the major difficulties have been overcome in present designs.

Features of Improvement

The features used to accomplish the above results comprise heavier and somewhat wider buckets for a given length with entrance and discharge edges rounded and last stages made sufficiently stiff to reduce as far as possible the use of tie wires. Where necessary tie wires of stronger construction and better design are used. With increased loadings, the steam pressures on buckets have been increasingly important and both buckets and dovetail connections have been designed to meet these increasingly severe conditions without increase of stress. The use of non-corrosive material is universal in the steam passages and the use of outside dovetails instead of inside dovetails is general for the intermediate as well as long buckets. Obstructions in exhaust chambers, such as ribs too near the last wheel, have been removed. Attention is paid to such details as correct edge thickness, correct fillet radii in root connection and suitable tenon connection at the tip. All of the above features are quantitatively evaluated and the proportioning is the result of systematic consideration.

During 1928 75 per cent of the troubles reported were discovered on inspection and only 25 per cent caused embarrassment in operation. Regular inspection and careful reporting of results by operating companies are important since only through such records of service can this company really know the true success of its designs.

STATEMENT BY THE WESTINGHOUSE ELECTRIC & MANUFACTURING CO., EAST PITTSBURGH, PA.

The statement of this company is divided into three parts: The first deals with the handling of blading troubles, the second with the designing of blades for new equipment and the third with the standardizing of blading practice to the maximum degree.

Handling of Blading Troubles

The working instructions of this company include a definite set-up whereby every large turbine blading repair is questioned, even though this company is requested merely to furnish an order of blading material. A study is then made to determine, if possible, the cause of the difficulty.

If the cause of the trouble is obscure, or insufficient facts have been accumulated, specialists are sent to make a further study of the situation. After the available data bearing on any particular accident have been carefully analyzed, a definite recommendation is made. The Steam Service Department of this company has an Engineering Section which collects and analyzes turbine troubles of all kinds, including blading. The Engineering Department also has a special Blading Section, which makes the detailed analyses of blade stresses and cooperates with the Service Department in the making of recommendations regarding blading troubles. This company is equipped to give the owners of its equipment the benefit of its broad practical experience on blading matters. It is to this end that these groups of engineers are organized.

If a blade failure occurs in a turbine designed ten or fifteen years ago, the first desire is to know the history of the trouble, as, occasionally, blade damage occurs through difficulties directly associated with the operation of the equipment. When the history of the events immediately surrounding the accident are known samples of the broken blades, or photographs of the wreckage are desired for inspection.

Simultaneously an analysis is made of the blade stresses, based on the present methods of stress determination. In some cases, it is found that the blades in older turbines are stressed beyond what is now considered the conservative limit. This is usually borne out by the types of fractures found among the broken blades. In such instances this company uses blades of stronger materials, made to their modern standards, the cure having been invariably successful.

It is difficult to place in the hands of users a complete set of instructions for the examination and inspection of blading. This is mainly because the blading art is changing so rapidly. The best procedure with large turbine equipment is for the operating people to get in touch with the Service Department of this company.

Throttle valves continue to leak occasionally; distorted turbine spindles and cylinders are the natural result. A too-rapid starting under these conditions results in rubbed, and in some cases broken blades. Blade breakage that follows from a blade rub is sometimes very deceptive as to the character of the breaks, as these may resemble long-time progressive fractures.

An important operating consideration is the question of blades filling up with solid matter, usually in the form of solids that become more or less firmly cemented to the surface of the blades. The injection of water into turbines with badly filled-up blades has been resorted to, although in one case a badly bent spindle resulted. If, however, turbine blades become filled up to such an extent that the bending stresses or the end thrust on the rotor becomes dangerous, serious troubles may occur. Such possibilities warrant a careful daily check of the pressure distribution on all central station main units.

Regarding the inspection of turbines, there are usually certain localities that the manufacturer's engineers know from experience may be the source of cracks or breakage should dangerous blade vibration occur. For example, on Westinghouse standard rolled reaction blades, the first place to inspect is at the inlet edge at a distance above the spindle or cylinder about equal to the width of the blade. The probability of blade breakage at this point is reduced by the rounding of the blade edges. If the blades are overstressed, or if there is heavy vibration, cracks will start at this point and slowly progress across the blades. In our older turbines where we did not round the packing as much as we do at the present time, a careful examination should be made of the blades adjacent to the packing, as in cases where sharp packing is pressed against the surface of the blades, breakage may start at this point. This is avoided in modern blading by giving the packing a generous radius on the upper edges.

The lashing wire should be carefully examined for breakage. In older Westinghouse reaction turbines, lashing wire breakage, if it occurs at all, will usually be between the first and second blades at the trailing end of the group. In ordinary blades of low stress where the breakage is not frequent, the lashing wires can be resoldered. The important point to watch when this is done is the cleaning of the breaks, and this, incidentally, is the point where the workman usually falls down. A careless workman is liable to daub the joint over with flux and solder and think the job well done. If there are many breaks in a single row, then it may be desirable either to install new lashing wire, or possibly to fit in an additional wire, which has sometimes been done without removing the blades from the spindle or cylinder. In such cases, a milling rig is available, by means of which a wire can be set in from the edges of the blades and soldered in place, all of which can be done in the field.

Another question that frequently comes up in connection with older reaction turbines is that of clearances. This company has accumulated considerable knowledge with regard to the distortion of large cylinder and spindle structures, from which it has been concluded that some of their older turbines were shipped with insufficient clearance over the tips of the reaction blades. For this reason this company sometimes recommends that the clearances be increased.

Another question that frequently arises concerns the effect of increased blade or dummy clearances on efficiency. With their modern turbines, this company can supply users with a curve, showing the rate at which the overall efficiency is depreciated per 0.010 in. increase in clearance in each row of blades and for each individual dummy. These curves are worked out so that if, for example, in the fifth spindle row of a given turbine, the clearance is 0.020 in. greater than the original value, the overall depreciation in efficiency can be read from the curve. In the case of accidental blade rubs, the operating people can decide the commercial value of replacing any given row or a number of rows of blades and thus be better able to decide when such replacements should be made for reasons of increased clearance. These statements also apply to low pressure blades where the tips become eroded by the action of entrained moisture.

Another question that sometimes arises is the corrosion and erosion of steel blades in the low pressure zones of large turbines. This type of blade usually looks worse than it really is. Around the dewpoint, for example, there is what appears to be a quite erratic type of corrosion that will occur here and there on the blades on the outlet edges, as well as on the inlet edges. It is particularly evident in the shadows in the fluid stream cast by the lashing wires. In such cases this company usually views the eroded blades from three standpoints: The first is that of mechanical efficiency. If the corrosion or erosion has progressed in the dewpoint regions to a point where the lashing wires are badly cut or the silver soldering is undermined, or where the outlet or inlet edges have been carried away so as to cause rapid change of section, this company usually recommends replacing such blades with others of stainless steel.

Where the mechanical strength is not impaired, it is next usual to consider the effect of this erosion or corrosion on efficiency. If the profiled tips of reaction blades are carried away to the degree where the clearances are seriously increased, then this must be decided on its own merits, based on the rate of change of efficiency with increased clearance, which can be determined from the data which this company will gladly furnish. In the case of reaction blades, the effect of erosion and corrosion on blade form is seldom sufficient to affect the efficiency abnormally. As stated above, the blades may have an extremely bad appearance, while the form has not been altered to the degree where the efficiency is seriously impaired.

In the case of low pressure blades, erosion is usually at the inlet edge, being most severe in the region of the blade tips. In the last few rows there is seldom a serious attack on the outlet edges. The water wear of the inlet edges is seldom bad enough to warrant blade replacements.

Where 5 per cent nickel steel blades are used, this company has in many cases coated the inlet edges with silver solder after a year of service. Silver solder, while a relatively soft alloy, is highly resistant to the erosive effect found in the last few rows of large turbines. This seems to be an entirely satisfactory treatment to which this company fully subscribes.

Designing of Blades for New Equipment

Following are some of the developments that have aided toward the improvement of turbine blading reliability.

The rounding of blade edges seems to be an obvious thing to do. The fatigue resistance of turbine blades (measured by the number of vibrations required to produce failure in a number of types of blade-testing machines employed by this company) is increased in the ratio of about three to one by the simple expedient of rounding and polishing edges. This rounding of edges is now carefully carried out on all blades, large or small, whether they be for new equipment or for repairs.

The edges of the lashing wire holes in double-lashed blades are carefully rounded. Our fatigue-testing machine results have shown improvements from 25 to 50 per cent in the fatigue resistance from the adoption of this simple change in process.

The upper edges of the packing pieces employed with drawn and upset blades are carefully rounded.

Improved blading materials have accomplished as much as anything else toward the increased turbine blade reliability. The standard materials employed by this company are as follows:

(a) Impulse blades—5 per cent nickel steel.

(b) Rolled and drawn reaction blades for small turbines—manganese copper.

(c) Reaction blading—both rolled and forged—for large central station turbines—stainless steel.

(d) Low pressure reaction blading for intermediate sizes of machines with low blade speeds—5 per cent nickel steel.

It must not be assumed that where manganese copper is employed instead of stainless steel that these materials are used interchangeably. The stainless steel is ordinarily operated at stresses about fifty per cent in excess of those considered safe for the manganese copper. Where manganese copper is used, the factor of safety is just about as great as in cases where stainless steel is employed.

The metallurgical work in connection with the control of the quality of the raw material, as well as the maintaining of uniform process results, has advanced substantially during the past few years. Space permits only a brief mention of this work. Our most notable improvements have been in the accumulation of a greater knowledge of the properties of materials under high temperature, a more complete knowledge of their fatigue properties, and, particularly, a more complete knowledge of such factors as hot-shortness and solder-cracking.

The problem of solder-cracking is little understood. If, for example, a piece of 30 per cent nickel steel wire is held in a vise and heated to the ordinary silver-soldering temperature, it may bend easily without breaking. Another piece of the same wire is coated with flux and heated to the silver-soldering temperature, coated with silver solder, and, if an attempt is made to bend it while the coated rod is still at soldering temperature, it will break. The molten solder has what might be called a strong corrosive action in the intercrystalline structure at the soldering temperature. Solder-cracking makes many otherwise good materials totally unfit for use as turbine blades.

It is but natural that knowledge of blading design has increased in the direction of stress-analysis determinations. With present methods of stress analysis, this company is now able to explain many older failures that were hitherto thought anomalous. In general, reaction blade stresses can be divided into four classes, as follows:

(a) Those due to centrifugal force.
(b) Those due to pressure drop over a given row.
(c) Those due to the tangential reaction.
(d) Those resulting from the so-called eccentric loading.

Coming to the design of long, low pressure blades, this company believes one of the most important factors is the distribution of the mass of the blade so that when all forces acting on the blade are considered, it tends to stand radially and thereby insure a uniform load over the blade section. If, for example, a long, low pressure blade were designed so that the center of gravity of the base section was offset some appreciable amount from the center of gravity of the active portion of the blade, eccentric stresses would come into play that might result in overstressing and ultimate failure.

In long, low pressure blades, an improved arrangement of lashing is employed, in which the lashing wires pass through the center of gravity of the blade section, with a heavy integral reinforcement on the blade to prevent localized stresses.

In the design of turbine blading, one of the most important things is the elimination of obstructions in the blade path that would cause an intermittent pulsation, such as might be created by a gap between the stationary blades at the horizontal joints. Great care is taken to maintain a uniform spacing of the stationary blades.

Obstructions in the exhaust chambers, such as projecting ribs that have been placed too close to the last row of blades, may set up pressure fluctuations and cause blade failure. It is also considered undesirable to bleed a turbine from the lower half, thereby creating an alternating stress in a given row of blades. The above statements will show our general tendencies in the design of blades for new equipment.

Coming to the question of blade fastenings, it is believed that, in general, the experience of users is that blade fastenings are generally stronger than the active portions of the blades. It may be said that trouble with the equipment of this company due to failure of blade fastenings is almost unknown.

Blade Research

In connection with overcoming of troubles and designing new blades, it is, of course, a hardship to the industry that the form of turbine blade best suited to secure the maximum efficiency with regard to energy conversion is the weakest kind of structure mechanically. In other words, beams of a crescent section would not be adopted in the building of a skyscraper. Some improvements can be realized by so designing the sections that the sharp outlet edges shall not be the fibers most remote from the neutral axis of the moment of least inertia. The inlet edges can be thick and rounded without serious loss in efficiency, while the outlet edges of reaction blades must be made as thin as possible, consistent with safety.

In order to determine the relative strength of various blade sections, forms of sections, rounding of blade edges, rounding of lashing wires, etc., a number of blade-testing machines have been designed and built by this company, which have, in the past few years, given excellent methods of comparing the relative values of different blade constructions. This company has a so-called hammer-testing machine, in which grooved blocks which contain several rows of blades may be mounted in a swinging hammer. This hammer is thrown back and forth between two stationary anvil blocks, thus subjecting the blades to alternate shocks, first in one direction and then in the other. The hammer is so adjusted that the fractures will take place between 20,000 and 400,000 blows. The fractures occur at the same points of weakness found in actual turbines. They progress, generally, in the same manner. The texture of the breaks

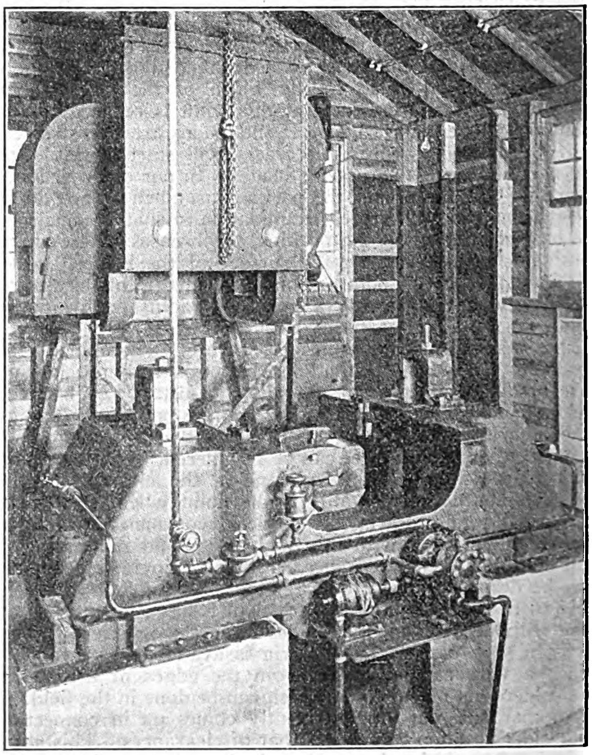

FIG. 9—TURBINE BLADE, HAMMER TESTING MACHINE —WESTINGHOUSE ELECTRIC & MFG. CO.

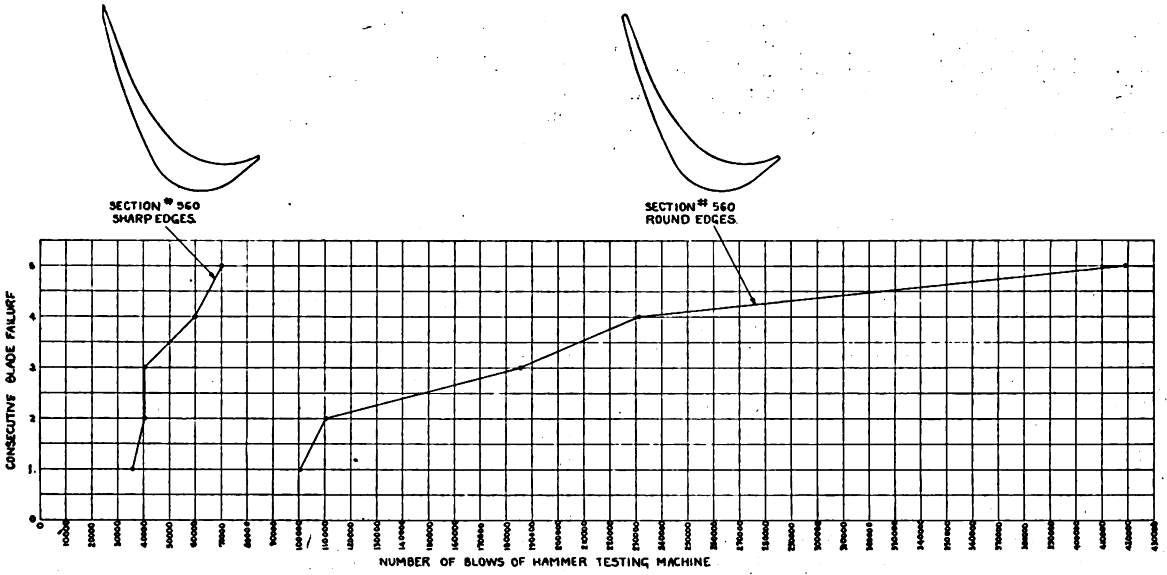

FIG. 10—IMPROVEMENT IN TURBINE BLADE FATIGUE RESISTANCE BY ROUNDING EDGES—WESTINGHOUSE ELECTRIC & MFG. CO.

resembles the breaks found in service. Many valuable results have been obtained from the hammer-testing machine, shown in Fig. 9.

A comparison of blades with sharp and rounded edges is shown in Fig. 10.

The so-called crank-testing machine is shown in Fig. 11. In this machine, groups of blades are held in moving cross-heads, so that their bases are moved rapidly back and forth, thereby stressing the assembled blade groups by reason of the inertia forces. The main advantage of the crank-testing machine is that we can obtain results in a much shorter space of time than with the hammer-testing machine.

A rotating-beam-testing machine which is used for testing single blades is shown in Fig. 12. The blade is held at its base by a heavy anvil block, while the outer end is held by an eccentric, which is, in turn, mounted on the end of a motor shaft. Many studies have been made with this equipment of certain blade types, particularly with respect to local reinforcing, rounding of lashing wire holes and allied problems.

A check is made of the natural frequency of a group of blades in every row in each large central station turbine shipped from the factory. This is done, first, to see that the frequencies of the longer blades do not agree with low multiples of the rotational frequency of the turbine rotor. The blade frequencies are determined with the aid of an oscillograph with a pick-up coil held adjacent to the blade surface, or, in case of non-ferrous blades, close to a small armature temporarily silver-soldered to one of the blade tips. The majority of this work is for statistical purposes, the main object being that the data shall be available for the study of obscure field breakage, should it take place.

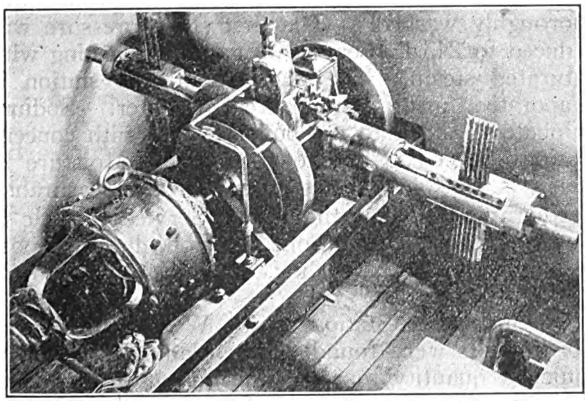

FIG. 11—TURBINE BLADE, CRANK TESTING MACHINE—WESTINGHOUSE ELECTRIC & MFG. CO.

A history is maintained of each individual large turbine, in which the various stresses are segregated, the natural frequencies of the lashed blade are tabulated, etc., in connection with which blade troubles may be studied.

Standardization of Blading Practice

In the preceding paragraphs, certain important changes in process have been mentioned. Such alterations are so important that they are being introduced as quickly as possible. Wherever possible, changes that lead to an increase of reliability are made retroactive and are made effective as far back as possible for repair work. In this connection, users may find an increase in prices in certain cases of repair blading. In most instances, they are caused by the introduction of modern blading standards for older equipment. Such recommendations are in accord with the general program of this company to serve turbine users in the best way, in line with the latest blading practice.

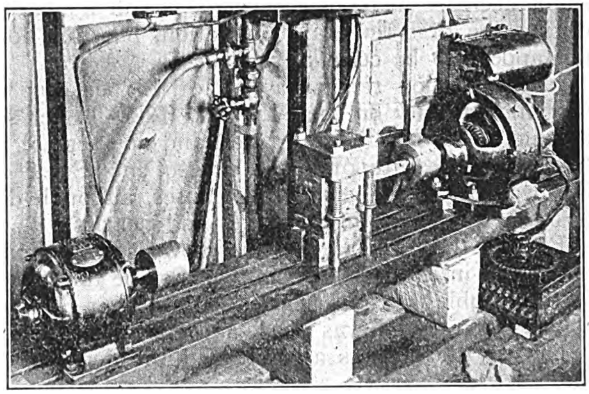

FIG. 12—TURBINE BLADE, ROTATING BEAM TESTING MACHINE, WESTINGHOUSE ELECTRIC & MFG. CO.

It is to be regretted that the turbine blading situation cannot be treated in a general way and characteristic information be placed in the hands of users that will apply to any case. This company is glad to place at the disposal of users any knowledge in its possession, and, as it is pointed out in the preceding comments, it has endeavored to do this whenever direct questions come to it from the operating companies. This policy has led to a substantial reduction in blading troubles; in fact, it is not unfair to state that, in the course of the next few years, blading troubles should be practically eliminated other than the ordinary corrosion and erosion that may still exist with the best materials yet obtainable.

DEPOSITS IN TURBINE BLADING

In response to a questionnaire concerning salt deposits in turbine blading, twelve companies reported troubles encountered in operation because deposits formed in the high pressure stages of their turbines. Other companies reported deposits in the low pressure stages, but this did not noticeably affect operation.

From the replies received, no method of cleaning blading which would be universally applicable was evolved. The information presented should be helpful in suggesting a method of approach when these troubles are encountered. The details for each problem must be worked out separately after due study of the installation and analysis of the salts deposited.

The deposit of salts in the high pressure stages of turbines must be considered seriously if it affects the capacity of the machine. This may result in increased load on blades or diaphragms, as well as adversely affecting the economy.

Deposits were encountered regardless of the operating pressures. The companies reporting trouble operated at pressures from 200 to 1200 lb. per sq. in. gage.

At Lakeside Station troubles with the 1200 lb. per sq. in. installation were partially corrected when the boiler concentrations were reduced to below 500 p.p.m. and the baffling in the drum improved. A slight decrease in turbine capacity is still noticeable during the first few days' operation, but this does not appear to be cumulative.

Edgar Station reports a loss of 15 per cent in carrying capacity on the 3150 kw., 1200 lb. per sq. in. unit in 26 months' operation and an increase in first stage pressure of 70 lb. per sq. in. Some of this was possibly due to other causes, although deposits are reported in all stages and nozzles.

Both of the foregoing stations now use tri-sodium phosphate in the feed water. During the time most of the trouble was experienced at the Edgar Station, a boiler compound was used, and considerable corrosion of the buckets accompanied the deposits of these salts.

Columbia Station of the Union Gas & Electric Co. showed a drop in carrying capacity from 44,000 kw. to 37,000 kw. in 45 days' operation. The throttle and first stage steam pressures were the same in both cases. The high pressure turbine outlet pressure dropped from 105 to 85 lb. per sq. in. gage, indicating a deposit in the high pressure stages at temperatures probably in excess of 500 deg. fahr.

At Philo Station of the Ohio Power Co. turbines No. 1 and 2 will deliver the rated capacity of 40,000 kw. after the machines are restored to service following an idle week-end. With a few days' operation the capacity decreases to 38,000 kw., which cannot be exceeded until the machine is again taken out of service for the week-end.

This is similar to reports from other plants, where a minor loss of capacity follows short periods of operation which is restored after an outage over the week-end. It is probable that the cooling down of the machine under these conditions either cracks off the scale or the initial charge of steam to roll the turbine carries sufficient moisture or is cooled below saturation and removes, at least, the load affecting portion of the deposit.

Reheat Boilers Source of Troubles

At both Columbia and Philo Station the reheat boilers are believed to be one source of these troubles. Water at Columbia was treated with lime, soda ash, ferrous sulphate and di-sodium phosphate with a concentration of approximately 900 p.p.m. maintained in the drums. Evaporators have recently been installed, but operating results are not yet available.

Crawford Avenue Station of the Commonwealth Edison Co. reports a loss of capacity as high as 25 per cent, requiring higher inlet steam pressures to carry a given load. This station formerly used Zeolite treated make-up, but now uses evaporated make-up. The concentrations are less, but the deposits still occur. Some phosphates are shown in the boiler water analyses submitted.

At Trinidad Station of the Texas Power & Light Co., the first stage pressure of the turbine increased during eight months' operation at 20,000 kw. load from 231 lb. per sq. in. gage to 289 lb. per sq. in. gage. The former pressure was obtained after the period of annual inspection when the rotor was thoroughly washed. The first stage pressure was reduced to 243 lb. per sq. in. gage by washing with saturated steam. The make-up at this station is evaporated, using Zeolite treated water. Sodium sulphate is added to the boiler drums with concentrations carried at 300 to 400 p.p.m. Moisture in steam is very low, being practically unmeasurable.

Kearny Station of the Public Service Electric & Gas Co. reports that on one occasion, due to deposits of salt, only 35,000 kw. could be carried on a 40,000 kw. unit.

At Springdale Station of the West Penn Power Co. deposits were found on the blading, but not in sufficient quantity to affect the output of the unit. Reduction in boiler concentrations from 1350 p.p.m. to about 600 p.p.m. has practically eliminated the deposit.

Kearny and Springdale Stations use tri-sodium phosphate with other chemicals for water treatment. Concentrations up to 2500 p.p.m. are carried at Kearny with boiler ratings maintained below 200 per cent. New drum baffling was also installed.

Rochester Gas & Electric Co., Station No. 3, operates on steam at 205 lb. per sq. in. gage and 480 deg. fahr. total temperature. The turbines are washed whenever a rise in the first stage pressure becomes evident.

Five stations report methods used in washing the turbines. Rochester Station No. 3 uses water introduced just ahead of the strainer through a ½ in. line when the machine is taken out of service. When a speed of 150 to 200 r.p.m. is reached, the throttle is cracked and the water admitted for approximately six minutes. During this operation the speed is held below 500 r.p.m. It is stated that this method is effective and has caused no apparent harm to the turbines. These are essentially low pressure, low temperature units from 7500 to 15,000 kw. capacity. The water admitted to the turbine cannot cause as great a change in temperature as would be the case with machines operating at high pressure and temperature.

Kearny used a similar method, taking care to avoid too rapid change in steam temperature.

Columbia Station uses saturated steam from a low pressure bleed point of another turbine, completely desuperheating the steam used by water jacketing the bleed steam line. The steam is admitted beyond the throttle valve with the turbine at rest. Circulation is obtained by blocking the drain traps connected to the high pressure cylinder, allowing them to discharge into the main condenser where a slight vacuum is maintained. This operation is continued until the turbine is returned to service.

Washing with Saturated Steam

At Crawford Avenue washing is done with saturated steam. Water from the boiler feed system is injected into the main steam lead just before the throttle valve at a slow rate until the steam temperature gradually being reduced reaches the saturation temperature. The temperature is held at saturation for a short time; the water is then gradually decreased and the temperature allowed to return to normal.

Trinidad Station uses saturated and wet steam to do the washing. Saturation is obtained by injecting hot feed water into the steam line through a high pressure spray nozzle. The effects of washing were indicated by conductivity tests of the condensate and operation discontinued when normal readings were obtained.

The Committee is unable to prove conclusively that any particular system of boiler water treatment or the presence of any particular chemicals is responsible for the trouble encountered. Some salts, of course, have a greater tendency to induce priming than others. There were installations where the use of certain chemicals apparently contributed to the trouble, but conflicting cases would arise where similar water treating methods were used, but no deposits were reported. Other factors not revealed by the reports received evidently contributed to this condition.

The troubles appear to increase with boiler drum concentrations and with boiler outputs. Soluble sodium salts formed a large percentage of the deposits analyzed, although in some cases the opposite was true and the soluble salts were a relatively small percentage of the total. In some instances appreciable proportions of sodium hydrate were found in deposits. The chemist for one company has pointed out that the melting point of sodium hydrate is 604 deg. fahr. Therefore, sodium hydrate might be carried over in the steam in a melted condition and readily become attached to or settle out on the blading at temperatures below 600 deg. fahr. It was expected, however, that this sodium hydrate would be gradually changed to sodium carbonate due to the action of carbon dioxide, which is undoubtedly present in the steam. The sodium hydrate in certain temperature zones makes an excellent cementing medium for attaching other salts to the blades. Even where the proportion of soluble salts is low it is believed that washing with saturated steam will weaken the structures so that the salts will fall off.

TURBINE MAINTENANCE AND CARRYING OF SPARE PARTS

Fifty-one replies were received from operating companies in connection with the questionnaire covering turbine maintenance and carrying of spare parts. Replies covered the practice of 58 power stations. The number of generating units included are in excess of 179, and represent a total capacity of more than 5,100,000 kw.

Spare Parts

All companies maintain a stock of some spare parts. One company reports that they are not justified in maintaining a supply of spare parts due to insurance covering breakdowns, and two companies report they are not justified in carrying the supply they have on hand. One company reports purchase of 1/3 set of stator coils after installation, and 2/3 after five years. Table XIII shows the practice of the reporting companies with regard to kind of spare parts carried in stock for their machines. Table XIV shows the manner in which spare parts are acquired.

Major Inspections

The companies are classified in Table XV according to the rules whereby the periods between major inspections are determined. Several companies report that time of inspection is based on both the elapsed time and hours in service.

TABLE XIII

TURBO-GENERATOR SPARE PARTS STOCKED BY OPERATING COMPANIES.

Name of Part	No. of Companies
Turbine spindles	4
Turbine blades	4
Main bearings	37
Thrust bearings	39
Throttle valve parts	26
Governor parts	46
Oil pump parts	39
Complete generators	2
Portion of generator stator winding	8

Replies with regard to the time necessary for an inspection of the vital running parts of the turbine indicate that the majority of companies interpreted this question as referring to the time required for a complete inspection of the unit, which varied in most cases from two to three weeks. One company reports it can make inspection of the vital running parts of its 60,000 kw. units and reassemble in 48 hours. Another reports 12 hours for a 22,500 kw. unit, and 8 hours for a 15,000 kw. unit. Other companies report 72 hours for the same work. It is not known to what extent the times reported represent periods when actual work was in progress.

TABLE XIV

TURBO-GENERATOR UNITS—METHOD OF ACQUIRING SPARE PARTS.

Method	No. of Companies
Inclusion of spare parts in the contract for unit	13
Spare parts purchased separately and after installation of unit	31
Arrangement with neighboring utility to carry a common supply of spare parts	4
Common supply of spare parts carried by associated companies	3
No arrangement with neighboring companies to carry a common supply of spare parts	40

TABLE XV

TURBO-GENERATOR UNITS—PERIOD BETWEEN GENERAL INSPECTIONS.

Condition	No. of Companies
Inspections based on elapsed time	35
Units inspected every year	27
Units inspected every 1 to 1½ years	1
Units inspected every 2 years	6
Units inspected every 3 years	1
Inspections based on unit service hours	9
Inspections based on no definite time schedule	2

Repair and Inspection Personnel

In general the companies use their own employees to make inspections and repairs. Five companies do not use their own employees for this work and apparently depend on the manufacturer. All companies, with the exception of one, engage a factory representative to supervise or be present while general inspections and repairs are in progress. One company reports that it does not use a factory representative in connection with general inspection and repairs, while several other companies only use factory assistance in connection with blade renewals or turbine and generator repairs of a special nature.

Performance Tests

The majority of companies depend on routine tests and station instrument records to determine the condition of their generating units. Eight companies report making tests following repairs which would effect turbine economy. Some companies conduct tests before and after repairs are made.

STEAM TURBINES FOR AUXILIARY DRIVES

The Committee reviewed the operation and maintenance of turbines for auxiliary drives for 1926, 1927 and 1928. Very few units recently installed by operating companies were reported upon. The information received did not disclose any operating experiences that were essentially new, but largely reviewed the operation and maintenance of this apparatus as reported in the 1927 report.

TESTS OF TURBO-GENERATOR UNITS

Reports of tests on turbo-generator units were received from member companies. These tests of 6000 to 60,000 kw. units were made under conditions that either represent normal operation or operation under special conditions to facilitate comparison with guarantees, or to observe the influence of certain operating conditions on unit economy.

With the advent of the regenerative cycle, the factors that influence economy became more numerous and testing of the unit became more complex. To determine the steam consumption of unit when steam is extracted from the turbine by weighing all the condensate is a problem that is easily solved only when the extraction stages are few and the bleed condensate drains to the condenser. Invariably, on the tests reported, only that part of the bleed condensate is weighed that drains to the condenser; the remainder of the bleed steam is calculated from the heat balance of the extraction heater. In some cases the efficiency of the extraction heater is separately determined and applied to heat balance calculations.

Table XVI shows the pertinent data for the turbines on which tests are reported, also the conditions of operation with respect to steam extracted.

Tests in previous reports represent straight con-

TABLE XVI

TURBO-GENERATOR TESTS—TURBINES FOR WHICH TESTS ARE REPORTED.

Test No.	Capacity Kw.	Manufacturer	Throttle Pressure Lb. Ga.	Throttle Temperature °F.	Stages of Steam Extraction
1	50,000	Westinghouse	265	615	2
1	50,000	Westinghouse	265	615	None
2	*43,750	Westinghouse	350	700	4
3	*52,500	Westinghouse	350	715	4
4	60,000	Westinghouse	285	700	2
5	*43,750	Westinghouse	350	700	None
6	50,000	General Electric	315	725	4
7	50,000	General Electric	375	700	3
7	50,000	General Electric	375	700	None
8	50,000	General Electric	270	600	None
9	30,000	General Electric	375	680	3
10	30,000	Allis-Chalmers	335	700	None
11	15,000	Allis-Chalmers	400	725	3
12	6,000	Allis-Chalmers	235	530	None

*Rating of Turbo-Generator in kv-a.

densing operation. Some of the tests in this report were made on units operating on the regenerative cycle, with data presented on the performance of the extraction heaters as well as the turbine and generator. Data are also furnished for the same units when operated straight condensing and on the regenerative cycle to disclose the thermal gain effected by extracting steam for feed water heating. The difference in economy of the same unit when operated straight condensing and when steam is extracted, however, may not equal the difference in economy for two similar machines, one designed to operate straight condensing and the other designed for extraction operation.

Tests are also presented that show the effect of changes in the exhaust vacua on the economy of a unit when operated on the regenerative cycle, also the effect on economy when bleed steam is used to evaporate make-up and the vapor returned for feed water heating.

TURBO-GENERATOR TEST NO. 1

A series of tests was made to determine the performance of this unit when no steam is extracted from the turbine, also when steam is extracted from two stages of the turbine for feed water heating. Tests were made during May, 1926.

Test Apparatus Data

Turbine: Tandem compound, Parsons type, Westinghouse machine rated at 50,000 kw., exhausting into a 70,000 sq. ft. Westinghouse radial flow, 2 pass, surface condenser. The machine is designed to operate with throttle steam at 265 lb. per sq. in. gage and 200 deg. fahr. superheat with the exhaust pressure at 1.0 in. of mercury abs. The turbine is provided with three governor control valves. When the unit is operated at 80 per cent power factor, and the turbine is supplied with steam at guarantee conditions, with no steam extracted, the primary control valve is fully open at 36,000 kw., the secondary valve at 45,000 kw. and the tertiary valve at 50,000 kw. During normal operation, steam is extracted from two points for feed water heating. The high pressure heater is supplied with bleed steam from the exhaust end of the high pressure cylinder. The low pressure heater is supplied with bleed steam from the center section of the semi-double flow low pressure cylinder.

Generator: Westinghouse, 62,500 kv-a., 80 per cent power factor, 60-cycle, 3-phase, Y-connected, 13,800 volt alternator with a 225 kw., 250 volt direct connected exciter.

The two extraction heaters are Wheeler closed type with horizontal return tubes arranged for four-pass flow of feed water passing through the heater. Each heater contains 3500 sq. ft. of heating surface made up of three-quarter inch, No. 16 B.W.G. seamless drawn copper tubes.

Method of Conducting Test

Eight 2-hr. runs were made with the turbine operating straight condensing. A similar number of runs was made with steam extracted at two points for feed water heating.

The generator output was measured at the generator terminals by the 3 wattmeter method with instruments read at minute intervals. A calibrated current transformer was inserted in each phase at the neutral and a calibrated potential transformer installed beween the neutral and each phase terminal.

During the non-bleed runs, the stop valve and hydraulic valves in the high and low pressure bleed steam lines were closed. The steam consumption of the unit was obtained by weighing the condensate from the main condenser and correcting this weight for water supplied to the low pressure turbine seals.

During the extraction tests the unit operated with its feed water system separated from the other units in the station. The high pressure bleed condensate discharged into the low pressure heater. The drains from the low pressure heater, which include the bleed condensate from the low pressure heater and the bleed condensate from the high pressure heater, were returned to the system by pumping into the boiler feed suction. The condensate from the main unit condenser, which includes the steam exhausted by the turbine and water supplied to the low pressure turbine seals, was obtained by weighing. The bleed condensate was not weighed on these tests. The quantity of bleed steam was calculated, based on observed data and heater efficiency curves that were previously determined from heat balance tests when condensate from bleeder heaters was weighed.

The quantity of feed water passing through the extraction heaters was equal to the steam supplied to the turbine and the water supplied to the low pressure turbine seals.

Results

A summary of the results of the test made with the turbine operating straight condensing is shown in Table XVII. The heat consumption of this unit under test condition corrected to guarantee and the performance guaranteed for the unit are graphically shown in Fig. 13.

The results of the tests with both extraction heaters in service are summarized in Table XVIII. The gross heat consumption is based on heat consumed by the turbine and the generator output. The net heat consumption is based on the heat consumption of the turbine, including steam jet air pumps and the generator output after the power used by the main condensate and the condenser circulating pumps has been deducted.

The curves in Fig. 14 show the heat consumption on both

TABLE XVII

TURBO-GENERATOR TEST NO. 1—SUMMARY OF TESTS—50,000-KW. WESTINGHOUSE TURBO-GENERATOR—NO STEAM EXTRACTED FROM TURBINE DURING THESE TESTS.

1. Run No.	27	39	34	31	25	28
2. Date	5/10/26	5/15/26	5/12/26	5/12/26	5/10/26	5/11/26
3. Net generator output, kw.	13,339	20,017	30,239	35,995	39,487	44,079
Turbine						
4. Steam pressure at throttle, lb. per sq. in. abs.	295.0	293.7	292.5	291.4	290.4	288.7
5. Steam pressure after primary valve, lb. per sq. in. abs.	115.4	166.9	235.7	276.7	280.5	276.4
6. Steam pressure after secondary valve, lb. per sq. in. abs.	86.8	124.5	175.1	216.6	237.2	263.5
7. Steam pressure after tertiary valve, lb. per sq. in. abs.	68.0	97.0	137.2	160.7	183.4	205.5
8. Steam pressure at high pressure bleed stage, lb. per sq. in. abs.	21.5	31.3	45.2	53.4	60.4	68.7
9. Steam pressure at low pressure bleed stage, lb. per sq. in. abs.	3.5	5.1	7.3	8.6	9.5	10.9
10. Steam pressure at exhaust, in. Hg. abs.	.64	.80	.91	1.0	1.1	1.3
11. Steam temperature at throttle, °F.	615.3	585.1	624.9	632.8	622.5	625.0
12. Steam superheat at throttle, °F.	199.4	169.6	209.7	218.0	207.9	211.0
13. Steam temperature at high pressure bleed stage, °F.	318.6	293.9	330.9	342.5	362.9	377.7
14. Steam temperature at low pressure bleed stage, °F.	147.8	163.4	178.7	185.9	191.3	197.3
15. Steam temperature at exhaust, °F.	63.8	70.3	74.0	77.7	80.3	83.9
Economy						
16. Total steam to unit (actual), lb. per hr.	148,429	219,569	307,864	359,697	402,180	453,615
17. Water rate (actual), lb. per hr.	11.128	10.970	10.181	9.993	10.185	10.291
18. Water rate (actual corrected to guarantee conditions), lb. per hr.	11.595	10.917	10.339	10.192	10.255	10.338
19. Heat consumption (actual), B.t.u. per kw-hr.	14,340	13,870	13,080	12,840	12,990	13,110
20. Heat consumption (actual corrected to guarantee conditions), B.t.u. per kw-hr.	14,770	13,900	13,170	12,980	13,065	13,170
21. Heat consumption (guaranteed), B.t.u. per kw-hr.	14,740	13,730	13,070	12,870	12,940	13,040
22. Overall thermal efficiency (actual), %.	23.81	24.62	26.11	26.60	26.29	26.05
23. Rankine cycle efficiency ratio (actual), %.	72.40	74.41	77.97	79.67	79.49	79.39
24. Generator efficiency, %.	91.48	93.97	95.54	95.97	96.15	96.34

TABLE XVIII

TURBO-GENERATOR TEST NO. 1—SUMMARY OF TEST—50,000-KW. WESTINGHOUSE TURBO-GENERATOR—STEAM EXTRACTED AT TWO STAGES FOR FEED WATER HEATING.

1. Run No.	24	20	18	19	17	16
2. Date	5/8/26	5/6/26	5/6/26	5/6/26	5/6/26	5/5/26
3. Net generator ouput, kw.	13,184	19,966	30,261	35,850	39,427	43,842
Turbine						
4. Steam pressure at throttle, lb. per sq. in. abs	291.2	290.1	287.5	288.5	285.8	284.5
5. Steam pressure after primary valve, lb. per sq. in. abs	123.2	170.7	252.3	277.3	273.1	267.9
6. Steam pressure after secondary valve, lb. per sq. in. abs	91.5	129.1	187.6	227.7	259.5	258.6
7. Steam pressure after tertiary valve, lb. per sq. in. abs	71.3	100.0	145.6	175.3	199.4	228.9
8. Steam pressure at high pressure bleed stage, lb. per sq. in. abs.	22.4	29.3	43.0	51.8	58.5	67.5
9. Steam pressure at low pressure bleed stage, lb. per sq. in. abs.	3.2	4.4	6.3	7.6	8.5	9.6
10. Steam pressure at exhaust, in. Hg. abs	.61	.71	.86	.98	1.1	1.2
11. Steam temperature at throttle, °F	579.3	595.2	606.0	615.5	605.5	609.7
12. Steam superheat at throttle, °F	164.5	180.7	192.5	201.6	192.5	197.0
13. Steam temperature at high pressure bleed stage, °F	270.5	290.7	302.1	331.9	343.3	374.8
14. Steam temperature at low pressure bleed stage, °F	144.4	157.2	172.0	180.2	185.5	191.4
15. Steam temperature at exhaust, °F	62.0	65.5	71.1	75.5	78.3	77.9
Low Pressure Heater						
16. Bleed steam pressure at heater inlet, lb. per sq. in. abs	3.2	4.2	5.8	6.9	7.8	8.7
17. Bleed steam temperature at heater inlet, °F	141.4	152.8	166.7	174.2	179.9	184.3
18. Bleed steam quality at heater inlet, %	98.2	98.1	98.2	98.4	98.0	98.2
19. Bleed condensate temperature, °F	142.8	153.9	168.0	175.4	180.5	185.2
20. Feed water temperature entering heater, °F	95.5	85.8	92.6	95.4	98.3	99.1
21. Feed water temperature leaving heater, °F	139.4	149.2	161.8	169.0	173.7	177.3
22. Heat removed from bleed steam, B.t.u. per lb	994.9	988.6	982.1	979.4	973.5	973.0
23. Heat absorbed by feed water, B.t.u. per lb	43.7	63.3	68.8	73.5	75.3	78.1
24. Heat absorbed by feed water, million B.t.u. per hr	7.24	14.85	23.26	29.83	34.86	41.14
25. Feed water passing thru heater, lb. per hr	165,685	234,520	338,054	406,133	462,953	526,720
26. Bleed steam to heater, lb. per hr	6,213	12,951	19,985	26,010	30,671	36,148
27. Bleed steam per pound of feed water heated (actual), lb	0.037	0.055	0.059	0.064	0.066	0.069
28. Bleed steam per pound of feed water heated (actual corrected for flash of high pressure bleed condensate), lb	0.0455	0.0645	0.0705	0.0769	0.0806	0.0849
29. Bleed steam per pound of feed water heated (theoretical), lb	0.0439	0.0640	0.0701	0.0750	0.0773	0.0803
30. Heater efficiency (apparent), %	96.5	99.2	99.4	97.5	95.9	94.6
*31. Terminal difference, °F	4.6	6.3	7.3	7.3	8.0	12.1
32. Logarithmetic mean temperature difference, °F	18.5	26.1	29.3	31.1	32.1	39.0
33. Coefficient of heat transfer, B.t.u. per hr. per sq. ft. per °F	112	163	227	274	310	301
34. Feed water velocity thru heater tubes, ft. per sec	1.17	1.66	2.39	2.88	3.28	3.72
35. Bleed steam pressure drop - turbine to heater inlet, lb. per sq. in.	0.0	0.2	0.5	0.7	0.7	0.9
36. Bleed steam temperature drop - turbine to heater inlet, °F	3.0	4.4	5.3	6.0	5.6	7.1
High Pressure Heater						
37. Bleed steam pressure at heater inlet, lb. per sq. in. abs	22.0	30.2	42.7	51.6	58.1	66.8
38. Bleed steam temperature at heater inlet, °F	268.7	289.7	298.7	329.0	341.3	375.2
39. Bleed steam superheat at heater inlet °F	35.7	39.0	27.5	46.0	50.7	75.4
40. Bleed condensate temperature, °F	224.0	243.0	266.1	277.5	286.4	296.6
41. Feed water temperature entering heater, °F	139.4	149.2	161.8	169.0	173.7	177.3
42. Feed water temperature leaving heater, °F	228.5	247.0	266.8	278.2	285.8	293.9
43. Heat removed from bleed steam, B.t.u. per lb	985.0	974.9	952.2	953.8	949.6	957.9
44. Heat absorbed by feed water, B.t.u. per lb	89.3	98.1	105.7	110.0	113.1	117.7
45. Heat absorbed by feed water, million B.t.u. per hr	14.80	23.01	35.73	44.67	52.36	61.99
46. Feed water passing thru heater, lb. per hr	165,685	234,520	338,054	406,133	462,953	526,720
47. Bleed steam to heater, lb. per hr	16,295	24,178	38,470	49,827	60,393	74,035
48. Bleed steam per pound of feed water heated (actual), lb	0.0983	0.1031	0.1138	0.1227	0.1305	0.1406
49. Bleed steam per pound of feed water heated (theoretical), lb	0.0907	0.1007	0.1110	0.1154	0.1190	0.123
50. Heater efficiency (apparent), %	92.3	97.7	97.5	94.0	91.2	87.5
*51. Terminal difference, °F	4.6	3.7	4.1	4.6	4.5	5.3
52. Logarithmetic mean temperature difference, °F	29.4	29.6	32.0	33.8	34.5	37.3
53. Coefficient of heat transfer, B.t.u. per hr. per sq. ft. per °F	144	222	319	378	434	475
54. Feed water velocity thru heater tubes, ft. per sec	1.19	1.70	2.47	2.98	3.40	3.88
55. Bleed steam pressure drop - turbine to heater inlet, lb. per sq. in.	-	0.6	1.7	2.0	2.2	2.3
56. Bleed steam temperature drop - turbine to heater inlet, °F	1.8	1.0	3.5	2.9	1.9	
Economy						
57. Net hotwell condensate, lb. per hr	141,105	195,310	277,427	328,192	369,836	414,570
58. Bleed steam to heaters, lb. per hr	22,508	37,129	58,455	75,837	91,064	110,183
59. Total steam to unit (actual), lb. per hr	163,613	232,439	335,882	404,029	460,900	524,753
60. Total steam to unit (corrected to guarantee), lb. per hr	166,397	235,171	337,193	406,976	457,682	522,629
61. Gross thermal efficiency (actual), %	24.69	26.78	28.48	28.46	27.96	27.68
62. Net thermal efficiency, auxiliaries deducted (actual), %	24.08	26.34	28.17	28.19	27.72	27.46

*Difference between saturation temperature at heater pressure and feed water temperature leaving heater.

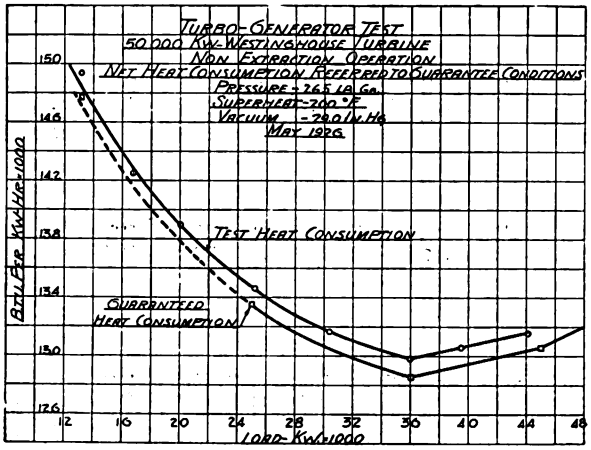

FIG. 13—NET HEAT CONSUMPTION, NO STEAM EXTRACTED FROM TURBINE—TURBO-GENERATOR TEST No. 1.

gross and net kw. output basis with steam extracted at two points for feed water heating. In Fig. 15 the relation is shown between the steam supplied to the unit, the steam exhausted to the condenser, and the steam extracted, both total and segregated, for the high and low pressure bleed points.

To facilitate comparison of the performance of the same unit under bleeding and non-bleeding operation, the steam flow at the throttle, the water rate and the thermal efficiency of the unit are shown respectively in Fig. 16, 17 and 18 for both conditions of operation.

TURBO-GENERATOR TEST No. 2

These tests were made on a turbo-generator unit to determine the economy of the unit when operating on the regenerative cycle, also to investigate the performance of the extraction heaters. Tests were made during November, 1927.

Test Apparatus Data

Turbine: Westinghouse Electric & Manufacturing Co.; 1800 r.p.m.; single cylinder with multi-exhaust blading, exhausting into a Westinghouse Electric & Manufacturing Co., 50,000 sq. ft. surface condenser.

Generator: Westinghouse Electric & Manufacturing Co.; 43,750 kv-a.; 80 per cent power factor; 13,800 volts; 3-phase; 60 cycle; 1800 r.p.m.

Exciter: Westinghouse Electric & Manufacturing Co.; d-c.; direct connected; 165 kw.; 250 volts; 1800 r.p.m.

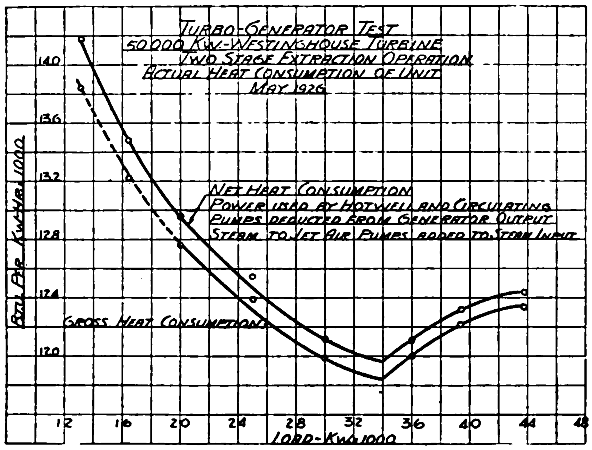

FIG. 14—GROSS AND NET HEAT CONSUMPTION, STEAM EXTRACTED AT TWO STAGES OF THE TURBINE—TURBO-GENERATOR TEST No. 1.

Generator air cooler: Griscom-Russell Co.; U-fin cooler; maximum working pressure, 50 lb. per sq. in. gage.

Low pressure closed heater: Griscom-Russell Co.; condenser type; four pass; maximum working pressure, steam, 50 lb. per sq. in. gage; water, 100 lb. per sq. in. gage; heating surface, 1700 sq. ft.; ⅝-in. O.D., No. 18 B.W.G., seamless drawn Admiralty tubes. Steam supplied to heater from fourth extraction stage.

Pre-cooler: Cochrane Co.; single pass, surface condenser; capacity, 400,000 to 1,000,000 lb. per hr.; heating surface, 150 sq. ft.; ⅝-in. O.D., No. 18 B.W.G. tubes. The pre-cooler is a surface condenser on the vent of the open heater.

Barometric condenser: Cochrane Co.; duplex nozzle jet heater; capacity, 500,000 to 1,000,000 lb. per. hr.

Open heater: Cochrane Co.; metering heater; deaerating type; capacity, 400,000 to 1,000,000 lb. per hr.; working pressure, 5 lb. per sq. in. gage.

Intermediate pressure heater: Griscom-Russell Co.; condenser type; four pass; maximum working pressure, steam, 65 lb. per sq. in. gage; water, 500 lb. per sq. in. gage; heating surface, 2000 sq. ft.; ⅝-in. O.D., No. 16 B.W.G., seamless drawn Admiralty tubes.

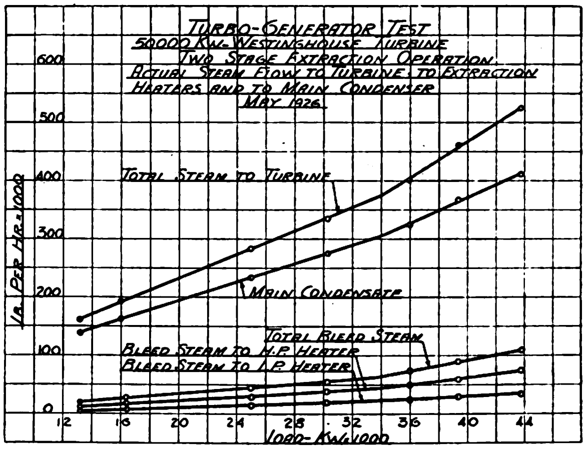

FIG. 15—STEAM DISTRIBUTION, STEAM EXTRACTED AT TWO STAGES OF THE TURBINE—TURBO-GENERATOR TEST No. 1.

High pressure heater: Griscom-Russell Co.; four pass; condenser type; maximum working pressure, steam, 170 lb. per sq. in. gage; water, 500 lb. per sq. in. gage; heating surface, 2000 sq. ft.; ⅝-in. O.D., No. 16 B.W.G., seamless drawn Admiralty tubes.

Method of Conducting Test

Tests were made at all loads under normal conditions of steam pressure and vacuum, no air being admitted to the condenser or air pumps.

Steam was extracted from four stages of the turbine for feed water heating.

The condensate from the hotwell of the main condenser was pumped through the low pressure closed heater to the weigh tanks. A test pump returned the condensate from the test storage tank to the condensate system at the pre-cooler, passing through the pre-cooler and the barometric condenser to the open heater. The open heater discharged to the boiler feed pumps. The condensate at feed water pressure passed through the intermediate pressure closed heater and high pressure closed heater to the boilers. The bleed condensate from the low pressure closed heater was drained to the hotwell of the main condenser. The bleed condensate from the intermediate and high pressure closed heaters was drained to the open heater.

The quantity of water passing through the low pressure heater and the vent condenser which is equal to the steam condensed by the main condenser and the bleed condensate from the low pressure closed heater was weighed on the

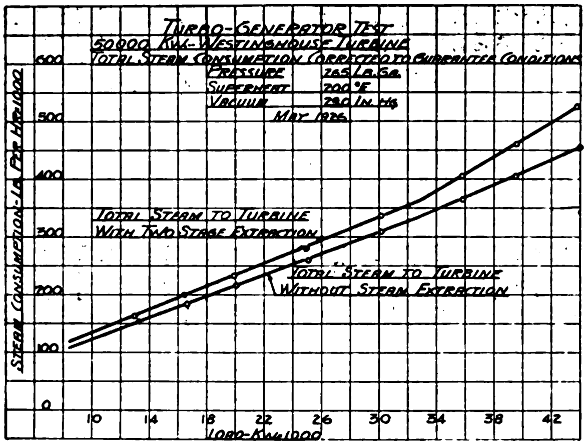

FIG. 16—STEAM TO TURBINE, WITH AND WITHOUT TWO STAGE EXTRACTION—TURBO-GENERATOR TEST NO. 1.

test weigh scales. The water supplied to all the other heaters was computed.

No corrections were necessary for seal water used. The high and low pressure seals of the main turbine and the condensate pump seals were supplied with condensate from the discharge of main condensate pump and recirculated in the system.

The kilowatt load was obtained from the switchboard polyphase watt-hour meter on which a high speed register had been installed. The watt-hour meter was adjusted and checked previous to the test and rechecked after the test, the calculations showing no corrections were to be applied for meter calibrations. The generator net output was corrected for phase angle and ratio of transformation of the instrument transformers used.

A chemical analysis of condensate and river water showed no condenser leakage.

The total steam consumption of the turbine was obtained by adding the weighed condensate and the calculated steam extracted from those stages of the turbine which have drains entering the system after the weigh tanks.

The bleeder steam was computed from heat equations involving the total heat in the steam at the heater inlet, the heat of the liquid of the bleed condensate, the weighed or computed water flow to the heater and temperature rise of water passing through the heater. The quality of the bleed steam to the low pressure closed heater was determined from the expansion curves of the turbine.

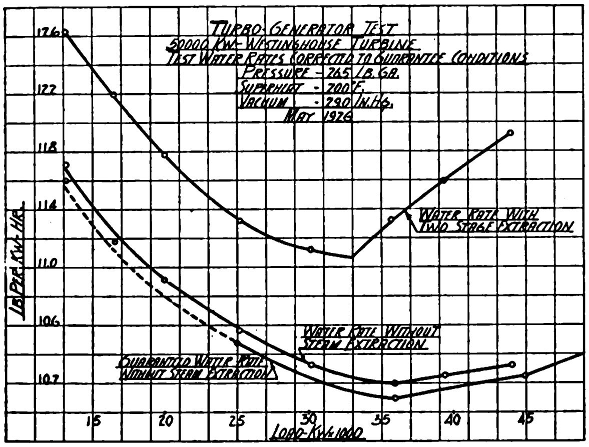

FIG. 17—WATER RATE WITH AND WITHOUT STEAM EXTRACTED AT TWO STAGES OF THE TURBINE—TURBO-GENERATOR TEST NO. 1.

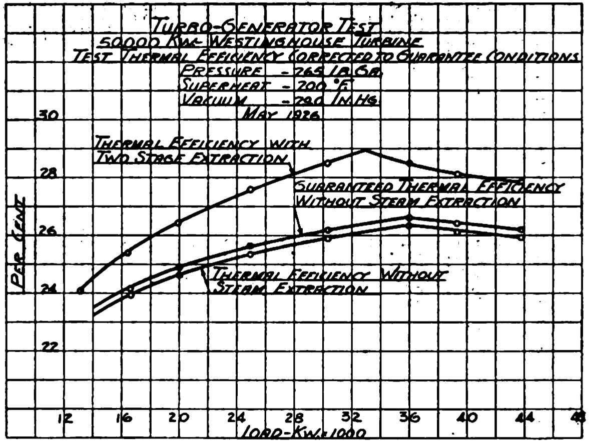

FIG. 18—THERMAL EFFICIENCY, WITH AND WITHOUT STEAM EXTRACTED AT TWO STAGES OF THE TURBINE—TURBO-GENERATOR TEST NO. 1.

Results

A summary of the test results with the turbine operating on the regenerative cycle with detailed data on the performance of the extraction feed water heaters and the auxiliary heaters entering into the heat balance of the unit is presented in Table XIX.

The steam superheat at the third extraction stage is effected by the high temperature steam from the balancing piston. The temperature at the outlet of the open heater is kept at approximately 215 deg. fahr. To maintain proper heat balance more or less steam is bled from the third extraction stage to the barometric condenser. This explains the wide variation in the bleed steam to the barometric condenser as shown on run F.

The generator heat losses were not recovered, river water being used to cool the air in the closed generator air cooling system.

The net heat consumption and the thermal efficiency of this unit are graphically presented in Fig. 19.

TURBO-GENERATOR TEST NO. 3

A series of tests was made on a Westinghouse turbo-generator unit to check the performance when operating on the regenerative cycle, also to investigate the performance of the extraction heaters. This unit rated at 52,500 kv-a.

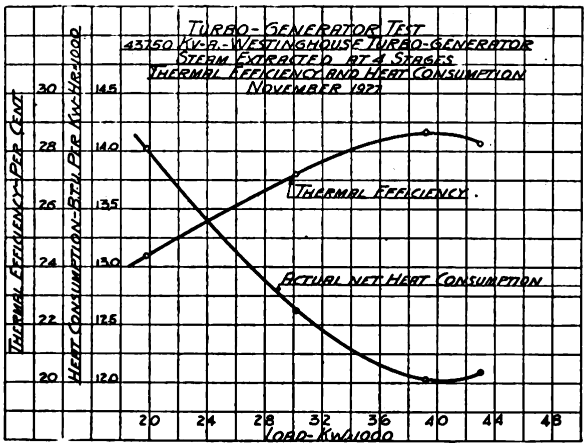

FIG. 19—THERMAL EFFICIENCY AND HEAT CONSUMPTION, STEAM EXTRACTED AT FOUR STAGES OF THE TURBINE—TURBO-GENERATOR TEST NO. 2.

TABLE XIX

TURBO-GENERATOR TEST NO. 2—SUMMARY OF TEST—43,750-KV-A. WESTINGHOUSE TURBO-GENERATOR UNIT—STEAM EXTRACTED FROM FOUR STAGES OF TURBINE.

1. Run No.	D	C	F	E
2. Date	11/26/27	11/25/27	11/28/27	11/28/27
3. Barometer, in. Hg	30.47	30.26	30.27	30.34
4. Net generator output (direct connected exciter), kw	19,700	30,310	39,630	43,050
5. Power factor, %	51.2	69.6	90.0	88.4
6. Excitation, kw	115	120	112	116
Turbine				
7. Steam pressure before strainer and throttle, lb. gage	360	360	356	353
8. Steam pressure after throttle, lb. gage	355	356	351	348
9. Steam pressure after primary valve, lb. gage	217.1	310.1	351.0	345.1
10. Steam pressure after secondary valve, lb. gage	79.1	115.7	335.2	342.2
11. Steam pressure after tertiary valve, lb. gage	78.6	115.3	178.8	260.7
12. Steam pressure at 1st extraction stage, lb. gage	77.4	115.1	156.6	179.0
13. Steam pressure at 2nd extraction stage, lb. gage	18.1	30.5	45.2	53.1
14. Steam pressure at 3rd extraction stage, lb. gage	-5.8	-2.4	2.0	3.6
15. Steam pressure at 4th extraction stage, in. Hg. abs	5.13	6.62	9.06	10.05
16. Steam pressure at exhaust, in. Hg. abs	1.20	.77	.99	1.09
17. Steam temperature before strainer and throttle, °F	697	699	691	688
18. Steam superheat before throttle, °F	259	261	254	252
19. Steam superheat at 1st extraction stage, °F	192	183	195	210
20. Steam superheat at 2nd extraction stage, °F	115	118	146	156
21. Steam superheat at 3rd extraction stage, °F	113	162	85	218
22. Steam quality at 4th extraction stage, %	96.1	95.3	95.0	95.3
23. Steam temperature at exhaust, °F	83.8	69.2	75.6	78.6
Low Pressure Heater				
24. Bleed steam pressure at heater inlet, in. Hg. abs	4.93	5.96	8.26	9.17
25. Bleed steam temperature at heater inlet, °F	131.6	139.1	152.4	156.9
26. Bleed steam quality at heater inlet, %	96.1	95.3	95.0	95.3
27. Bleed condensate temperature, °F	128.4	117.4	107.2	106.7
28. Feed water temperature entering heater, °F	94.2	78.4	82.0	84.0
29. Feed water temperature leaving heater, °F	123.9	128.8	139.2	139.5
30. Feed water passing thru heater, lb. per hr	214,850	299,090	377,010	413,080
31. Bleed steam to heater, lb. per hr	6,490	15,240	22,230	22,730
32. Bleed steam per pound of feed water heated, lb	0.0302	0.0510	0.0590	0.0550
33. Logarithmetic mean temperature difference, °F	20.8	30.2	35.7	39.9
34. Coefficient of heat transfer, B.t.u. per hr. per sq. ft. per °F.	219	357	432	410
35. Feed water velocity thru heater tubes, ft. per sec	3.00	4.18	5.27	5.78
36. Bleed steam pressure drop - turbine to heater inlet, in. Hg	0.20	0.66	0.80	0.88
37. Feed water pressure drop across heater, lb. per sq. in	7.9	16.1	21.8	26.9
Pre-Cooler				
38. Feed water temperature entering pre-cooler, °F	122.5	129.5	139.1	139.4
39. Feed water temperature leaving pre-cooler, °F	149.9	150.3	152.1	154.8
40. Feed water passing thru pre-cooler, lb. per hr	212,500	291,960	375,990	403,460
41. Steam from open heater vent to pre-cooler, lb. per hr	6,020	6,280	5,050	6,420
Barometric Condenser				
42. Bleed steam pressure at condenser inlet, lb. gage	-7.2	-3.7	0.8	2.3
43. Bleed steam temperature at condenser inlet, °F	295.1	360.0	299.9	438.4
44. Bleed steam superheat at condenser inlet, °F	113	162	85	218
45. Feed water temperature entering condenser, °F	145.4	147.7	148.5	150.8
46. Feed water and bleed steam mixture leaving condenser, °F	169.5	180.2	152.9	181.0
47. Feed water entering condenser, lb. per hr	212,500	291,960	375,990	403,460
48. Bleed steam to heater, lb. per hr	4,880	8,850	1,540	11,010
49. Bleed steam per pound of feed water heated, lb	0.0230	0.0303	0.0041	0.0273
50. Bleed steam pressure drop - turbine to condenser inlet, lb. per sq. in	1.4	1.3	1.2	1.3

TABLE XIX—(*Continued*)

Open Heater				
51. Feed water temperature entering heater, °F	169.5	180.2	152.9	181.0
52. Feed water (mixture) temperature leaving heater, °F	218.2	218.1	215.6	217.3
53. Feed water to heater, lb. per hr	217,380	300,810	377,530	414,470
54. Bleed condensate from high and intermediate pressure heater, lb. per hr	23,400	41,100	67,470	75,840
55. Pre-cooler condensate to heater, lb. per hr	6,020	6,280	5,050	6,420
56. Total feed water to heater, lb. per hr	246,800	348,190	450,050	496,730
57. Auxiliary steam condensed, lb. per hr	9,040	7,330	16,460	6,140
Intermediate Pressure Heater				
58. Bleed steam pressure at heater inlet, lb. gage	17.2	28.5	41.3	48.6
59. Bleed steam temperature at heater inlet, °F	368	389	435	452
60. Bleed steam superheat at heater inlet, °F	114	117	147	156
61. Bleed condensate temperature, °F	254.9	272.8	288.8	296.0
62. Feed water temperature entering heater, °F	220.0	219.0	217.5	219.2
63. Feed water temperature leaving heater, °F	253.1	268.6	288.2	294.6
64. Feed water passing thru heater, lb. per hr	255,840	355,520	466,510	502,870
65. Bleed steam to heater, lb. per hr	8,600	18,120	33,820	38,930
66. Bleed steam per pound of feed water heated, lb	0.0336	0.0510	0.0725	0.0774
67. Logarithmetic mean temperature difference, °F	10.1	18.2	-	20.4
68. Coefficient of heat transfer, B.t.u. per hr. per sq. ft. per °F.	424	491	-	945
69. Feed water velocity thru heater tubes, ft. per sec	2.94	4.10	5.41	5.84
70. Bleed steam pressure drop - turbine to heater inlet, lb. per sq. in	0.9	2.0	3.9	4.5
71. Feed water pressure drop across heater, lb. per sq. in	3.7	7.2	12.0	12.4
High Pressure Heater				
72. Bleed steam pressure at heater inlet, lb. gage	74.0	108.8	152.7	173.7
73. Bleed steam temperature at heater inlet, °F	511	527	562	587
74. Bleed steam superheat at heater inlet, °F	192	183	195	210
75. Bleed condensate temperature, °F	319.4	343.7	366.6	376.1
76. Feed water temperature entering heater, °F	257.0	272.8	289.0	296.3
77. Feed water temperature leaving heater, °F	313.3	333.9	356.0	363.9
78. Feed water passing thru heater, lb. per hr	255,840	355,520	466,510	502,870
79. Bleed steam to heater, lb. per hr	14,800	22,980	33,650	36,910
80. Bleed steam per pound of feed water heated, lb	0.0578	0.0646	0.0721	0.0734
81. Logarithmetic mean temperature difference, °F	24.7	30.6	34.6	37.2
82. Coefficient of heat transfer, B.t.u. per hr. per sq. ft. per °F.	297	365	468	477
83. Feed water velocity thru heater tubes, ft. per sec	3.01	4.23	5.61	6.08
84. Bleed steam pressure drop - turbine to heater inlet, lb. per sq. in	3.4	6.3	3.9	5.3
85. Feed water pressure drop across heater, lb. per sq. in	3.8	8.0	13.3	13.8
Economy				
86. Total steam to turbine including bleed steam, lb. per hr	242,600	348,640	445,800	499,300
87. Water rate, including bleed steam (actual), lb. per kw-hr	12.31	11.50	11.25	11.60
88. Heat consumption, net generator output basis (actual), B.t.u. per kw-hr	14,050	12,640	12,020	12,100
89. Thermal efficiency (actual), %	24.3	27.0	28.4	28.2

TABLE XX

TURBO-GENERATOR TEST NO. 3—SUMMARY OF TEST—52,500-KV-A. WESTINGHOUSE TURBO-GENERATOR UNIT—STEAM EXTRACTED AT FOUR STAGES.

1. Run No.	B	A	C	D
2. Date	6/30/28	6/29/28	7/2/28	7/2/28
3. Barometer, in. Hg	29.76	29.86	30.00	30.00
4. Net generator output (direct connected exciter), kw	21,510	30,410	38,160	44,200
5. Power factor, %	57.5	71.1	86.4	97.1
6. Excitation, kw	106	134	122	114
Turbine				
7. Steam pressure before strainer and throttle, lb. gage	354	353	356	353
8. Steam pressure after primary valve, lb. gage	236	324	355	351
9. Steam pressure after secondary valve, lb. gage	82	116	220	347
10. Steam pressure after tertiary valve, lb. gage	82	117	151	201
11. Steam pressure at 1st extraction stage, lb. gage	79.9	114.2	147.4	178.9
12. Steam pressure at 2nd extraction stage, lb. gage	20.2	32.6	44.5	55.4
13. Steam pressure at 3rd extraction stage, lb. gage	-4.5	-1.4	4.0	6.6
14. Steam pressure at 4th extraction stage, in. Hg. abs	5.30	6.97	8.66	10.21
15. Steam pressure at exhaust, in. Hg. abs	1.36	1.49	1.67	1.86
16. Steam temperature before strainer and throttle, °F	713	712	710	712
17. Steam temperature at 1st extraction stage, °F	532	536	562	602
18. Steam temperature at 2nd extraction stage, °F	383	392	412	434
19. Steam temperature at 3rd extraction stage, °F	329.2	336.8	353.2	407.7
20. Steam temperature at 4th extraction stage, °F	137.3	146.5	155.2	161.0
21. Steam temperature at exhaust, °F	87.5	91.4	94.1	98.0
Extraction Heaters				
Bleed steam pressure drop from turbine				
22. To high pressure heater, lb. per sq. in.	2.8	3.7	4.3	6.3
23. To intermediate heater, lb. per sq. in.	-	1.2	2.9	4.4
24. To barometric condenser, lb. per sq. in.	0.2	0.4	1.4	0.8
25. To low pressure heater, in. Hg	0.13	0.39	0.50	0.73
26. Condensate temperature leaving main condenser hotwell, °F	88.4	92.7	96.2	99.9
27. Feed water temperature entering low pressure heater, °F	101.8	103.0	105.5	108.0
28. Feed water temperature entering pre-cooler, °F	132.0	142.0	148.0	152.0
29. Feed water temperature entering barometric condenser, °F	156.6	160.7	164.4	166.9
30. Feed water temperature entering open heater, °F	182.7	199.1	205.6	207.9
31. Feed water temperature entering intermediate pressure heater, °F	221.3	221.7	222.8	222.9
32. Feed water temperature entering high pressure heater, °F	257.8	274.1	284.7	292.6
33. Feed water temperature leaving low pressure heater, °F	133.7	141.7	149.7	154.4
34. Feed water temperature leaving pre-cooler, °F	157.1	161.8	165.0	167.0
35. Feed water temperature leaving barometric condenser, °F	182.7	199.1	205.6	207.9
36. Feed water temperature leaving open heater, °F	220.9	221.2	221.5	221.5
37. Feed water temperature leaving intermediate pressure heater, °F	258.2	272.7	283.2	290.4
38. Feed water temperature leaving high pressure heater, °F	314.0	330.1	340.5	350.9
39. Bleed steam to low pressure heater, lb. per hr	7,140	11,620	16,480	20,100
40. Auxiliary steam to pre-cooler, lb. per hr	5,820	6,080	6,370	6,670
41. Bleed steam to barometric condenser, lb. per hr	5,520	10,910	14,290	16,520
42. Auxiliary steam condensed in open heater, lb. per hr	7,140	3,320	710	-1,650
43. Bleed steam to intermediate pressure heater, lb. per hr	9,980	18,660	27,220	36,330
44. Bleed steam to high pressure heater, lb. per hr	15,330	21,000	25,860	32,190
Bleed steam per pound of feed water heated				
45. At low pressure heater, lb.	0.0321	0.0396	0.0456	0.0476
46. At barometric condenser, lb.	0.0247	0.0368	0.0396	0.0386
47. At intermediate pressure heater, lb.	0.0374	0.0524	0.0626	0.0701
48. At high pressure heater, lb.	0.0574	0.0590	0.0594	0.0621
Economy				
49. Steam to the main condenser (actual), lb. per hr	214,690	280,960	344,810	401,420
50. Total steam to unit including bleed steam, lb. per hr	252,660	343,150	428,660	506,560
51. Water rate including bleed steam (actual), lb. per kw-hr	11.75	11.28	11.23	11.46
52. Heat consumption (actual), B.t.u. per kw-hr	13,300	12,270	12,040	12,070
53. Thermal efficiency, %	25.7	27.8	28.4	28.3

at 90 per cent power factor, operating at 1800 r.p.m., is provided with four extraction nozzles that supply steam to heat feed water. The tests were made in June, 1928.

The extraction heaters for this unit are identical with the extraction heating equipment described for the unit under turbo-generator test No. 2. The Westinghouse single cylinder, multi-exhaust type turbine is also the same in size. These turbo-generator units differ by the higher connected generator capacity of the unit on which this test was made.

The method of conducting this test and computing the results is similar to that reported under turbo-generator test No. 2.

This test was made under normal unit conditions.

Test results, presented in Table XX, show the performance of the unit with steam extracted at four stages for feed water heating, with the exhaust vacuum at approximately 28.5 in. of mercury. Results of turbo-generator Test No. 2 show the performance of a similar installation, but with the turbine exhaust vacuum at approximately 28.0 in. of mercury.

Fig. 20 shows the actual heat consumption and thermal efficiency of the unit when operating on the regenerative cycle.

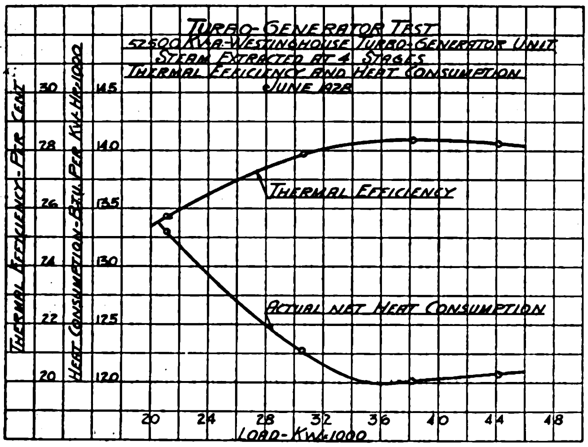

FIG. 20—THERMAL EFFICIENCY AND HEAT CONSUMPTION, STEAM EXTRACTED AT FOUR STAGES OF THE TURBINE—TURBO-GENERATOR TEST NO. 3.

TURBO-GENERATOR TEST NO. 4

The object of this test was to determine the performance of the turbo-generator unit when operating with steam extracted from two stages of the turbine and to compare this performance with the guarantee. Tests made in December, 1928.

Test Apparatus Data

The turbo-generator unit is a single cylinder, impulse-reaction, 1800 r.p.m. unit manufactured by Westinghouse Electric & Manufacturing Co., with rated capacity of 60,000 kw. at 85 per cent power factor. The turbine is provided with four extraction nozzles and operates with steam at 290 lb. per sq. in. gage and 700 deg. fahr. total temperature. This is the first single cylinder machine of its size constructed by this company.

Method of Conducting Tests

The unit was operated with steam extracted from the two lower stages over the load range of 15,000 to 58,000 kw. Two three-hour runs were made at the contract point of about 49,000 kw. which corresponds to the load carried by the primary and secondary valves. All other tests were of two hours duration with a total of nine tests made with the extraction heaters in service.

The steam consumption of the turbine was determined by weighing the condensate. The scales were checked before the tests with standard weights, the errors found were well within the A. S. M. E. test code requirements and scale readings were used without calibration corrections. The bonnets of the gate valves at the tank discharges were provided with bleeder lines for frequent checking for condensate that might escape. They were found tight at all times.

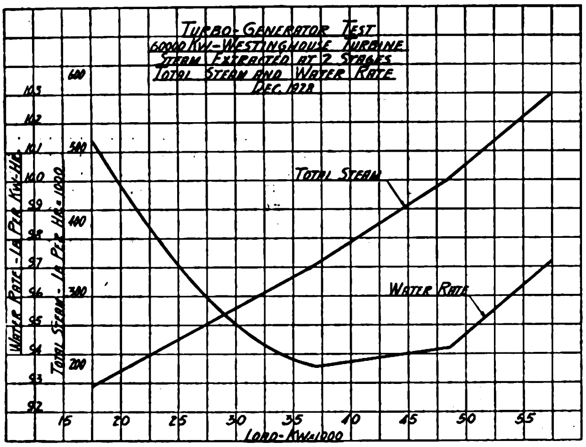

FIG. 21—TOTAL STEAM AND WATER RATE, STEAM EXTRACTED AT TWO STAGES OF THE TURBINE—TURBO-GENERATOR TEST NO. 4.

The electrical output was measured with special calibrated indicating instruments. The power factor was held as close as possible at 85 per cent.

All steam pressures were measured with absolute pressure gages located at the exhaust connection between the turbine and condenser. The calculated results were based on an average of these pressures.

The steam temperature at the throttle was measured by calibrated engraved stem mercury thermometers. The exhaust temperature was measured with engraved stem thermometers inserted through rubber stoppers placed in openings at opposite sides of the exhaust connection, between the turbine and condenser.

Other significant data on the turbine condenser and heaters were taken with either special test instruments or with calibrated commercial instruments.

Results

The performance of this turbo-generator unit is graphically shown in Fig. 21 and 22. A condensed summary of results is presented in Table XXI. The guaranteed performance is also tabulated to facilitate comparison of expected and actual performance.

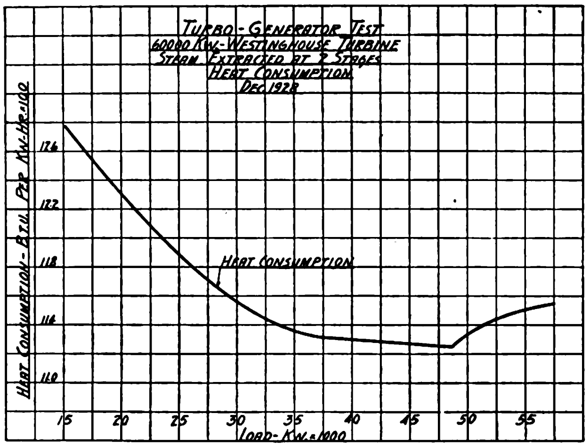

FIG. 22—HEAT CONSUMPTION, STEAM EXTRACTED AT TWO STAGES OF THE TURBINE—TURBO-GENERATOR TEST NO. 4.

TABLE XXI

TURBO-GENERATOR TEST NO. 4—SUMMARY OF TEST 60,000-KW. WESTINGHOUSE TURBO-GENERATOR UNIT—STEAM EXTRACTED AT TWO STAGES.

1. Run No	1	2	Guarantee
2. Net output, kw	48,945	48,819	49,750
3. Steam pressure at throttle, lb. gage	284	285	290
4. Steam pressure at exhaust, in. Hg. abs	.81	.83	.75
5. Steam temperature at throttle, °F	704	706	700
6. Corrected heat consumption, B.t.u. per kw-hr	11,294	11,247	11,440
7. Overall efficiency, %	30.19	30.32	29.81

TURBO-GENERATOR TEST NO. 5

This series of tests made in January, 1928, on a turbo-generator unit to check its performance when no steam is extracted from the turbine with the turbine exhaust vacua at 28.5 and 29.0 in. of mercury.

Test Apparatus Data

Turbine: Westinghouse Electric & Manufacturing Co.; 1800 r.p.m.; single cylinder type with multi-exhaust blading, exhausting into a Westinghouse Electric & Manufacturing Co. 50,000 sq. ft. surface condenser.

Generator: Westinghouse Electric & Manufacturing Co.; 43,750 kv-a., 80 per cent power factor; 13,800 volts, 3-phase, 60 cycle, 1800 r.p.m.

Exciter: Westinghouse Electric & Manufacturing Co.; d-c.; direct connected; 165 kw.; 250 volts; 1800 r.p.m.

Method of Conducting Tests

Tests were made at loads ranging between 16,000. and 43,000 kw. with the exhaust vacua held constant at 29.0 and 28.5 in. of mercury respectively. All runs were of three hour duration.

The turbine was operated without extracting steam. Pressure was maintained at 325 lb. per sq. in. gage by throttling the main throttle valve.

The kilowatt load was obtained from the switchboard polyphase wattmeter on which a high speed register was installed. The watthour meter was adjusted and checked previous to the test and rechecked after the test, the calibration showing no corrections to be applied to the meter. The generator net output was corrected for phase-angle and ratio of transformation of instrument transformers.

The steam consumption of the turbine was obtained by weighing the condensate, correction being made for hotwell level, condenser leakage and condensate from steam jet air pump whenever the pump was used. The high and low pressure seals of the main turbine and the condensate pump seals were supplied with condensate taken from the discharge of condensate pump. The weighing scales were calibrated previous to the test.

Tests were made on each run for condenser leakage. Chemical titrations were made for salt content in the river water and condensate from the condenser. The vacuum was regulated by admitting air at the turbine exhaust.

Computations

The steam consumption was corrected to guarantee conditions of 325 lb. per sq. in. gage and 271 deg. fahr. superheat. A 1 per cent correction is allowed for a 25 lb. per sq. in. variation in steam pressure and 1 per cent for each 15 deg. fahr. variation of superheat at the throttle.

Results

The results of the tests are shown in Table XXII and XXIII with the total steam to the unit, and the water rate and the efficiencies are shown graphically in Fig. 23 and 24.

This series of tests in which no steam was extracted from the turbine can be compared to the operation of the same unit when steam was extracted at 4 stages of the turbine. The latter results are reported under Turbo-Generator Test No. 2.

TURBO-GENERATOR TEST NO. 6

The object of tests made during April, 1928, was to determine the economy of the turbo-generator unit at 1, 1½ and 2 in. of mercury back pressure, with steam extracted at four stages for feed water heating.

Test Apparatus Data

Turbine: General Electric Co.; 50,000 kw.; 1800 r.p.m.; exhausting into a Worthington, two-pass, concentric shell, 56,000 sq. ft., surface condenser.

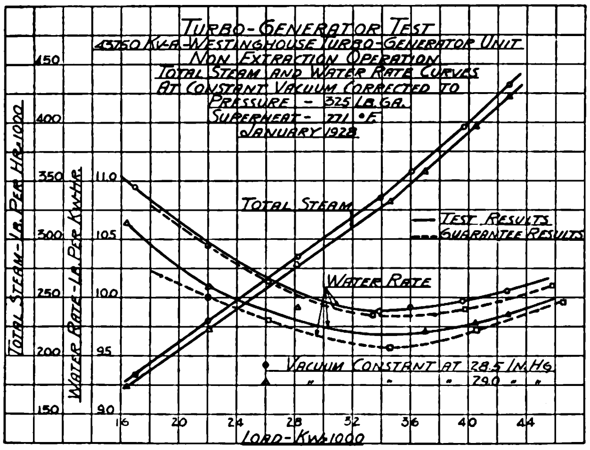

FIG. 23—TOTAL STEAM AND WATER RATE AT DIFFERENT VACUA, NO STEAM EXTRACTED FROM THE TURBINE—TURBO-GENERATOR TEST NO. 5.

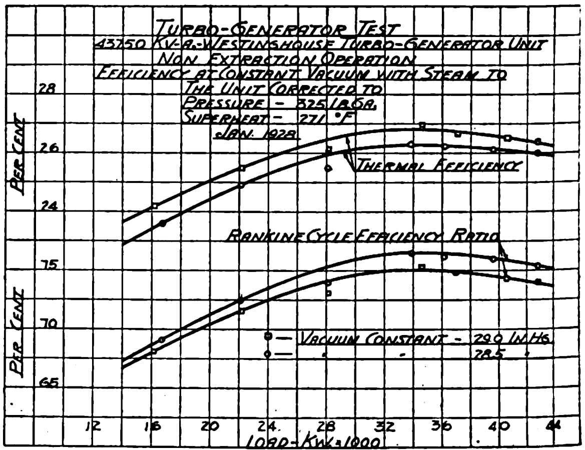

FIG. 24—THERMAL EFFICIENCY AND EFFICIENCY RATIO AT DIFFERENT VACUA, NO STEAM EXTRACTED FROM THE TURBINE—TURBO-GENERATOR TEST NO. 5.

TABLE XXII

TURBO-GENERATOR TEST NO. 5—SUMMARY OF TESTS—43,750-KV-A. WESTINGHOUSE TURBO-GENERATOR UNIT—NO STEAM EXTRACTED FROM TURBINE—VACUUM CONSTANT AT 28.5 IN. HG.

1. Run No.	0	B	K	M
2. Date	1/23/28	1/13/28	1/20/28	1/21/28
3. Barometer, in. Hg	30.15	29.54	29.58	29.95
4. Net generator output (direct connected exciter), kw	16,920	28,160	36,080	42,890
5. Excitation, kw	83	103	110	96
Turbine				
6. Steam pressure before throttle, lb. gage	352	348	351	354
7. Steam pressure after throttle, lb. gage	323	323	321	320
8. Steam pressure after primary valve, lb. gage	173.5	273.3	321.0	320.0
9. Steam pressure after secondary valve, lb. gage	68.5	111.8	-	319.0
10. Steam pressure after tertiary valve, lb. gage	69.5	111.7	141.6	198.7
11. Steam pressure at 1st extraction stage, lb. gage	68.4	112.0	143.1	173.0
12. Steam pressure at 2nd extraction stage, lb. gage	14.9	33.1	45.0	55.9
13. Steam pressure at 3rd extraction stage, lb. gage	-6.1	-1.3	2.5	4.8
14. Steam pressure at 4th extraction stage, lb. gage	-12.2	-10.6	-9.6	-8.8
15. Steam pressure at exhaust, in Hg. abs	1.62	1.50	1.50	1.48
16. Steam temperature at throttle, °F	675	675	670	676
17. Steam superheat at throttle, °F	237	240	233	238
18. Steam temperature at exhaust, °F	89.9	90.0	90.0	90.3
19. Condensate temperature leaving hotwell, °F	90.8	88.6	88.2	85.6
Economy				
20. Total steam consumption (actual), lb. per hr	190,620	292,990	366,790	438,770
21. Water rate (actual), lb. per kw-hr	11.26	10.40	10.17	10.23
22. Total steam consumption (corrected to guaranteed conditions), lb. per hr	185,230	287,780	358,380	430,880
23. Water rate (corrected to guaranteed conditions), lb. per kw-hr.	10.95	10.22	9.93	10.05
24. Rankine cycle efficiency ratio, %	69.1	74.0	76.2	75.3
25. Heat consumption (actual), B.t.u. per kw-hr	14,440	13,370	13,040	13,150
26. Thermal efficiency (actual), %	23.6	25.5	26.2	26.0

TABLE XXIII

TURBO-GENERATOR TEST NO. 5—SUMMARY OF TESTS 43,750-KV-A. WESTINGHOUSE TURBO-GENERATOR UNIT—NO STEAM EXTRACTED FROM TURBINE VACUUM CONSTANT AT 29.0 IN. HG.

1. Run No.	N	H	D	F
2. Date	1/23/28	1/18/28	1/16/28	1/17/28
3. Barometer, in. Hg	30.19	29.97	30.51	29.96
4. Net generator output (direct connected exciter), kw.	16,330	28,190	36,960	42,840
5. Excitation, kw.	84	102	112	104
Turbine				
6. Steam pressure before throttle, lb. gage	357	357	352	351
7. Steam pressure after throttle, lb. gage	320	324	321	322
8. Steam pressure after primary valve, lb. gage	159.5	262.9	316.0	322.0
9. Steam pressure after secondary valve, lb. gage	62.1	106.6	-	319.0
10. Steam pressure after tertiary valve, lb. gage	62.7	106.0	140.9	189.0
11. Steam pressure at 1st extraction stage, lb. gage	61.6	107.7	141.9	169.7
12. Steam pressure at 2nd extraction stage, lb. gage	12.7	30.9	43.9	54.7
13. Steam pressure at 3rd extraction stage, lb. gage	-7.3	-2.3	2.0	5.0
14. Steam pressure at 4th extraction stage, lb. gage	-12.4	-11.0	-10.1	-9.0
15. Steam pressure at exhaust, in Hg. abs	1.02	1.00	1.01	1.03
16. Steam temperature at throttle, °F	668	678	682	694
17. Steam superheat at throttle, °F	230	240	245	258
18. Steam temperature at exhaust, °F	76.7	76.2	77.4	76.2
19. Condensate temperature leaving hotwell, °F	78.0	75.7	74.6	72.4
Economy				
20. Total steam consumption (actual), lb. per hr	178,200	284,200	363,680	424,460
21. Water rate (actual), lb. per kw-hr	10.91	10.08	9.84	9.91
22. Total steam consumption (corrected to guaranteed conditions), lb. per hr	173,940	279,750	358,840	422,390
23. Water rate (corrected to guaranteed conditions), lb. per kw-hr.	10.65	9.92	9.71	9.86
24. Rankine cycle efficiency ratio, %	68.1	73.1	74.8	74.0
25. Heat consumption (actual), B.t.u. per kw-hr	14,120	13,100	12,810	12,950
26. Thermal efficiency (actual), %	24.2	26.1	26.6	26.4

Generator: General Electric Co.; a-c.; 55,555 kv-a.; 90 per cent power factor; 13,800 volts; 3-phase; 60 cycle; 1800 r.p.m.

Exciter: General Electric Co.; d-c.; direct connected; 250 kw.; 250 volts; 1800 r.p.m.

Instruments

The steam pressure before the throttle was measured at two points by standard test gages, graduated to 1 lb. per sq. in. scale divisions. The temperature of the steam to the turbine was also measured at two points by engraved mercury thermometers, calibrated for total immersion. These thermometers were used in wells filled with solder with temperatures of the stem taken to correct for stem exposure.

The exhaust pressure was measured at the turbine exhaust nozzle by four absolute pressure type gages.

Condenser leakage was determined by an Evershed conductivity meter and miniature condenser. Steam from a main unit steam line was sampled under a vacuum to prevent contamination from gases in the atmosphere. The conductivity of the hotwell condensate was compared to the conductivity of the condensed steam, plus a small percentage of raw water. The amount of leakage was calculated.

The condensate from the main condenser was weighed on two Strait tank scales, equipped with a registering beam. Weighing was timed with a stop-watch.

Electrical data were taken from indicating laboratory instruments connected to each of the three phases. The wattmeters were read at minute intervals. Current transformers and all instruments used were calibrated before the tests. After the tests were completed, all instrument transformer ratios and phase angle corrections were checked.

Method of Conducting Tests

Tests were made at loads ranging from 20,000 to 54,000 kw. The tests were grouped into three series, with the back pressure on each series maintained constant at approximately 1, 1½ and 2 in. of mercury. The back pressure was controlled by admitting air at the suction of the vacuum pump.

The unit was operated with steam bled to the deaerating and closed feed water heaters, but evaporators were out of service during the tests. Condensate was pumped by the hotwell pump through the generator air cooler, oil cooler, No. 1 heater and then to main condensate weigh tanks. The water from the weigh tanks discharged into a test tank. It was then pumped through the heater vent condenser to the deaerating heater, discharging by gravity to the boiler feed pump. The feed pump discharge passes through No. 3 and No. 4 heaters to the boilers to complete the cycle. The flow diagram of the main condensate, the bleed steam and bleed condensate are shown in Fig. 25.

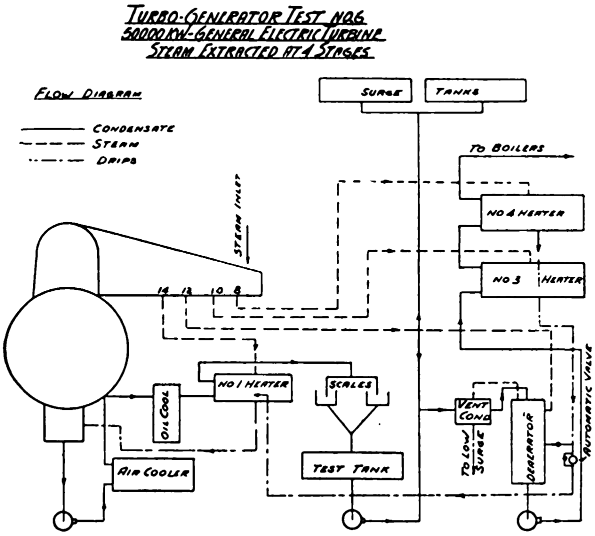

FIG. 25—FLOW DIAGRAM OF THE MAIN CONDENSATE, STEAM EXTRACTED AT FOUR STAGES OF THE TURBINE—TURBO-GENERATOR TEST NO. 6.

At light loads, the bleed condensate from the high pressure heaters normally goes to the No. 1 heater through an automatic unloading valve. When the pressure at No. 3 heater is sufficient to drain the bleed condensate into the deaerator, the unloading valve closes, discharging the drain into the water space of the deaerator. On runs No. 7, 8 and 9 the unloading valve was by-passed, the drain passing through No. 1 heater to the main condenser hotwell. Runs No. 14 to 28 inclusive were made with the valve in the drain line to the deaerator closed.

The turbine seals and the expansion joint were supplied with water taken from the condensate line between the condenser and the weigh tanks. The internal leakage from these seals drained to the condenser. The external leakage was separately weighed for each run.

The water for the condensate pump seals was taken from a surge tank. The amount was determined by the rate of the tank level change during the test.

Drainage from the vent condenser was weighed.

Computations

All calculations are based on the kilowatt output as obtained by the indicating wattmeters, corrected for instrument error. The integrated watthour meter output served to check the indicated output.

The heat consumption of the unit was calculated as follows:

Heat in steam at throttle, times the throttle flow; minus the heat of the liquid at final feed water temperature, times the flow through the final heater; plus the heat of the liquid at saturation temperature, at turbine back pressure, times net condensate; plus or minus heat in surge tank water due to level change; all divided by the load in kw.

In calculating the amount of steam extracted, the available heat of each pound of extraction steam was taken as the heat content of the steam entering the heater minus the heat of the liquid of the drain at the heater saturation temperature. When the drains were returned from a high pressure to a low pressure heater, the amount of heat added was taken as the difference in the heats of the liquids.

The quality of the bleed steam at the lowest extraction stage, when not superheated, was very near the saturation line on the Mollier diagram. The steam was assumed to be dry saturated when not in a superheated state.

The turbine is designed to operate with initial steam conditions at 315 lb. per sq. in. gage pressure and 725 deg. fahr. total temperature. Corrections provided by the manufacturer were used to reduce the water rates and the heat consumption of the unit actually obtained, to guarantee conditions.

Results

The test consisted of 28 runs. A detailed summary of the results of six of these runs, made at 29.0 in. of mercury vacuum, is shown in Table XXIV. In Table XXV similar data are presented for tests made at 28.5 and at 28.0 in. of mercury. Due to the change in level in the surge tanks between the start and the finish of the run there were variations between the throttle flow and the flow through the vent condenser, deaerator and the high pressure heaters.

Fig. 26, 27 and 28 show the water rate, heat consumption and thermal efficiency of the unit at constant back pressure corrected to guaranteed throttle steam pressure and temperature.

The total quantity of steam extracted from the turbine during the tests at 29.0 in. of mercury and the per cent of throttle flow that it represents at different unit loads are shown in Fig. 29.

The relation between the condensate temperature leaving the extration heaters and the loads on the unit is shown in Fig. 30.

TABLE XXIV

TURBO-GENERATOR TEST NO. 6—SUMMARY OF TESTS—50,000-KW. GENERAL ELECTRIC TURBO-GENERATOR UNIT—STEAM EXTRACTED AT FOUR STAGES—VACUUM CONSTANT AT 29.0 IN. HG.

1. Test No.	7	14	15	19	27	28
2. Date	4/13/28	4/14/28	4/14/28	4/16/28	4/17/28	4/17/28
3. Duration, hr.	1	1	1	1	1	1
4. Average load on unit, kw.	38,368	50,265	30,204	20,145	43,036	53,943
5. Power factor, %	86.7	86.8	86.1	87.2	87.8	99.8
6. Barometer, in. Hg. at 32 °F.	29.38	29.59	29.61	29.82	29.59	29.59
Turbine						
7. Steam pressure before throttle, lb. gage	309.9	311.4	319.2	317.8	312.3	308.4
8. Steam pressure after primary valve, lb. gage	299.8	296.1	294.2	196.4	298.4	288.0
9. Steam pressure after secondary valve, lb. gage	299.4	300.0	215.0	144.8	303.7	295.5
10. Steam pressure after tertiary valve, lb. gage	186.0	270.1	133.0	88.8	213.9	287.0
11. Steam pressure at exhaust, in. Hg. abs.	1.044	0.921	0.996	0.996	1.015	1.001
12. Steam temperature before throttle, °F.	698.0	703.2	722.2	720.4	700.7	693.8
13. Steam superheat before throttle, °F.	273.3	278.1	294.9	293.4	275.3	269.5
14. Steam temperature at exhaust, °F.	83.2	77.8	82.0	81.0	83.0	81.0
Condenser						
15. Hotwell condensate temperature, °F.	81.1	80.4	78.2	77.8	82.0	83.3
16. Inlet circulating water temperature, °F.	49.0	47.2	47.2	46.5	47.9	48.1
17. Outlet circulating water temperature, °F.	65.0	63.8	60.3	56.0	62.0	66.0
No. 1 Heater						
18. Water passing thru heater, lb. per hr.	371,300	514,560	281,010	197,160	420,140	558,750
19. Steam pressure, lb. abs.	6.4	8.9	5.4	3.9	7.7	9.8
20. Steam temperature, °F.	170.0	184.5	158.0	146.0	176.5	188.0
21. Inlet water temperature, °F.	100.8	101.2	101.6	97.5	100.5	102.5
22. Outlet water temperature, °F.	166.5	177.3	155.7	144.0	172.0	180.0
23. Heat absorbed by condensate per lb. of steam, B.t.u. per lb.	995.8	987.2	1002.7	1009.7	992.0	985.1
24. Steam bled to heater, lb. per hr.	19,160	32,889	11,647	7,523	27,292	25,470
Deaerating Heater						
25. Water passing thru heater, lb. per hr.	405,914	505,409	313,239	158,611	401,512	551,391
26. Steam pressure to heater, lb. abs.	15.0	21.1	16.0	11.1	21.0	19.3
27. Steam temperature to heater, °F.	217.2	282.5	213.3	199.8	252.0	279.2
28. Inlet water temperature, °F.	163.7	174.0	153.9	140.1	167.5	176.6
29. Outlet water temperature, °F.	209.5	225.0	211.0	187.0	225.8	220.0
30. Steam bled to heater, lb. per hr.	19,066	26,068	18,405	7,585	24,045	24,106
31. Total water discharged from heater, lb. per hr.	424,980	531,477	331,644	166,196	425,557	575,497
Vent Condenser						
32. Water passing thru condenser, lb. per hr.	405,914	505,409	313,239	158,611	401,512	551,391
33. Inlet water temperature, °F.	153.9	170.8	150.7	137.4	165.4	174.7
34. Outlet water temperature, °F.	163.7	174.0	153.9	140.1	167.5	176.6
35. Entering vapor temperature, °F.	213.1	242.8	213.3	199.8	231.6	226.1
36. Quantity of vapor (weighed), lb. per hr.	320	58	45	-	38	-
37. Vacuum at vent condenser vacuum pump, in. Hg.	18.2	15.8	19.4	19.0	17.6	15.3

TABLE XXIV—(*Continued*)

No. 3 Heater						
38. Water passing thru heater, lb. per hr.	424,980	531,477	331,644	166,196	425,557	575,497
39. Steam pressure, lb. abs.	47.8	68.7	41.7	23.0	59.2	70.7
40. Steam temperature, °F.	349.8	428.2	321.0	312.0	393.4	428.0
41. Inlet water temperature, °F.	212.7	228.2	212.0	178.0	225.5	224.4
42. Outlet water temperature, °F.	272.8	295.7	262.0	240.0	287.0	297.7
43. Steam bled to heater, lb. per hr.	25,835	35,600	16,840	10,101	26,130	41,840
No. 4 Heater						
44. Water passing thru heater, lb. per hr.	424,980	531,477	331,644	166,196	425,557	575,497
45. Steam pressure, lb. abs.	95.8	134.2	68.3	49.2	111.7	144.7
46. Steam temperature, °F.	451.8	430.7	412.8	400.0	495.0	531.0
47. Inlet water temperature, °F.	267.0	297.0	256.2	237.3	283.4	297.5
48. Outlet temperature, °F.	318.3	342.1	298.2	281.0	330.7	347.0
49. Steam bled to heater, lb. per hr.	22,783	24,818	14,427	7,383	20,850	29,383
Oil Cooler						
50. Water passing thru cooler, lb. per hr.	371,300	514,560	281,010	197,160	420,140	558,750
51. Inlet water temperature, °F.	98.9	100.0	99.0	93.5	99.6	102.0
52. Outlet water temperature, °F.	100.8	101.2	101.6	97.5	100.5	102.5
53. Inlet oil temperature, °F.	119.1	120.4	120.4	116.5	120.0	121.5
54. Outlet oil temperature, °F.	107.5	108.8	108.0	104.0	108.0	109.0
Generator Air Cooler						
55. Water passing thru cooler, lb. per hr.	371,300	514,560	281,010	197,160	420,140	558,750
56. Inlet water temperature, °F.	89.5	92.0	86.0	78.5	90.3	94.0
57. Outlet water temperature, °F.	98.9	100.0	99.0	93.5	99.6	102.0
58. Inlet air temperature, °F.	134.3	141.8	134.4	122.0	139.0	140.5
59. Outlet air temperature, °F.	97.0	99.9	96.0	88.6	98.0	100.5
Economy						
60. Net weighed condensate, lb. per hr.	373,468	513,100	278,435	200,580	425,072	566,010
61. Bleed condensate (not weighed), lb. per hr.	19,066	26,068	18,405	7,585	24,045	24,106
62. Net steam to turbine, lb. per hr.	392,534	539,168	296,840	208,165	449,117	590,116
63. Water rate (actual), lb. per kw-hr.	10.23	10.73	9.83	10.33	10.43	10.94
64. Water rate (corrected) lb. per kw-hr.	10.00	10.53	9.80	10.29	10.22	10.65
65. Difference in flow thru No. 4 heater and throttle, %	8.8	-1.7	10.9	-18.5	-4.1	-1.2
66. Total heat in steam at throttle, B.t.u. per lb.	1358.4	1361.0	1370.2	1369.3	1359.7	1356.4
67. Heat of liquid at final feed water temperature, B.t.u. per lb.	288.4	313.1	267.7	250.1	301.3	318.3
68. Heat consumption (actual), B.t.u. per kw-hr.	10,842	11,296	11,646	11,859	11,135	11,462
69. Heat consumption (corrected), B.t.u. per kw-hr.	10,643	11,148	10,113	11,807	11,008	11,304
70. Thermal efficiency (actual), %	31.52	30.31	32.02	28.74	30.61	29.58
71. Thermal efficiency (corrected), %	32.07	30.62	32.16	28.91	31.00	30.19

TABLE XXV

TURBO-GENERATOR TEST NO. 6—SUMMARY OF TESTS—50,000-KW. GENERAL ELECTRIC TURBO-GENERATOR UNIT—STEAM EXTRACTED AT FOUR STAGES.

	Vacuum Constant at 28.5 In. Hg.			Vacuum Constant at 28.0 In. Hg.		
1. Test No.	8	16	20	9	17	21
2. Date	4/13/28	4/14/28	4/16/28	4/13/28	4/14/28	4/16/28
3. Duration, hr.	1	1	1	1	1	1
4. Average load on unit, kw.	39,347	30,151	20,211	38,617	30,387	20,102
5. Power factor, %	86.1	86.7	90.5	86.7	87.0	90.0
6. Barometer, in. Hg. at 32°F.	29.30	29.63	29.81	29.21	29.65	29.79
Turbine						
7. Steam pressure before throttle, lb. gage	308.8	319.4	318.7	316.0	314.1	320.5
8. Steam pressure after primary valve, lb. gage	298.1	302.6	208.0	305.6	299.4	214.0
9. Steam pressure after secondary valve, lb. gage	300.0	227.6	154.8	306.5	238.5	157.4
10. Steam pressure after tertiary valve, lb. gage	190.3	140.9	95.2	197.6	148.5	96.4
11. Steam pressure at exhaust, in. Hg abs	1.480	1.559	1.502	1.939	1.992	2.004
12. Steam temperature before throttle, °F.	693.0	709.3	713.7	701.5	697.9	718.4
13. Steam superheat before throttle, °F.	268.7	281.9	286.4	275.1	272.0	290.6
14. Steam temperature at exhaust, °F.	95.0	94.4	94.0	101.9	105.0	104.0
Condenser						
15. Hotwell condensate temperature, °F.	85.9	88.8	83.7	90.0	88.4	89.6
16. Inlet circulating water temperature, °F.	49.0	47.2	46.8	49.0	47.3	46.9
17. Outlet circulating water temperature, °F.	66.0	60.9	56.6	66.7	61.4	57.3
No. 1 Heater						
18. Water passing thru heater, lb. per hr.	380,490	291,760	211,110	390,870	303,250	217,270
19. Steam pressure, lb. abs	6.5	5.6	4.1	6.5	5.8	4.4
20. Steam temperature, °F.	172.6	161.0	147.9	173.9	162.2	149.0
21. Inlet water temperature, °F.	101.0	107.5	103.9	100.3	106.9	107.5
22. Outlet water temperature, °F.	169.0	158.8	146.8	170.8	160.6	148.0
23. Heat absorbed by condensate per lb. of steam, B.t.u. per lb.	994.2	1001.0	1008.6	994.8	1000.4	1007.9
24. Steam bled to heater, lb. per hr.	21,140	11,194	6,487	22,545	13,300	6,073
Deaerating Heater						
25. Water passing thru heater, lb. per hr	385,900	297,437	205,473	393,440	290,956	196,889
26. Steam pressure to heater, lb. abs	16.7	17.0	12.7	16.4	17.7	13.4
27. Steam temperature to heater, °F.	220.3	216.2	205.0	225.5	220.6	206.2
28. Inlet water temperature, °F.	167.8	157.1	145.7	168.5	158.3	144.9
29. Outlet water temperature, °F.	215.4	216.0	169.5	214.5	220.2	156.0
30. Steam bled to heater, lb. per hr	18,929	18,100	4,989	18,623	18,658	2,234
31. Total water discharged from heater, lb. per hr	404,829	315,537	210,462	412,144	309,614	199,123
Vent Condenser						
32. Water passing thru condenser, lb. per hr	385,900	297,437	205,473	393,440	290,956	196,889
33. Inlet water temperature, °F.	159.2	153.7	142.5	160.4	154.3	142.3
34. Outlet water temperature, °F.	167.8	157.1	145.7	168.5	158.3	144.9
35. Entering vapor temperature, °F.	218.4	216.2	205.0	217.5	220.6	206.2
36. Quantity of vapor (weighed), lb. per hr.	370	63	-	383	72	-
37. Vacuum at vent condenser vacuum pump, in. Hg	17.0	19.5	18.8	16.8	19.5	18.3
No. 3 Heater						
38. Water passing thru heater, lb. per hr	404,829	315,537	210,462	412,144	309,614	199,123
39. Steam pressure, lb. abs	50.9	40.4	26.3	52.3	42.6	26.5
40. Steam temperature, °F.	353.3	312.9	308.3	359.6	310.0	309.1
41. Inlet water temperature, °F.	219.7	218.2	160.8	218.0	221.7	148.0
42. Outlet water temperature, °F.	276.7	263.8	238.3	276.7	267.5	239.4
43. Steam bled to heater, lb. per hr	23,098	14,489	16,221	24,197	14,341	18,118
No. 4 Heater						
44. Water passing thru heater, lb. per hr	404,829	315,537	210,462	412,144	309,614	199,123
45. Steam pressure, lb. abs	98.2	62.5	49.5	101.6	80.6	51.8
46. Steam temperature, °F.	454.7	408.8	398.3	463.1	405.3	398.1
47. Inlet water temperature, °F.	271.7	260.4	234.4	272.7	263.8	234.0
48. Outlet water temperature, °F.	320.7	300.1	281.7	321.6	302.9	283.0
49. Steam bled to heater, lb. per hr	20,741	12,990	10,134	21,044	12,766	10,167
Economy						
50. Net weighed condensate, lb. per hr	383,640	292,521	214,902	394,896	305,820	221,348
51. Bleed condensate (not weighed), lb. per hr	18,929	18,100	4,989	18,623	18,658	2,234
52. Net steam to turbine, lb. per hr	402,569	310,621	219,891	413,519	324,478	223,582
53. Water rate (actual), lb. per kw-hr.	10.50	10.30	10.93	10.71	10.68	11.12
54. Water rate (corrected), lb. per kw-hr.	10.23	10.13	10.77	10.64	10.45	11.06
55. Difference in flow thru No. 4 heater and throttle, %	1.1	1.8	-2.6	0.6	-3.8	-9.1
56. Total heat in steam at throttle, B.t.u. per lb.	1366.0	1363.7	1365.8	1364.9	1358.2	1368.0
57. Heat of liquid at final feed water temperature, B.t.u. per lb.	290.9	269.7	250.8	291.8	272.6	252.1
58. Heat consumption (actual), B.t.u. per kw-hr.	11,293	11,209	12,133	11,400	11,546	12,468
59. Heat consumption (corrected), B.t.u. per kw-hr.	11,083	11,078	12,069	11,273	11,398	12,428
60. Thermal efficiency (actual), %	30.53	30.33	27.95	29.64	29.24	27.08
61. Thermal efficiency (corrected), %	30.80	30.80	28.28	30.28	29.94	27.46

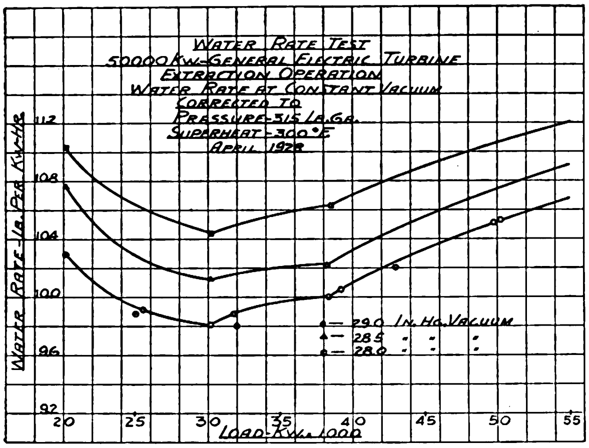

FIG. 26—WATER RATE AT CONSTANT VACUA, STEAM EXTRACTED AT FOUR STAGES OF THE TURBINE—TURBO-GENERATOR TEST No. 6.

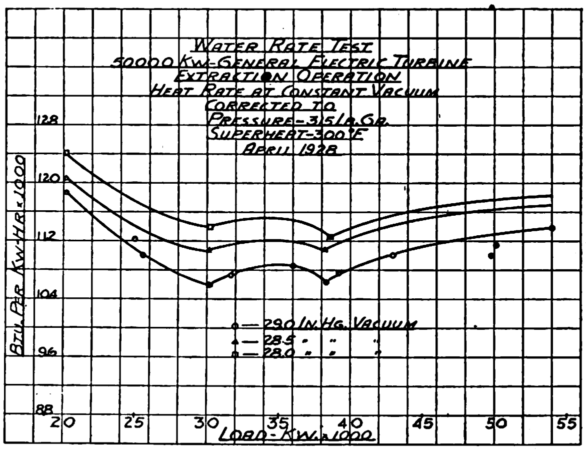

FIG. 27—HEAT RATE AT CONSTANT VACUA, STEAM EXTRACTED AT FOUR STAGES OF THE TURBINE—TURBO-GENERATOR TEST No. 6.

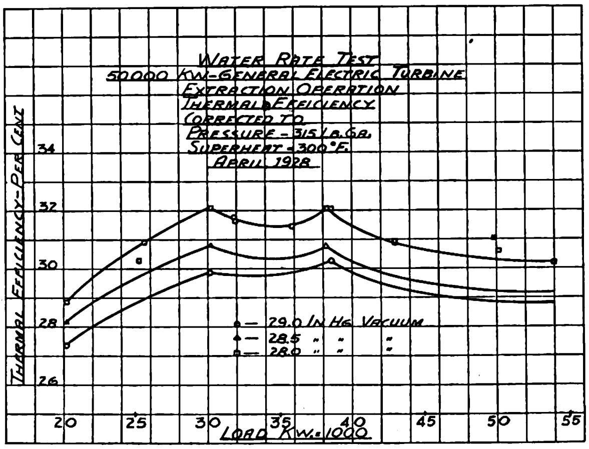

FIG. 28—THERMAL EFFICIENCY AT CONSTANT VACUA, STEAM EXTRACTED AT FOUR STAGES OF THE TURBINE—TURBO-GENERATOR TEST No. 6.

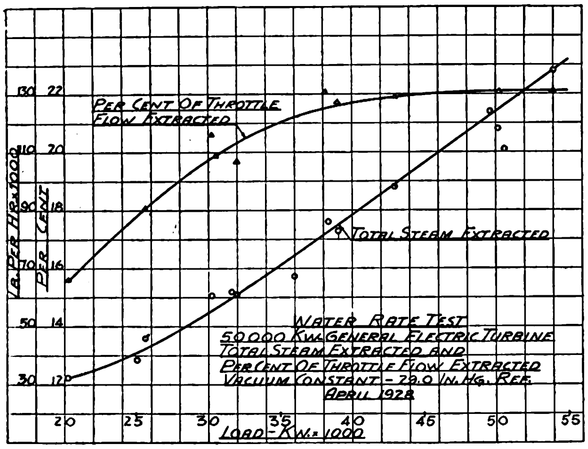

FIG. 29—TOTAL STEAM EXTRACTED AND PER CENT OF THROTTLE FLOW EXTRACTED WITH STEAM BLED AT FOUR STAGES OF THE TURBINE—TURBO-GENERATOR No. 6.

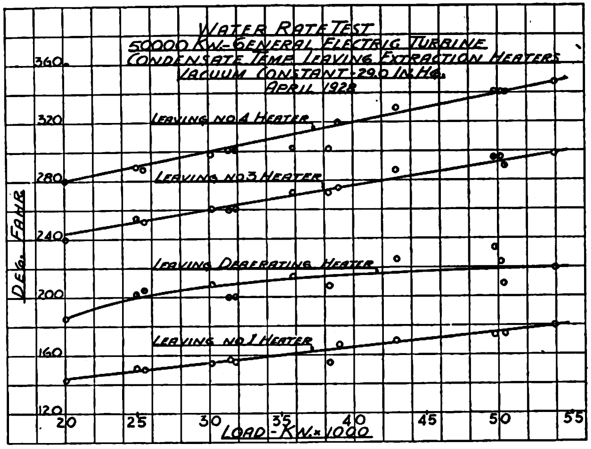

FIG. 30—FEED WATER TEMPERATURE, LEAVING EXTRACTION HEATERS—TURBO-GENERATOR TEST No. 6.

TABLE XXVI

TURBO-GENERATOR TEST NO. 7—SUMMARY OF TESTS ON 50,000-KW. GENERAL ELECTRIC TURBO-GENERATOR UNIT—STEAM EXTRACTED AT THREE STAGES OF TURBINE—VACUUM CONSTANT AT 29.0 IN. HG.

1. Run No.	19	20	25	26	21	22
2. Date	3/29/27	3/29/27	3/30/27	3/30/27	3/29/27	3/29/27
3. Generator output, kw.	49,300	45,700	45,700	45,700	34,400	24,600
Turbine						
4. Steam pressure at the throttle, lb. per sq. in. abs.	389.6	394.6	389.5	388.5	393.6	400.6
5. Steam pressure after primary valve, lb. per sq. in. abs.	350.6	351.6	348.5	347.5	272.6	204.6
6. Steam pressure after secondary valve, lb. per sq. in. abs.	224.6	211.6	208.5	208.5	160.6	118.6
7. Steam pressure in chamber of 1st extraction stage, in. Hg. abs.	64.35	57.56	55.94	57.51	45.41	33.21
8. Steam pressure in chamber of 2nd extraction stage, in. Hg. abs.	17.91	16.42	16.24	16.61	12.67	9.74
9. Steam pressure in chamber of 3rd extraction stage, in. Hg. abs.	5.37	5.08	5.29	4.91	4.04	3.17
10. Steam pressure at exhaust, in. Hg. abs.	.98	1.02	1.00	.99	1.03	.92
11. Steam temperature at the throttle, °F.	672	673	693	684	685	683
12. Total heat in steam at throttle, B.t.u. per lb.	1343.1	1343.4	1353.4	1348.1	1348.4	1348.9
13. Condensate temperature leaving main condenser hotwell, °F.	81	82	79	77	81	81
Third Extraction Stage Heater						
14. Bleed steam pressure at heater inlet, in. Hg. abs.	4.75	4.36	4.54	3.61	3.11	2.54
15. Bleed steam temperature at heater inlet, °F.	129	124	128	121	120	108
16. Total heat in bleed steam at heater, B.t.u. per lb.	1046.5	1026.6	1037.1	1032.7	1032.5	1033.1
17. Bleed condensate temperature, °F.	144	140	137	129	133	133
18. Feed water temperature entering heater, °F.	81	82	79	77	81	81
19. Feed water temperature leaving heater, °F.	116	114	122	117	100	94
20. Feed water passing thru heater, lb. per hr.	483,000	448,000	440,000	431,000	334,000	254,500
21. Bleed steam to heater, lb. per hr.	15,400	13,110	5,170	16,720	5,590	3,040
22. Heat in bleed steam to heater, million B.t.u. per hr.	16.13	13.46	5.36	17.285	5.76	3.14
23. Heat in evaporator vapor to heater, million B.t.u. per hr.	-	-	13.49	-	-	-
24. Heat in flash from 2nd extraction stage bleed condensate, million B.t.u. per hr.	1.65	1.20	1.47	1.565	.32	.03
25. Heat in flash from evaporator and evaporator condenser drains, million B.t.u. per hr.	.84	1.08	.41	-	.83	.45
26. Total heat to heater, million B.t.u. per hr.	18.62	15.74	20.73	18.850	6.91	3.62
27. Heat in condensate drains from heater, million B.t.u. per hr.	1.72	1.41	1.81	1.62	.56	.31
28. Net heat transfer to feed water, million B.t.u. per hr.	16.90	14.33	18.92	17.23	6.35	3.31
Second Extraction Stage Heater						
29. Bleed steam pressure at heater inlet, in. Hg. abs.	13.95	12.56	13.04	13.21	10.11	7.74
30. Bleed steam temperature at heater inlet, °F.	175	172	175	177	162	151
31. Total heat in bleed steam at heater, B.t.u. per lb.	1136	1134.5	1135	1135	1130.4	1126
32. Bleed condensate temperature, °F.	178	168	172	162	142	135
33. Feed water temperature entering heater, °F.	116	114	122	117	100	94
34. Feed water temperature leaving heater, °F.	168	165	169	168	153	139
35. Feed water passing thru heater, lb. per hr.	483,000	448,000	440,000	431,000	334,000	254,500
36. High pressure shaft packing leak off steam to heater, lb. per hr.	2745	3211	3125	3435	2596	2180
37. Total heat in shaft packing leak off steam to heater, B.t.u. per lb.	1307	1307	1322	1320	1302	1293
38. Bleed steam to heater, lb. per hr.	20,700	17,600	15,460	15,370	13,150	7,980
39. Heat in bleed steam to heater, million B.t.u. per hr.	23.50	19.95	17.56	17.44	14.9	8.98
40. Heat in shaft packing leak off steam to heater, million B.t.u. per hr.	3.6	4.2	4.13	4.51	3.4	2.82
41. Heat in flash from 1st extraction heater bleed condensate, million B.t.u. per hr.	1.44	1.51	1.14	2.04	1.18	.7
42. Total heat to heater, million B.t.u. per hr.	28.54	25.66	22.83	23.99	19.48	12.5
43. Heat in condensate drains from heater, million B.t.u. per hr.	3.42	2.81	2.61	2.44	1.77	1.03
44. Net heat transfer to feed water, million B.t.u. per hr.	25.12	22.85	20.22	21.55	17.71	11.47

TABLE XXVI—(*Continued*)

First Extraction Stage Heater						
45. Bleed steam pressure at heater inlet, in. Hg. abs	45.55	42.36	34.94	42.21	33.51	23.44
46. Bleed steam temperature at heater inlet, °F	236	233	221	234	220	207
47. Total heat in bleed steam at heater, B.t.u. per lb	1159	1158	1154	1159	1153	1150
48. Bleed condensate temperature, °F	235	235	221	233	217	201
49. Feed water temperature entering heater, °F	183	182	170	167	173	160
50. Feed water temperature leaving heater, °F	233	230	219	231	218	201
51. Feed water passing thru heater, lb. per hr	483,000	448,000	440,000	431,000	334,000	254,500
52. Bleed steam to heater, lb. per hr	25,200	22,540	23,230	28,800	15,760	10,620
53. Heat in bleed steam to heater, million B.t.u. per hr	29.28	26.07	26.83	33.38	18.18	12.21
54. Heat in bleed condensate, million B.t.u. per hr	5.12	4.56	4.41	5.79	2.93	1.78
55. Net heat transfer to feed water, million B.t.u. per hr	24.16	21.51	22.42	27.59	15.25	10.43
Evaporator						
56. Bleed steam pressure at coil inlet, in Hg. abs	44.05	41.86	32.24	-	32.61	23.64
57. Bleed steam temperature at coil inlet, °F	236	233	219	-	220	206
58. Bleed condensate temperature, °F	209	219	168	-	212	187
59. Shell vapor pressure, in Hg. abs	18.15	17.66	5.04	-	12.11	11.84
60. Water temperature to evaporator, °F	40	40	40	-	40	40
61. Water to evaporator, lb. per hr	7,320	7,740	12,094	-	6,680	5,350
62. Bleed steam to evaporator, lb. per hr	8,450	9,025	13,210	-	7,710	6,000
Evaporator Condenser						
63. Vapor pressure in condenser, in. Hg. abs	17.75	17.56	-	-	14.01	10.24
64. Vapor temperature in condenser, °F	187	186	-	-	177	165
65. Condenser drain temperature, °F	185	187	-	-	165	157
66. Feed water temperature entering condenser, °F	168	165	169	168	153	139
67. Feed water temperature leaving condenser, °F	183	182	170	167	173	160
68. Feed water passing thru condenser, lb. per hr	483,000	448,000	440,000	431,000	334,000	254,500
69. Vapor to evaporator condenser, lb. per hr	7,320	7,740	12,094	-	6,680	5,350
Economy						
70. Steam to turbine, lb. per hr	482,000	444,000	441,000	442,300	343,500	258,000
71. Total steam extracted from turbine, lb. per hr	69,750	62,275	57,070	60,890	42,210	27,640
72. Heat in steam to turbine, million B.t.u. per hr	647.5	595.5	596.5	595.5	462	347.8
73. Heat in condensate leaving condenser, million B.t.u. per hr	23.65	22.4	20.66	19.40	16.38	12.47
74. Heat transferred to feed water, million B.t.u. per hr	73.42	66.30	61.56	66.37	45.99	30.56
75. Heat chargeable to turbine unit, million B.t.u. per hr	550.43	506.8	514.28	509.73	399.63	304.77
76. Heat equivalent of electrical output, million B.t.u. per hr	168.35	156.06	156.06	156.06	117.47	84.0
77. Heat consumption of unit, B.t.u. per kw-hr	11,165	11,089	11,253	11,154	11,617	12,389
78. Thermal efficiency of unit, %	30.6	30.8	30.4	30.7	29.4	27.6

TABLE XXVII

TURBO-GENERATOR TEST NO. 7—SUMMARY OF TESTS—50,000-KW. GENERAL ELECTRIC TURBO-GENERATOR UNIT—NO STEAM EXTRACTED FROM TURBINES—VACUUM CONSTANT AT 29.0 IN. HG.

1. Run No.	15	16	17	18
2. Date	3/28/27	3/28/27	3/28/27	3/28/27
3. Generator output, kw.	50,300	48,100	34,200	24,500
Turbine				
4. Steam pressure at the throttle, lb. per sq. in. abs.	391.6	392.6	395.6	399.6
5. Steam pressure after the primary valve, lb. per sq. in. abs.	303.6	352.6	263.6	201.6
6. Steam pressure after secondary valve, lb. per sq. in. abs.	282.6	212.6	154.6	115.6
7. Steam pressure in chamber of 1st extraction stage, in Hg. abs.	68.51	61.73	46.11	34.9
8. Steam pressure in chamber of 2nd extraction stage, in Hg. abs.	21.78	19.40	14.28	10.82
9. Steam pressure in chamber of 3rd extraction stage, in Hg. abs.	7.01	6.38	4.62	3.45
10. Steam pressure at exhaust, in Hg. abs.	1.02	1.04	1.03	.99
11. Steam temperature at throttle, °F.	683	681	678	670
12. Condensate temperature leaving main condenser hotwell, °F.	81	82	81	80
Economy				
13. Steam to turbine, lb. per hr.	479,000	444,500	330,000	247,850
14. Heat in steam to turbine, million B.t.u. per hr.	644.7	597.7	443	332.2
15. Heat in condensate leaving condenser, million B.t.u. per hr.	23.41	22.24	15.89	11.87
16. Heat chargeable to turbine unit, million B.t.u. per hr.	621.29	575.46	427.11	320.33
17. Heat equivalent of electrical output, million B.t.u. per hr.	171.77	164.26	116.79	83.66
18. Heat consumption of unit, B.t.u. per kw-hr.	12,352	11,963	12,488	13,075
19. Thermal efficiency of unit, %	27.6	28.6	27.3	26.1

TURBO-GENERATOR TEST NO. 7

Tests were made to determine the economy of the turbo-generator unit, when operating without extracting steam from the turbine, also when steam is extracted from three stages of the turbine to heat the feed water and to operate the evaporator. The range and variation of the extraction steam pressures between the turbine casing and the heaters were also investigated. Tests were made during March, 1927.

Test Apparatus Data

Turbine: General Electric Co.; 50,000 kw.; single cylinder; operating at 1200 r.p.m. It is designed for three stage steam extraction with initial steam conditions at 390 lb. per sq. in. gage pressure and 700 deg. fahr. total temperature.

Generator: General Electric Co.; 75,000 kv-a., 1200 r.p.m. alternator.

The first extraction nozzle, located at the fourteenth stage of the turbine, supplies steam to the first extraction stage feed water heater and the evaporator. The steam extracted at the second and third extraction nozzles, which are located respectively at the seventeenth and nineteenth stages of the turbine, is used only for feed water heating. The leakage from the high pressure shaft seals enters the second extraction stage heater.

The evaporator supplied with steam from the first extraction nozzle is so installed that the vapor can be directed either to an evaporator vapor condenser, located in the feed water heating system between the first and second extraction stage feed water heaters, or the vapor can be directed to the lowest pressure extraction heater which, during normal operation, is supplied only by steam extracted from the nineteenth stage of the turbine.

Method of Conducting Test

Extraction and non-extraction tests were made at generator loads ranging from 25,000 to 50,000 kw. with the turbine back pressure maintained constant at 1.0 in. of mercury.

Tests made with steam extracted from the turbine include observations for the specified range of loads with the evaporator vapor condensed in the evaporator condenser. To observe the effects of evaporator operation on the unit economy, tests were made at a constant load of 45,700 kw. with the evaporator out of service, also with the evaporator in service with the vapor condensed in the evaporator condenser on one test and the vapor condensed in the lowest pressure extraction heater on another test.

The feed water from the unit includes the steam condensed in the main condenser, the high pressure shaft packing steam leakage condensed in the second extraction stage heater, the bleed condensate from the evaporator and all extraction heaters and the condensate make-up added to the system by the evaporator. This feed water is pumped by the main condensate pump, respectively, through the third extraction stage heater, the second extraction stage heater, the evaporator condenser and the first extraction stage heater to the boiler feed pump to be returned to the boilers.

The extraction steam pressures were indicated by mercury filled manometers and steam temperatures were indicated by glass, engraved stem, thermometers in oil filled wells.

To obtain the pressure of the steam in the extraction chamber of the first extraction stage, the casing was drilled for a connection at a point 30 deg. below the horizontal center line of the casing. The inner opening of this pressure connection is in the chamber at the periphery of the fourteenth stage wheel. For the extraction chamber pressure connections at the third extraction stage the casing was drilled 45 deg. below the horizontal center line and a pressure connecting tube was brought out through the side of the exhaust casing.

The extraction steam temperatures were measured at a point near the pressure connection at the heater steam inlet, about 12 in. from the heater shell.

The steam supplied to the unit and the feed water passing through the feed water heaters during the tests were determined by flow meter measurements. Both the steam flow meter and the condensate flow meter were calibrated by weighed water tests.

The high pressure shaft packing leakage was measured by a pitot tube and a differential indicating manometer.

Results

A summary of the results of the tests with steam extracted from three stages of the turbine is shown in Table XXVI. Test run No. 19 was made with the primary valve full open, the secondary valve being throttled.

Test run No. 20 was made with the primary valve full open with the secondary valve closed. During test runs No. 21 and 22 the primary valve was throttled and the secondary valve closed. On test runs No. 19 to 22 inclusive, the evaporator vapor was condensed in the evaporator condenser.

Test run No. 25 was made with the primary valve full open with the evaporator vapor condensed in the third stage extraction heater instead of the evaporator condenser. Test run No. 26 was made at the same generator load as obtained on test run No. 19, but the evaporator was taken out of service and steam extracted, only, for feed water heating.

A summary of the test results when the turbine was operated without steam extraction is shown in Table XXVII.

Test run No. 15 was made with the secondary valve full open, test run No. 16 with the primary valve full open and test runs No. 17 and No. 18 with the primary valve throttled.

A heat balance diagram for the unit is shown in Fig. 31. The auxiliary power consumption is not deducted from the generator output when unit economy is considered.

The relation between the heat supplied to the turbine and the total heat extracted at the three extraction stages is shown in Fig. 32. The per cent of total heat to the unit that was extracted is also shown. In Fig. 33 the heat extracted at each extraction nozzle is graphically presented.

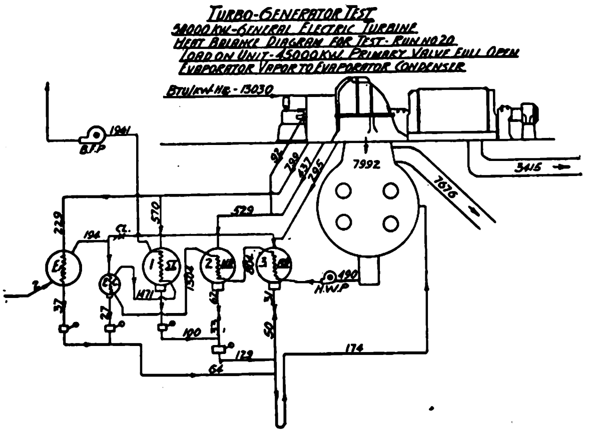
TURBO-GENERATOR TEST
50000 KW-GENERAL ELECTRIC TURBINE
HEAT BALANCE DIAGRAM FOR TEST-RUN NO 20
LOAD ON UNIT-45000 KW PRIMARY VALVE FULL OPEN
EVAPORATOR VAPOR TO EVAPORATOR CONDENSER
BTU/KW HR-13030
1941
B.F.P
92
799
437
295
7992
3415
7676
229
570
529
194
E
EC
1
2
3
1471
1504
62
53
37
27
190
129
64
50
174
490
H.W.P

FIG. 31—HEAT BALANCE DIAGRAM, STEAM EXTRACTED FROM THREE STAGES OF THE TURBINE, EVAPORATOR DISCHARGING VAPOR TO EVAPORATOR CONDENSER—TURBO-GENERATOR TEST NO. 7.

Fig. 34 shows the steam pressures at each extraction chamber with and without steam extracted from the turbine.

Fig. 35 shows the relation between the heat equivalent of the electrical output and the heat absorbed by the feed water in passing through the extraction heaters.

Heat consumption of the unit and the water rate of the unit for the extraction tests with the evaporator vapor passing to the evaporator condenser are graphically shown in Fig. 36.

TURBO-GENERATOR TEST NO. 8

The object of tests made in May, 1928, was to determine the water rate of 50,000 kw., 1200 r.p.m., General Electric turbo-generator unit when operated straight condensing and to compare the performance with the manufacturer's guarantee.

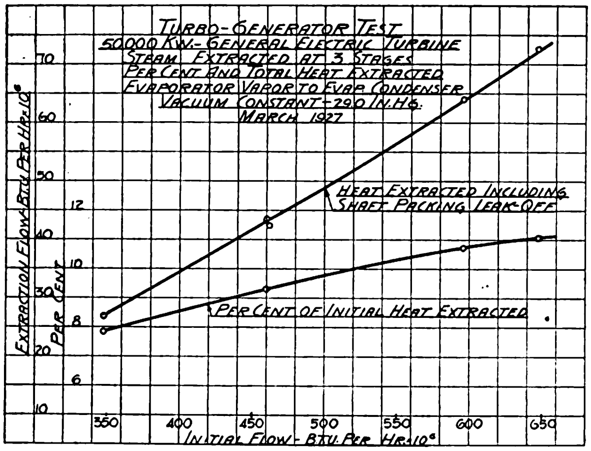

FIG. 32—HEAT EXTRACTED AND PER CENT OF THROTTLE HEAT EXTRACTED, STEAM BLED AT THREE STAGES OF THE TURBINE—TURBO-GENERATOR TEST NO. 7.

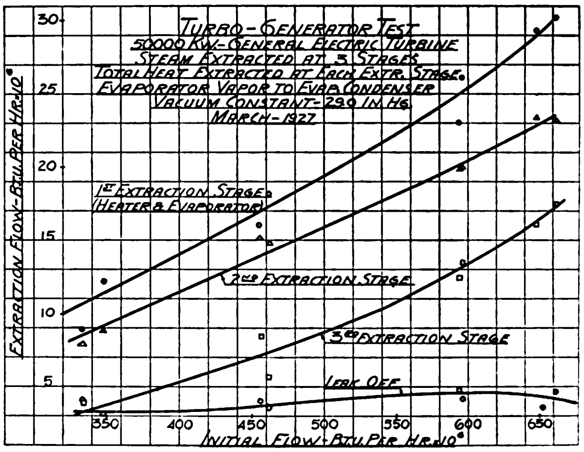

FIG. 33—HEAT EXTRACTED AT EACH EXTRACTION NOZZLE, STEAM BLED AT THREE STAGES OF THE TURBINE—TURBO-GENERATOR TEST NO. 7.

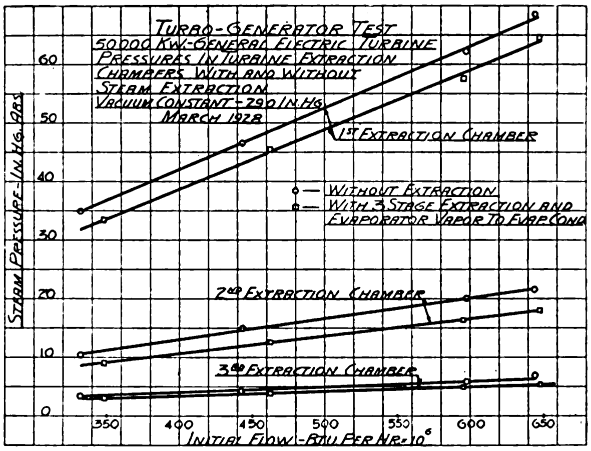

FIG. 34—EXTRACTION CHAMBER STEAM PRESSURES, WITH AND WITHOUT STEAM EXTRACTED AT THREE STAGES OF THE TURBINE—TURBO-GENERATOR TEST NO. 7.

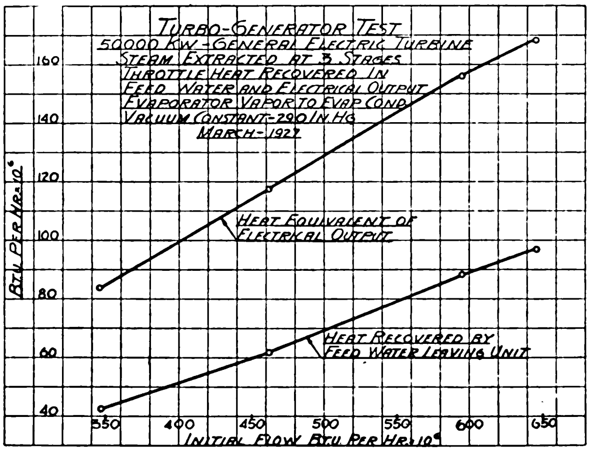

FIG. 35—HEAT EQUIVALENT OF ELECTRICAL OUTPUT AND THE HEAT ABSORBED BY FEED WATER, STEAM EXTRACTED AT THREE STAGES OF THE TURBINE—TURBO-GENERATOR TEST NO. 7.

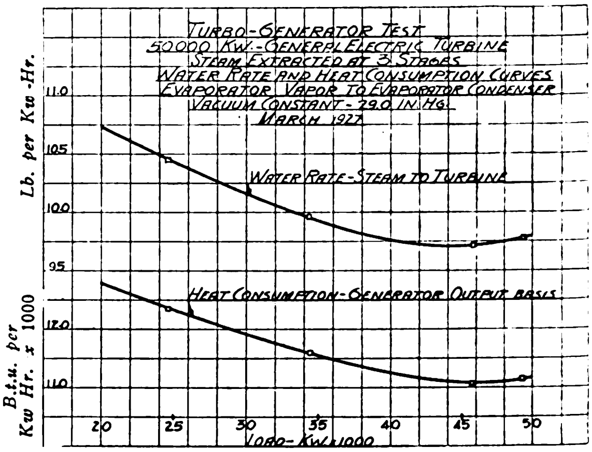

FIG. 36—WATER RATE AND HEAT CONSUMPTION, STEAM EXTRACTED AT THREE STAGES OF THE TURBINE—TURBO-GENERATOR TEST NO. 7.

TABLE XXVIII

TURBO-GENERATOR TEST NO. 8—SUMMARY OF TEST—50,000-KW. GENERAL ELECTRIC TURBO-GENERATOR UNIT—NO STEAM EXTRACTED FROM TURBINE.

1. Run No.		3	1	6	5
2. Date	5/10/28	5/9/28	5/9/28	5/11/28	5/10/28
3. Net generator output, kw.	15,090	24,730	34,680	39,810	50,390
4. Power factor, %	82.5	85.1	83.2	84.2	95.2
Turbine					
5. Steam pressure at throttle, lb. per sq. in. abs.	284.9	283.9	282.5	282.0	280.2
6. Steam pressure after primary valve, lb. per sq. in. abs	124.6	186.2	255.0	272.8	268.9
7. Steam pressure after secondary valve, lb. per sq. in abs	56.2	88.5	124.8	149.5	204.1
8. Steam pressure at exhaust, in. of Hg. abs	0.730	0.871	1.098	1.269	1.709
9. Steam temperature at throttle, °F.	577.5	614.4	612.6	608.4	627.8
10. Steam superheat at throttle, °F.	164.8	201.9	200.6	196.6	216.5
11. Steam temperature at exhaust, °F.	67.3	72.3	78.1	82.5	90.1
Condenser					
12. Condensate temperature leaving hotwell, °F.	68.4	73.7	79.2	82.7	89.3
13. Circulating water entering condenser, °F.	51.8	51.3	50.6	52.0	52.2
14. Circulating water leaving condenser, °F.	57.0	58.9	60.5	63.6	62.6
Economy					
15. Total steam consumption, lb. per hr	174,780	260,300	355,840	415,480	535,020
16. Water rate (actual), lb. per kw-hr	11.59	10.53	10.26	10.44	10.62
17. Water rate (actual corrected to guaranteed conditions), lb. per kw-hr.	11.64	10.69	10.19	10.19	10.30
18. Water rate (guaranteed), lb. per kw-hr	11.68	10.68	10.21	10.05	10.47
19. Heat consumption (actual), B.t.u. per kw-hr	14,660	13,480	13,050	13,210	13,450
20. Heat consumption (actual corrected to guaranteed conditions), B.t.u. per kw-hr.	14,840	13,630	12,990	12,990	13,130
21. Heat consumption (guaranteed), B.t.u. per kw-hr	14,890	13,610	13,010	12,810	13,350
22. Rankine cycle efficiency ratio (actual), %	72.6	77.2	80.2	79.7	79.7
23. Overall thermal efficiency (actual), %	23.3	25.3	26.2	25.8	25.4
24. Overall thermal efficiency (actual corrected to guaranteed conditions), %	23.0	25.1	26.3	26.3	26.0
25. Overall thermal efficiency (guaranteed), %	22.9	25.1	26.3	26.7	25.6

Method of Conducting Test

All tests made were of two hours' duration and ranged in load from 15,000 to 50,000 kw. During these tests the bleed steam valves and condenser make-up valves were closed. Condensate from the hotwell was supplied to the turbine seals.

The steam leak-off from the high pressure gland was condensed in the low pressure extraction heater and weighed.

The main unit condensate was weighed in test tanks. The drains from the atmospheric relief valve, the turbine seals and main condensate pump seals were separately weighed.

Steam pressure before the throttle was measured on calibrated test gages graduated to 0.5 lb. per sq. in. The throttle steam temperature was measured by special engraved test thermometers, graduated to 0.5 deg. fahr. The temperature indicated was corrected for stem exposure.

The vacuum at the turbine exhaust was measured on barometric type mercury columns.

The generator output was measured by the three wattmeter method. Calibrated split type current transformers were installed between the generator switch and the selector switches. The station potential transformers were used and calibrated for the burden carried during the tests.

A summary of the results of this test is presented in Table XXVIII with the water rate graphically presented in Fig. 37.

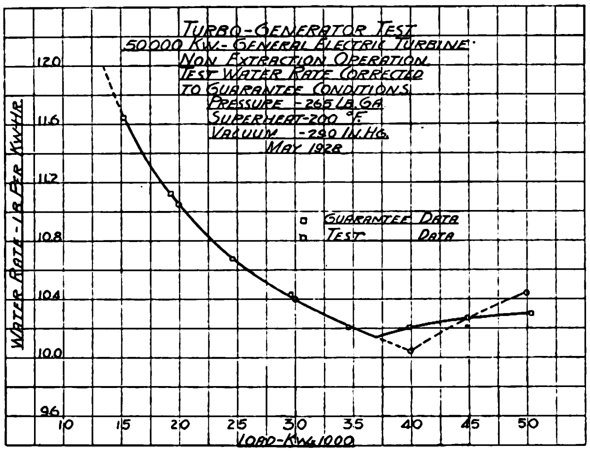

FIG. 37—WATER RATE CORRECTED TO GUARANTEE CONDITIONS, NO STEAM EXTRACTED FROM THE TURBINE—TURBO-GENERATOR TEST NO. 8.

TURBO-GENERATOR TEST NO. 9

This test was made to determine the economy of a General Electric turbo-generator unit when operating straight condensing, also when steam is extracted from three stages of the turbine to heat feed water. Test was made during August, 1927.

The turbo-generator unit, operating at 1800 r.p.m., is rated at 30,000 kw. The turbine is provided with three extraction nozzles located at the seventh, eleventh and fourteenth stages of the turbine. It is designed to operate with throttle steam at 375 lb. per sq. in. gage pressure and 258 deg. fahr. superheat with the exhaust pressure at 1.5 in. of mercury abs.

Steam consumption for the non-bleed tests was determined by a venturi tube and manometer installation in the main condensate line. This was corrected for leakage in the main condenser, condensate entering the condenser from the turbine shaft seals and the air ejectors. On the bleed tests the steam consumption was obtained by totaling the main condensate which was metered and the bleed steam to the individual heaters which was calculated from observed data. A venturi tube metering installation in the boiler feed line leaving the unit and a flow meter measuring the steam to the throttle were used to check the test results reported.

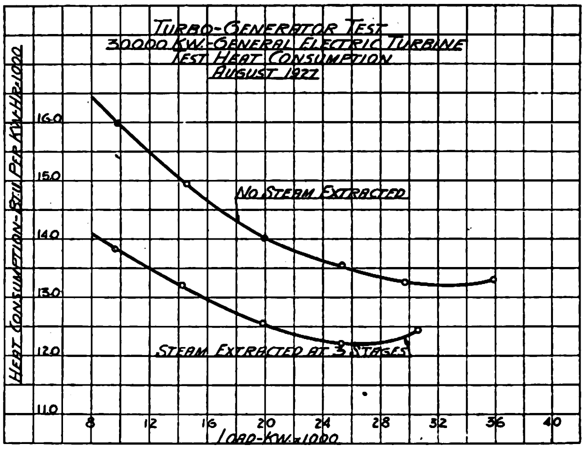

FIG. 38—HEAT CONSUMPTION, WITH AND WITHOUT STEAM EXTRACTED AT THREE STAGES OF THE TURBINE—TURBO-GENERATOR TEST NO. 9.

A condensed summary of the results of the tests made with steam extracted at three stages is shown in Table XXIX. Heat consumption for both test conditions is shown in Fig. 38.

Fig. 39 shows the path of the bleed steam and main condensate, also the heaters and coolers entering into the heat cycle of the unit.

TURBO-GENERATOR TEST NO. 10

The object of tests made during July, 1928, was to determine the water rate of the turbo-generator when operated without bleeding at loads at which guarantees were made by the manufacturer.

Test Apparatus Data

Turbine: Allis-Chalmers; 30,000 kw.; single cylinder; straight reaction; 1800 r.p.m.; exhausting into a single pass, 30,000 sq. ft. surface condenser.

Generator: Allis-Chalmers; a-c.; 30,000 kw.; 80 per cent power factor; 12,000 volt; 3-phase; 60 cycle; 1800 r.p.m.; served by a 100 kw. direct connected exciter which is excited by a small pilot exciter of a 4 kw. capacity.

Instruments

Special test gages were used to measure the steam pressure at the throttle. Normal operating gages were used

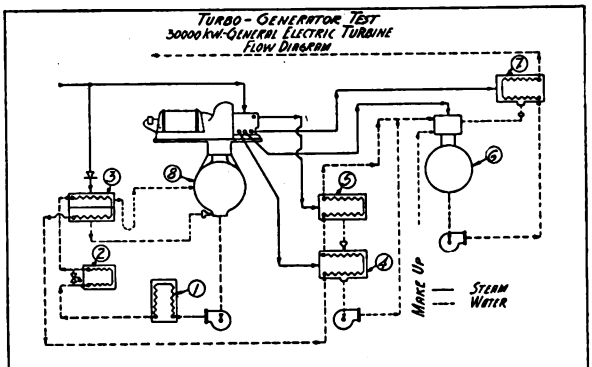
TURBO-GENERATOR TEST
30000 KW.-GENERAL ELECTRIC TURBINE
FLOW DIAGRAM
①
②
③
④
⑤
⑥
⑦
⑧
MAKE UP
— STEAM
---- WATER
1 GENERATOR AIR COOLER
2 OIL COOLER
3 STEAM JET AIR CONDENSER
4 3RD EXTRACTION STAGE HEATER
5 GLAND STEAM CONDENSER
6 2ND EXTRACTION STAGE (OPEN) HEATER
7 1ST EXTRACTION STAGE HEATER
8 CONDENSER

FIG. 39—MAIN CONDENSATE FLOW DIAGRAM, STEAM EXTRACTED AT THREE STAGES OF THE TURBINE—TURBO-GENERATOR TEST NO. 9.

TABLE XXIX

TURBO-GENERATOR TEST NO. 9—SUMMARY OF TEST—30,000-KW. GENERAL ELECTRIC TURBO-GENERATOR UNIT—STEAM EXTRACTED AT THREE STAGES.

1. Run No.	1	2	3	4
2. Date	8/18/27	8/16/27	8/18/27	8/17/27
3. Net generator output, kw.	9,540	19,800	25,200	30,700
4. Excitation, kw.	71	92	96	99
Turbine				
5. Steam pressure at throttle, lb. gage	382	376	369	366
6. Steam pressure after primary valve, lb. gage	156	293	359	356
7. Steam pressure after secondary valve, lb. gage	86	163	204	292
8. Steam pressure at exhaust, in. Hg. abs	2.34	2.15	2.78	2.91
9. Steam temperature at throttle, °F	695	671	688	681
10. Steam superheat at throttle, °F	251	229	248	241
11. Steam temperature at exhaust, °F	106.5	103.7	112.5	114.1
12. Condensate temperature leaving main condenser hotwell, °F	98.2	101.5	104.8	112.4
13. Condensate temperature leaving generator air-cooler, °F	112.2	110.0	111.4	117.2
14. Condensate temperature leaving oil cooler, °F	119.2	114.3	114.9	120.0
15. Condensate temperature leaving air ejector condenser, °F	130.5	120.9	120.0	124.2
Heaters				
16. Steam pressure in 3rd extraction stage heater, in. Hg. abs	5.7	9.47	11.33	14.36
17. Steam pressure in gland steam condenser, in. Hg. abs	11.91	17.42	21.81	21.41
18. Steam pressure in 2nd extraction stage (open) heater, lb. gage	3,3	2.5	4.0	2.7
19. Steam pressure in 1st extraction stage heater, lb. gage	15.8	60.1	72.2	78.9
20. Feed water temperature leaving 3rd extraction stage heater, °F	138.3	158.1	164.3	173.8
21. Feed water temperature leaving gland steam condenser, °F	160.4	181.9	187.4	191.5
22. Feed water temperature leaving 2nd extraction stage heater, °F	173.8	217.8	215.1	213.7
23. Feed water temperature leaving 1st extraction stage heater, °F	237.7	300.0	310.2	313.8
Economy				
24. Total steam consumption (actual), lb. per hr	127,110	235,640	286,270	373,750
25. Heat consumption (actual), B.t.u. per kw-hr	13,830	12,560	12,220	12,450

TABLE XXX

TURBO-GENERATOR TEST NO. 10—SUMMARY OF TEST—30,000-KW. ALLIS-CHALMERS TURBO-GENERATOR UNIT—NO STEAM EXTRACTED FROM TURBINE.

1. Test No	2	1	5	4	3
2. Date of test	7/5/28	7/5/28	7/7/28	7/6/28	7/6/28
3. Duration of test, hr	2	2	2	2	2
4. Barometer, in. Hg	29.460	29.450	29.480	29.505	29.530
Turbine					
5. Steam pressure at throttle, lb. gage	334.7	331.0	340.2	336.8	331.1
6. Steam pressure after primary valve, lb. gage	128.2	221.8	312.6	336.0	329.8
7. Steam pressure after secondary valve, lb. gage	62.7	113.1	164.6	179.6	234.1
8. Steam pressure at exhaust, in. Hg. abs	1.955	1.875	2.187	2.223	2.480
9. Steam temperature at throttle, °F	683.6	678.0	709.8	697.1	702.7
10. Steam temperature at exhaust, °F	101.3	99.8	104.9	105.4	108.5
Generator					
11. Generator output, kw	8,164	15,484	22,839	24,696	30,592
12. Voltage, XY phase, volts	11,480	11,610	11,870	11,975	12,080
13. Voltage, ZY phase, volts	11,490	11,610	11,860	11,960	12,040
14. Voltage, YZ phase, volts	11,400	11,550	11,820	11,930	12,010
15. Current, X phase, amperes	541.6	960.8	1362.4	1460.8	1792.4
16. Current, Y phase, amperes	543.2	982.8	1372.4	1475.2	1811.2
17. Current, Z phase, amperes	518.0	951.6	1351.2	1452.4	1784.8
18. Power factor, %	77.1	80.0	81.7	81.7	81.75
19. Field voltage, volts	109.2	139.9	180.0	199.6	223.9
20. Field current, amperes	197.7	249.2	305.8	327.7	375.8
21. Excitation, kw	21.6	34.9	55.0	65.4	84.1
Condenser					
22. Condensate temperature in hotwell, °F	100.0	98.3	103.8	103.9	108.0
23. Inlet circulating water temperature, °F	76.0	75.0	75.6	75.5	75.5
24. Outlet circulating water temperature, °F	80.05	81.8	85.0	84.95	86.65
25. Heat content of exhaust steam, B.t.u. per lb	1033.0	998.2	999.3	990.0	998.2
26. Water circulated thru condenser, g.p.m	46,616	43,742	43,684	45,993	48,840
Economy					
27. Net condensate from the turbine, lb. per hr	97,823	159,591	221,368	236,704	295,524
28. Net condensate at contract conditions, lb. per hr	96,615	156,846	222,816	235,432	294,581
29. Steam consumption at contract conditions, lb. per kw-hr	11.834	10.130	9.756	9.533	9.629
30. Guaranteed steam consumption, lb. per kw-hr	12.536	10.747	10.314	10.243	10.399
31. Rankine cycle efficiency ratio of unit, %	64.92	75.64	80.25	81.91	82.12
32. Thermal efficiency of unit, %	22.15	25.75	27.20	27.52	27.38

for steam pressure measurements after the primary and secondary valves.

All temperatures were taken from mercury in glass thermometers. A 6-in. immersion laboratory thermometer was used to measure the steam temperature at the throttle. The stem of this thermometer was immersed in solder to the immersion mark and no stem corrections were applied to the temperature as indicated by this instrument. The exhaust steam temperature was read from industrial type thermometers.

Two mercury columns located at opposite corners of the turbine exhaust opening, measured the vacuum on the turbine.

Calibrated measuring tanks were used to determine the quantity of condensate discharged from the condenser. The electrolytic conductivity method of determining condenser leakage was used, but no trace of raw water contamination was detected, and condenser leakage was considered to be zero on all tests.

The electrical output was measured at the generator terminals by integrating watthour meters and a duplicate set of indicating wattmeters. The output by the integrating meters was used for checking purposes only. Instrument transformers used were calibrated previous to the test, with the same secondary burden which they were to carry during the tests.

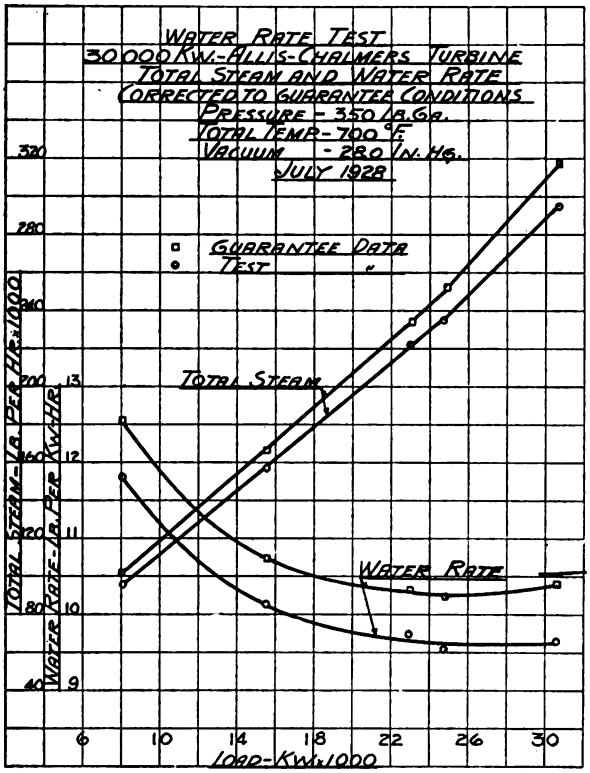

FIG. 40—TOTAL STEAM AND WATER RATE, NO STEAM EXTRACTED FROM THE TURBINE—TURBO-GENERATOR TEST No. 10.

Method of Conducting Tests

The tests were made at one-quarter, one-half, three-quarter, most efficient and full loads. Observations on each test covered a period of two hours.

The turbine is provided with four extraction nozzles. The two low pressure nozzles supply steam for feed water heating, the next higher pressure nozzle supplies steam for evaporator operation and the highest pressure nozzle supplies steam for cracking scale from the evaporator coils. During these tests, all bleed lines were closed and no steam was extracted from the turbine. To keep the bleed lines free from condensate, the drains from the two low pressure bleed lines were trapped to the condenser. Valves in these drain lines were cracked slightly during the tests.

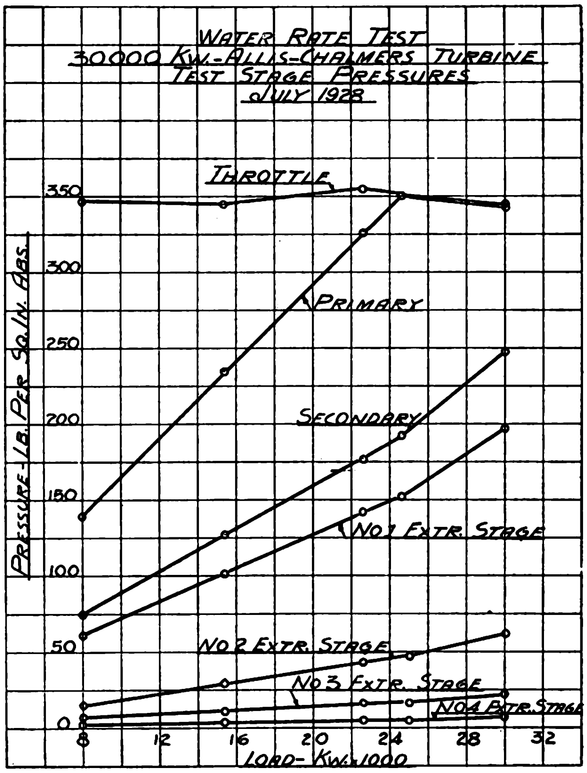

FIG. 41—STAGE STEAM PRESSURES, NO STEAM EXTRACTED FROM THE TURBINE—TURBO-GENERATOR TEST No. 10.

The hotwell condensate was pumped through the ejector condenser to the calibrated measuring tanks.

The primary jet of the air ejector drains back to the hotwell of the main condenser. The amount of steam supplied to the primary jets was calculated from the nozzle dimensions and deducted from the condensate withdrawn from the condenser.

A booster pump withdraws condensate from the discharge side of the condenser condensate pump and discharges to the seal tank from which water flows by gravity to seal the turbine shaft and the atmospheric relief valves. The overflow from the seal tank, the leakage from the turbine seals and the overflow from the atmospheric seals were drained to a measuring tank and the condensate, withdrawn for sealing use, which was not returned to the condenser was accounted for on every test.

Results

A summary of the test data is shown in Table XXX. Fig. 40 shows the total steam Willans' Line and the steam consumption per kilowatt-hour for test results corrected to guarantee conditions. It also shows the performance guaranteed by the manufacturer for non-bleeding operation.

The curves in Fig. 41 show the relation between the load on the unit and the stage steam pressures.

Fig. 42 shows the thermal efficiency of the unit for non-bleeding operation and the Rankine Cycle efficiency ratio of the unit based on actual steam conditions and output measured at the generator terminals.

TURBO-GENERATOR TEST No. 11

The object of tests made during October, 1928, was to determine the heat consumption of the turbo-generator unit

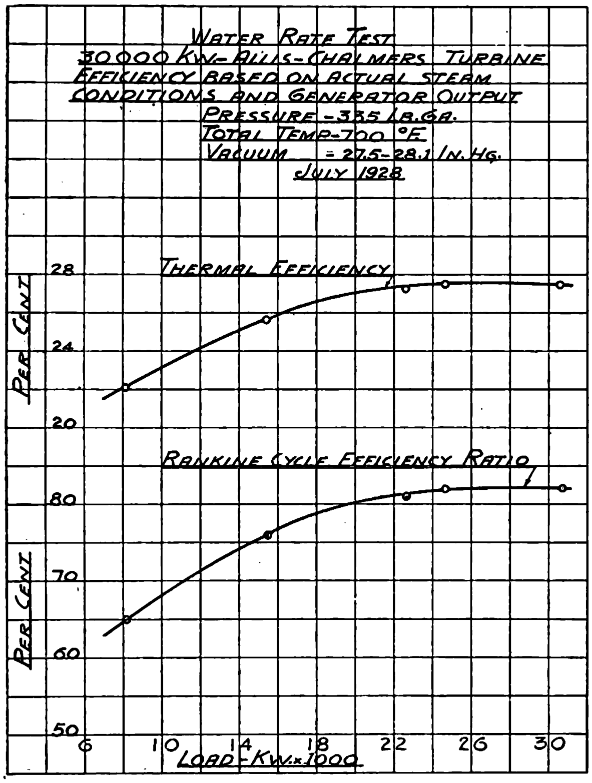

FIG. 42—THERMAL EFFICIENCY AND EFFICIENCY RATIO, NO STEAM EXTRACTED FROM THE TURBINE—TURBO-GENERATOR TEST NO. 10.

when steam was extracted from three stages of the turbine for feed water heating.

Test Apparatus Data

Turbine: Allis-Chalmers; designed to operate with steam at 400 lb. per sq. in. gage pressure, 725 deg. fahr. total temperature and 2 in. of mercury back pressure. It is of the full reaction type designed to extract steam from three stages to heat the condensate from the unit as it is returned to the boiler feed system.

Generator: Allis-Chalmers; 3-phase, 50 cycle, 11,000-volt alternator, rated at 15,000 kw. at 80 per cent power factor and 1500 r.p.m. The excitation is furnished by a 100 kw.. 250-volt direct connected exciter.

The low pressure and the high pressure extraction heaters are of the closed-heater type furnished by the Griscom-Russell Co. The intermediate extraction heater is of the open-heater type built by the Cochrane Co.

Method of Conducting Test

The condensate from the main condenser was pumped by the main condensate pump to the weigh tanks. This included the main turbine condensate, water from condenser tube leakage, the drains from the steam jet air pump and the low pressure heater bleed condensate. The sealing water for the turbine glands and the atmospheric relief valve was so circulated in the system that they did not influence the results of the condensate weighed at the tanks.

The condenser tube leakage was determined by weighing the leakage that took place with normal water circulated through the condenser, with the condenser steam space under atmospheric pressure. The amount thus obtained was corrected to test condition by increasing the tube leakage in proportion to the increase in pressure difference between the steam and water space of the condenser for the two conditions.

The steam pressure at the turbine throttle was maintained constant at the pressure specified in the guarantee by manual steam pressure control. Because the boilers superheat the steam higher than guarantee, the steam temperature at the throttle could also be maintained practically constant by the use of a de-superheating jet placed in the main steam line and supplied with water from the boiler feed system. With exception of the test made at approximately 4000 kw. when the steam demand was low, little difficulty was experienced in maintaining the desired steam pressures and temperatures.

When the load on the unit was such that the intermediate bleed stage was under a vacuum, steam was supplied to the intermediate, open type, extraction heater from the high pressure bleed stage.

Tests were made at approximately one-quarter, one-half, three-quarter and full loads with the duration of each test from two to three hours. The unit was operated with steam extracted from the three stages of the turbine and operation was normal except that the evaporator which normally receives steam from the intermediate extraction stage and discharges the vapor to the open heater was out of service.

Computations

The quantity of bleed steam to each extraction heater was calculated from the heat absorbed by the feed water passing through the heater and the heat in the bleed steam transferred to the feed water. The total heat of the bleed steam to the low pressure heaters was obtained from information furnished by the manufacturer.

No corrections were necessary for the temperature and pressure of steam supplied to the turbine. The vacuum correction applied was based on the ratio of the actual available heat in the steam to the available heat under guarantee conditions. This correction was applied to the steam exhausted to the condenser.

The steam consumption of the air ejector reported at 900 lb. per hr. was based on factory tests. As the drains from the ejector discharge into the main condenser this amount was deducted from the weighed condensate in calculating the turbine steam consumption.

The condenser leakage with the turbine out of service amounted to 125 lb. per hr. under vacuum. This was calculated to reach 250 lb. per hr., the correction being applied to the condensate as weighed.

Results

A summary of the data and results of this test are presented in Table XXXI.

In Fig. 43 the heat consumption of the unit is shown for test results corrected to guarantee conditions and also the guaranteed performance when operating on the regenerative cycle.

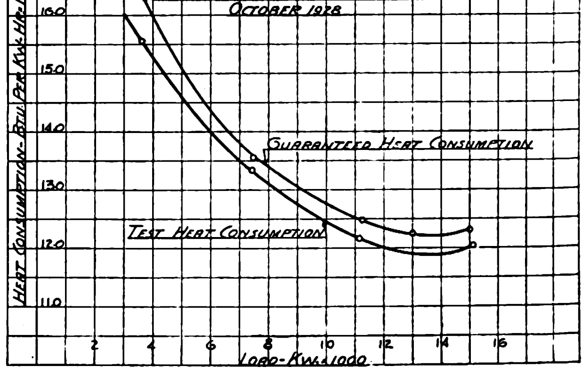

FIG. 43—ACTUAL AND GUARANTEED HEAT CONSUMPTION, STEAM EXTRACTED AT THREE STAGES OF THE TURBINE—TURBO-GENERATOR TEST NO. 11.

TABLE XXXI

TURBO-GENERATOR TEST NO. 11—SUMMARY OF TEST—15,000-KW. ALLIS-CHALMERS TURBO-GENERATOR UNIT—STEAM EXTRACTED AT THREE STAGES FOR FEED WATER HEATING

1. Run No.	4	1	2	3
2. Date	10/4/28	10/2/28	10/2/28	10/4/28
3. Net generator output, kw.	3,641	7,463	11,168	15,235
4. Power factor, %	79.2	74	90	99.5
Turbine				
5. Steam pressure before throttle, lb. per sq. in. abs	415.3	416.3	417.0	415.7
6. Steam pressure after primary valve, lb. per sq. in. abs	140.3	252.6	357.9	406.2
7. Steam pressure after secondary valve, lb. per sq. in. abs	67.8	125.6	178.2	253.3
8. Steam pressure at exhaust, in. Hg. abs	1.28	1.66	2.08	2.61
9. Steam temperature before the throttle, °F	725	725	725	725
10. Total heat in steam before the throttle, B.t.u. per lb	1,375	1,375	1,375	1,375
11. Steam temperature at exhaust, °F	85.0	92.0	99.0	110.5
12. Condensate temperature leaving main condenser hotwell, °F	80.3	91.4	101.8	106.7
Low Pressure Heater				
13. Bleed steam pressure at heater, lb. per sq. in. abs	5.2	9.1	13.0	17.9
14. Bleed steam temperature at heater, °F	167.4	189.7	205.9	222.1
15. Total heat in bleed steam at heater, B.t.u. per lb	1,115	1,107	1,108	1,120
16. Bleed condensate temperature, °F	128.6	151.1	164.2	171.5
17. Feed water temperature entering heater, °F	101.6	103.5	110.8	121.3
18. Feed water temperature rise thru heater, °F	23.1	42.5	46.9	50.6
19. Feed water passing thru heater, lb. per hr	42,644	77,344	109,350	152,672
20. Bleed steam to heater, lb. per hr	967	3,328	5,257	7,879
Intermediate Pressure (Open) Heater				
21. Bleed steam pressure at heater, lb. per sq. in. abs	-	18.3	26.3	37.4
22. Bleed steam temperature at heater, °F	-	311.8	315.2	352.0
23. Total heat in bleed steam at heater, B.t.u. per lb	-	1,198	1,198	1,214
24. Feed water temperature entering heater, °F	124.7	146.0	157.7	171.9
25. Feed water temperature rise thru heater, °F	76.9	57.0	46.0	32.3
26. Feed water to open heater, lb. per hr	42,644	77,344	109,350	152,672
27. Bleed condensate from high pressure heater, lb. per hr	2,535	8,400	14,400	24,800
28. Total feed water to heater, lb. per hr	45,179	85,744	123,750	177,472
29. Bleed steam to heater, lb. per hr	2,874	3,507	3,520	1,619
High Pressure Heater				
30. Bleed steam pressure at heater, lb. per sq. in. abs	32.4	62.3	86.9	118.5
31. Bleed steam temperature at heater, °F	463.0	481.2	488.8	539.0
32. Total heat in bleed steam at heater, B.t.u. per lb	1,268	1,274	1,275	1,297
33. Bleed condensate temperature, °F	250.0	292.0	313.0	335.0
34. Feed water temperature entering heater, °F	201.6	203.0	203.7	204.2
35. Feed water temperature leaving heater, °F	257.0	298.5	320.0	342.0
36. Feed water temperature rise thru heater, °F	55.4	95.5	116.3	137.8
37. Feed water passing thru heater, lb. per hr	48,053	89,251	127,270	179,091
38. Bleed steam to heater, lb. per hr	2,535	8,400	14,400	24,800
Economy				
39. Water rate (actual), lb. per kw-hr	13.04	11.84	11.29	11.59
40. Heat consumption (actual), B.t.u. per kw-hr	15,178	13,263	12,387	12,505
41. Heat consumption (corrected to guarantee conditions), B.t.u. per kw-hr	15,534	13,364	12,197	12,069
42. Heat consumption (guaranteed), B.t.u. per kw-hr	16,300	13,540	12,490	12,310

TURBO-GENERATOR TEST NO. 12

This series of tests was made during August, 1928, to determine the water rate of the turbo-generator unit when operated straight condensing.

Test Apparatus Data

Turbo-generator: Allis-Chalmers; rated at 6000 kw. at 80 per cent power factor; 2300/4000 volts; 3-phase; 60 cycle; operating at 36,000 r.p.m. The turbine exhausts into an Allis-Chalmers two pass; 11,750 sq. ft. surface condenser.

Turbine: Designed to operate with initial steam at 235 lb. per sq. in. gage pressure and 520 deg. fahr. total temperature and exhausts to the condenser at 2.0 in. of mercury, back pressure. The unit is operated straight condensing although the turbine is provided with four extraction nozzles.

Results

Steam consumption of the unit was obtained by weighing the condensate from the main unit condenser and subtracting from this the weight of the primary ejector drains and the turbine seal water that appeared as condensate from the condenser, but did not represent steam supplied to the unit. Tests for condenser leakage disclosed that no leakage was present during the water rate tests.

Results of these tests are summarized in Table XXXII.

The high back pressure on run No. 2, made at 3024 kw. load on the unit was due to abnormal condenser conditions that did not prevail during the other runs of the test series.

Run No. 3 was made as nearly as possible at the most efficient load, which is just below the load at which the overload valve opens.

The actual steam rate corrected to guarantee conditions and the guarantee steam rate over the entire load range are shown in Fig. 44.

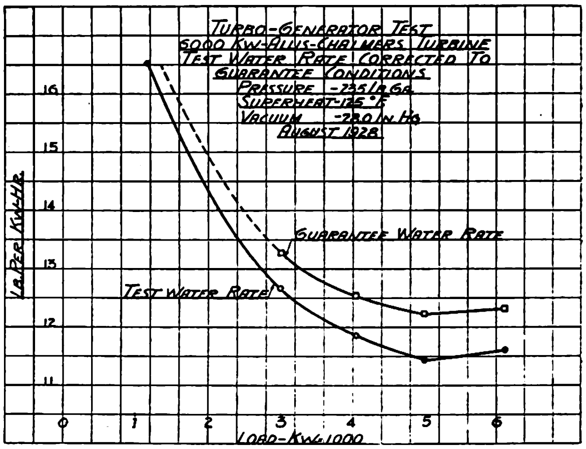

FIG. 44—ACTUAL AND GUARANTEED WATER RATE, NO STEAM EXTRACTED FROM THE TURBINE—TURBO-GENERATOR TEST NO. 12.

OPERATING COMPANIES' STATEMENTS

STATEMENT BY THE ALABAMA POWER CO., BIRMINGHAM, ALA.

During the annual inspection of the 30,000-kw. General Electric turbine, in January, 1928, one-half of the retaining shoulder, holding the fourth stage nozzle diaphragm against axial movement was found to be cracked as shown in Fig. 45 and 46. The turbine is a 17-stage Curtis, 1800 r.p.m. machine operating with steam conditions at 200 lb. per sq. in. gage pressure, 200 deg. fahr. superheat and 1.0 in. of mercury back pressure. For load up to 22,000 kw. steam is admitted only to the first stage nozzles. For loads above 22,000 kw. and up to 30,000 kw. additional steam is admitted to the fifth stage, before the diaphragm nozzles, through a secondary inlet valve. This secondary steam enters the turbine at an annular ring (cast integral with the shell), through a radial opening. It was at this opening that the break occurred.

The part of the casing adjoining the crack that separated from the shoulder formed a strip 51 in. long. The middle section of this strip separated from its original position

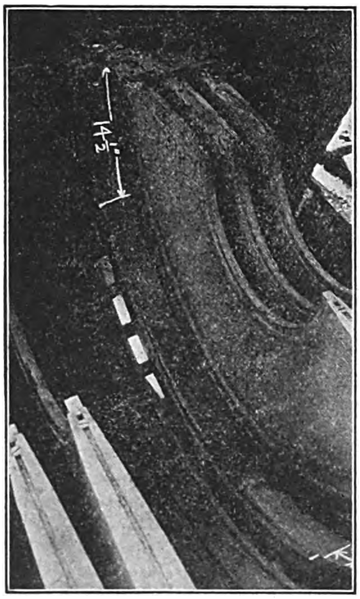

FIG. 45—CRACK IN TURBINE CYLINDER, 30,000-KW. GENERAL ELECTRIC TURBINE—ALABAMA POWER CO.

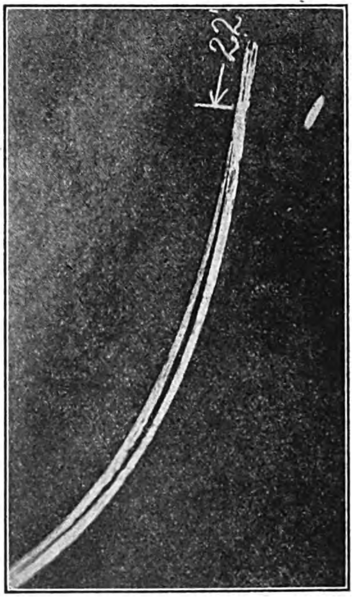

FIG. 46—BORDER OF CRACK IN CYLINDER LEADED TO SHOW THE BREAK. 30,000-KW. GENERAL ELECTRIC TURBINE—ALABAMA POWER CO.

TABLE XXXII

TURBO-GENERATOR TEST NO. 12—SUMMARY OF TESTS—6000-KW. ALLIS-CHALMERS TURBO-GENERATOR UNIT—NO STEAM EXTRACTED FROM THE TURBINE

1. Test No.	5	1	4	3	2
2. Date of test	8/17/28	8/17/28	8/17/28	8/17/28	8/17/28
3. Duration of test, hr.	2	2	2	2	2
4. Barometer, in. Hg	29.40	29.43	29.38	29.40	29.40
Turbine					
5. Steam pressure at throttle, lb. gage	240.2	229.8	238.2	236.7	231.0
6. Steam pressure after primary valve, lb. gage	59.8	149.7	185.3	232.6	238.8
7. Steam pressure after secondary valve, lb. gage	28.8	72.5	94.2	115.2	154.4
8. Steam pressure at exhaust, in. Hg. abs	1.19	1.92	1.40	1.55	1.58
9. Steam temperature at throttle, °F	525.2	549.8	530.8	537.7	548.7
10. Steam temperature at exhaust, °F	81.4	98.0	86.6	88.4	91.2
Generator					
11. Generator output, kw-hr	1176	3024	4065	4902	6156
12. Voltage (average per phase), volts	2536	2518	2527	2520	2520
13. Current (average per phase), amperes	237.3	502.1	536.2	677.7	846.9
14. Power factor, %	65.2	79.9	100	95.7	96.3
15. Excitation, kw	8.9	13.8	9.2	11.5	13.1
16. Net power output at terminals, kw	1167	3010	4056	4890	6143
Condenser					
17. Condensate temperature in hotwell, °F	81.0	98.6	87.6	89.4	92.6
18. Inlet circulating water temperature, °F	76.6	76.2	77.4	78.0	77.6
19. Outlet circulating water temperature, °F	79.3	85.9	83.8	85.4	87.1
20. Heat content of exhaust steam, B.t.u. per lb	1006	991	957	956	971
21. Water circulated thru condenser (metered), g.p.m.	12,441	7,343	12,401	12,479	12,593
Economy					
22. Net condensate from the turbine, lb. per hr	18,143	37,313	45,987	54,054	69,085
23. Steam consumption at actual condition, lb. per kw-hr	15.56	12.40	11.32	11.06	11.25
24. Steam consumption corrected to guarantee condition, lb. per kw-hr	16.52	12.67	11.87	11.45	11.62
25. Steam consumption guaranteed, lb. per kw-hr	-	13.30	12.52	12.22	12.30
26. Rankine cycle efficiency ratio of unit, %	54.2	71.3	75.5	78.2	76.8
27. Thermal efficiency of unit, %	17.9	22.5	24.6	25.2	24.7

approximately ⅝ in., but the ends remained intact. No material damage was done to the rotating parts. Nothing was observed on which an estimate of the cause or the date of the break could be based. That it occurred some time between February, 1927, and January, 1928, is all that is known.

The damaged piece was removed by cutting at each end. To hold the fourth stage diaphragm in its proper place, a keyway was cut both in the shell and the lower half of the diaphragm at the bottom diameter of each. This is illustrated in Fig. 47. The key inserted at this point was designed to take all of the stress imposed by the diaphragm. A very small clearance was left between the diaphragm and the original shoulder while the machine was cold. With the machine at operating temperature the diaphragm is believed to be in its normal position against the remaining shoulder, imposing little, if any, stress on it.

The machine has not been inspected since repairs were made. No further break at this shoulder is anticipated even though the cause of the original break has never been determined.

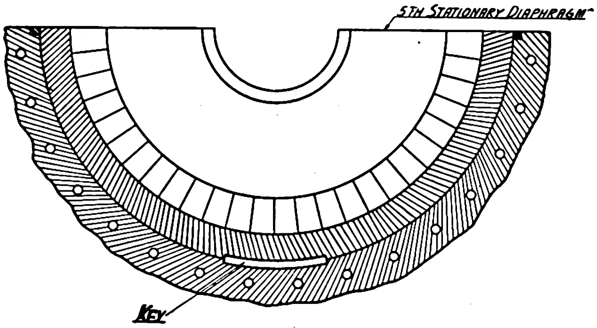

FIG. 47—LOCATION OF KEY HOLDING THE DIAPHRAGM IN PLACE, 30,000-KW. GENERAL ELECTRIC TURBINE—ALABAMA POWER CO.

STATEMENT BY W. S. BARSTOW & CO., READING, PA.

Holland Station

The turbo-generator unit for the Holland Station consists of a high pressure and a low pressure turbine rated at a total capacity of 55,750 kw. The specified steam conditions are 1250 lb. per sq. in. gage pressure and 750 deg. fahr. total temperature at the throttle of the high pressure turbine with the low pressure turbine exhausting into a condenser at 29.0 in. of mercury. Data pertaining to the unit are presented in Table XXXIII.

TABLE XXXIII

TURBINE DATA—HOLLAND STATION, NEW JERSEY POWER & LIGHT COMPANY.

1. Capacity of unit, kw.	55,750
2. Capacity of high pressure element, kw.	11,920
3. Capacity of low pressure element, kw.	43,830
4. Speed of high pressure element, r.p.m.	3,600
5. Speed of low pressure element, r.p.m.	1,800
6. Voltage, volts	13,800

The steam at the high pressure exhaust varies in pressure from 100 lb. per sq. in. gage at 13,000 kw. load to 416 lb. per sq. in. gage at 55,750 kw. The high pressure exhaust passes through the steam and gas reheater increasing the temperature to 750 deg. fahr. before being admitted to the low pressure turbine.

The turbine is designed for multivalve steam admission to give a low steam consumption over a wide range of load.

Steam is bled from the high pressure exhaust and the sixth, tenth and fourteenth stages of the low pressure turbine to heat feed water. The final feed water temperature is 433 deg. fahr. at rated turbine load.

An exciter direct connected to the low pressure unit excites both the low pressure and the high pressure generator. A sub-exciter on the same shaft dispenses with the field rheostats on the generator.

The low pressure turbine is provided with an emergency governor that operates the trip valve. It also has a control governor that can be used if the low pressure turbine is operating alone. Under normal conditions, the high pressure governor will control all operation with the high pressure exhaust passing through the reheater to the low pressure turbine.

STATEMENT BY THE COMMONWEALTH EDISON CO., CHICAGO, ILL.

Automatic Frequency Control

The perfection of frequency control in an electricity supply system is very desirable in order that operating companies may render the best possible service. While variations in frequency are not always as readily apparent as variations in voltage, they are objectionable in all classes of service where uniform speed is a factor.

The advantages of automatic frequency control lie not alone in precision speed regulation, but also in improved parallel operation of power stations and interconnected power systems. Economies resulting from such control are rather intangible but can best be measured by the effect on system interconnections, the decrease of so-called power drifts from one system to another and in the promotion of merchandise sales.

Factors Entering into Control Design

Frequency is ideally controlled when a predetermined standard is continuously maintained. To attain this standard it is necessary that the energy supply for the turbines vary simultaneously with every variation in system load. This is automatically approached by the use of electrical and mechanical relays that cause the energy supply to change almost simultaneously with demand on the system.

Load changes on the system cause the corrective stimulus to be applied. Since the inertia of the entire rotating system of turbines, converting apparatus, and motor load is involved, over-regulation is likely to take place unless the corrective measure is limited and stability readily established. This dictates that the automatic control should be intermittent with corrective influence applied steadily until the desired correction is complete.

The natural period of oscillation of long interconnecting lines between electric systems is in the order of the time it takes the usual turbine governor to respond to changes in loading. For these reasons it seems most desirable that the corrective influence of the automatic control should be small, intermittent and applied at periods entirely out of the range of natural periods of oscillation of any part of the system under control.

The control should be such that its operation will not lower the efficiency of the plant nor produce undesirable load swings on the station apparatus. Neither should it affect the system nor the unit under its direct control due to failure of any of its parts. It should relinquish control during periods of manual frequency regulation of the unit on which it is installed and in case of a system disturbance of any moment the effects of the control must be instantly removed.

With these and other limitations in mind a controller was built and installed on a 90,000 kw. unit. Due to the governor characteristic and the setting of the admission valves at this unit undesirable load swings would occur. The control was therefore transferred to a 75,000 kw. unit where its performance was very satisfactory.

Description of Control and Its Operation

The frequency control includes two major divisions, the one maintains close instantaneous frequency and the other prevents the integration of a time error as measured by an

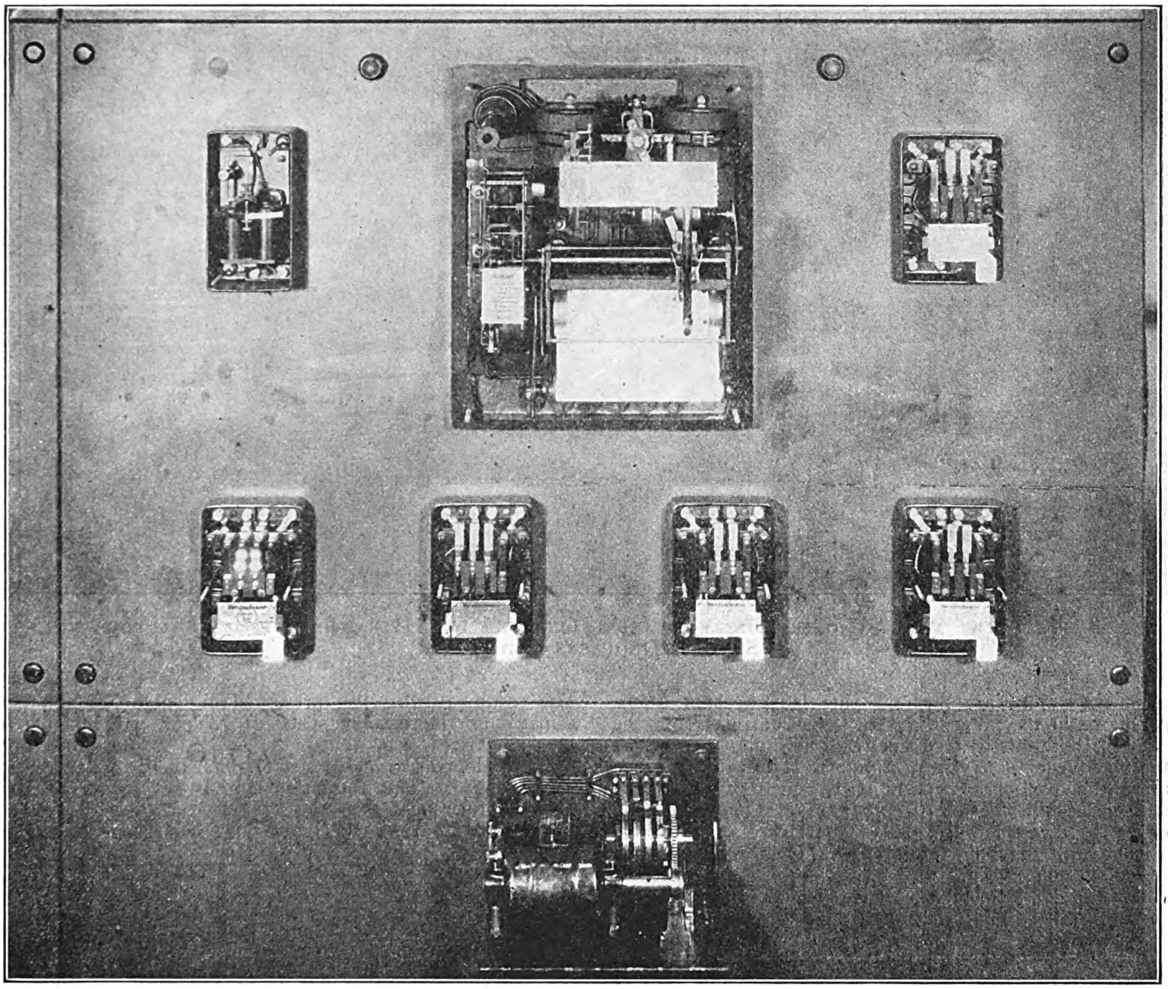

FIG. 48—SWITCHBOARD FREQUENCY CONTROL APPARATUS—COMMONWEALTH EDISON CO.

electric clock. The switchboard apparatus is shown in Fig. 48. No additional equipment at the turbine was necessary as the control operates the standard governor motor.

The first part of the controller consists of a contact-making device operated by a high grade frequency meter. Its function is to maintain an instantaneous frequency within 0.05 cycle plus or minus, and operates from 0.05 to 0.25 cycle plus or minus of the adopted standard. The control automatically goes out of service when deviations in frequency exceed 0.25 cycle.

While the frequency meter used is the best obtainable it is difficult to maintain an accuracy of more than 99.95 per cent. Even with such a degree of accuracy it is true that time-frequency integration may be in error.

The second part of the controller operates within 0.05 plus or minus of the standard frequency and takes care of possible inaccuracy of the frequency meter. It consists of a set of synchronous motor driven contactors, relays and a high grade precision clock, the accuracy of which is frequently checked against U. S. observatory time signals.

The synchronous motor operated cam-contactors acting between contacts on the clock mechanism and the governor control motor on the turbine, serve to synchronize the frequency-time with clock-time. The device goes through this operation once each minute, offering the corrective impulse to the turbine. If the timing of the electric system is correct, no corrective impulse is transmitted. The duration of this impulse is about one second and the load change on the unit is approximately 1000 kw.

In order that the load on a unit will not be seriously disturbed by a protracted tendency for the system frequency to run high or low, a load-range relay was devised to limit the possible load change to within any desired range which is selective at the option of the operator. If the unit is to operate at an average load of 60,000 kw. the load limit device is set to cover the range from 50,000 to 70,000 kw. If the control should cause the load to change more than 10,000 kw. plus or minus, the device goes out of service and attracts the attention of the operator.

Inaccuracies in frequency meters and master clocks were at once revealed by the operation of the control. It was found possible, however, to hold the frequency within 0.05 cycle plus or minus and can now be maintained at will for indefinite periods. The system frequency obtained with manual and automatic regulation is shown in Fig. 49.

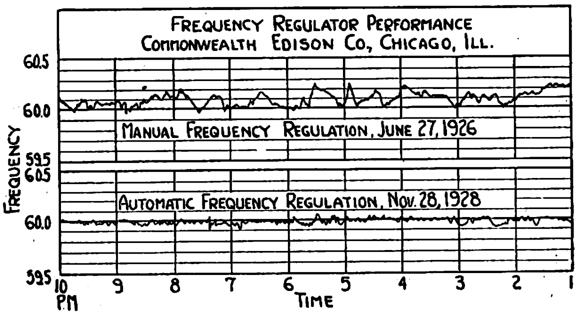

FIG. 49—FREQUENCY WITH AND WITHOUT AUTOMATIC REGULATION—COMMONWEALTH EDISON CO.

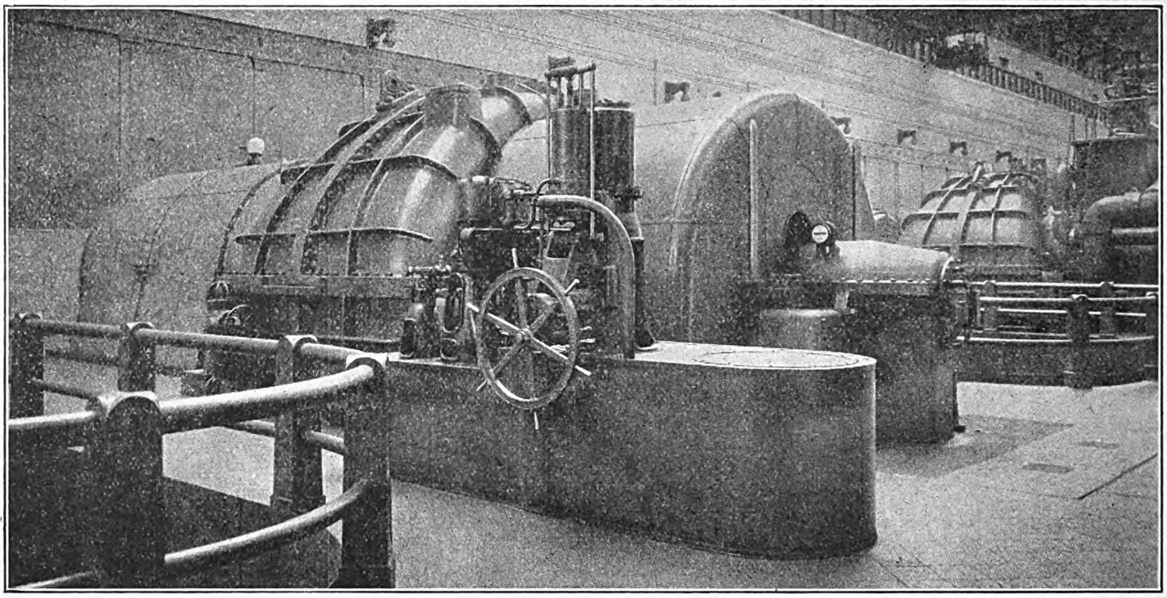

FIG. 50—41,250-KW. WESTINGHOUSE, SINGLE-CYLINDER TURBINE WITH HYDRAULIC TYPE OF GOVERNOR—COLFAX STATION, DUQUESNE LIGHT CO.

Present indications are that the sluggish governor seems to have more in its favor than the sensitive one from the standpoint of automatic frequency regulation.

Actual load variations from minute to minute on a large system as the one in connection with which this company operates are small. The load swings on the controlling station are in the order of 7000 to 10,000 kw. on a system which has a load of about 900,000 kw. and is interconnected with other systems.

By means of this control the entire system in the Chicago area, including the Public Service Co. of Northern Illinois, The Commonwealth Edison Co., the Northern Indiana Public Service Co., the Illinois Superpower Co. and also the Ohio-Michigan Power Co. have been able to operate so as to maintain correct frequency-time for periods of twenty-four hours and more. This means that the greatest error at any time during this period was less than one second and also that the greatest error in frequency was 0.05 cycle.

Experience gained over a period of six months indicated that it is desirable to control more than one unit in the Chicago district in order not to disturb tie line loads and station operation. Two controllers are now in service and at least three more will be in the near future. The machines so controlled will be in two or possibly four stations.

STATEMENT BY THE DUQUESNE LIGHT CO., PITTSBURGH, PA.

Hydraulic Governors

During the year 1927 two Westinghouse, 41,250 kw. turbo-generating units were installed at the Colfax Station of this company. These units, one of which is shown in Fig. 50, are of the single cylinder, Bauman type, arranged for four stage bleeding.

These turbines are equipped with hydraulic type of governors. The governors consist essentially of an impeller, mounted directly on the turbine shaft, producing an oil pressure proportional to the square of the turbine speed. This pressure actuates a relay controlling the steam supplied to the turbine. The impeller also serving as a pump supplies oil to the governing mechanism, the lubrication system and to an ejector that maintains a positive pressure in the impeller suction chamber to insure stable operation.

Tests were made on one of these turbines to investigate the performance of the hydraulic governor and determine the increase in speed, when full load is suddenly released. The results of this test presented in Table XXXIV show a maximum increase in speed of 7.7 per cent when a load of 43,500 kw. was released. Fig. 51 shows the turbine speed, and primary valve travel immediately after the load was dropped. The automatic stop is set to operate at 11 per cent overspeed.

The operation of the governors has been satisfactory.

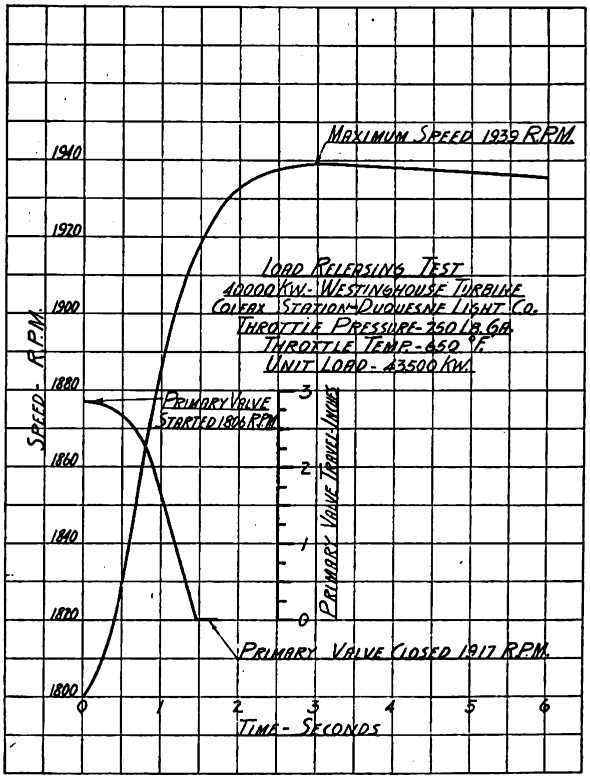

FIG. 51—TURBINE SPEED RISE AND PRIMARY VALVE TRAVEL AFTER FULL LOAD WAS RELEASED ON HYDRAULICALLY GOVERNED TURBINE—COLFAX STATION, DUQUESNE LIGHT CO.

TABLE XXXIV

SUMMARY OF DATA—LOAD RELEASING TEST 40,000-KW. WESTINGHOUSE TURBO-GENERATOR UNIT WITH HYDRAULIC TYPE OF GOVERNOR—COLFAX STATION.

1. Run No.	1	2	3
2. Net output, kw.	25,000	40,000	43,500
3. Steam pressure at throttle valve, lb. gage.	260	245	250
4. Steam pressure at primary valve, lb. gage.	217	227	236
5. Steam pressure at secondary valve, lb. gage.	75	185	233
6. Normal speed of unit, r.p.m.	1,800	1,800	1,800
7. Maximum speed of unit, r.p.m.	1,878	1,924	1,939
8. Increase in speed, r.p.m.	78	124	139
9. Increase in speed, %.	4.3	6.9	7.7

Emergency Auxiliary Power Supply

No. 3 unit at the Brunot Island Station of this company, as originally installed, consisted of a 3000 kw., 12,000 volt generator, driven by a Westinghouse combined impulse-reaction turbine, exhausting into a jet condenser.

During the year 1925 the unit was converted into a house unit to serve as an emergency source of power for the electrically driven station auxiliaries. The generator was rewound for 2300 volts, and the turbine blading changed, as shown in Fig. 52.

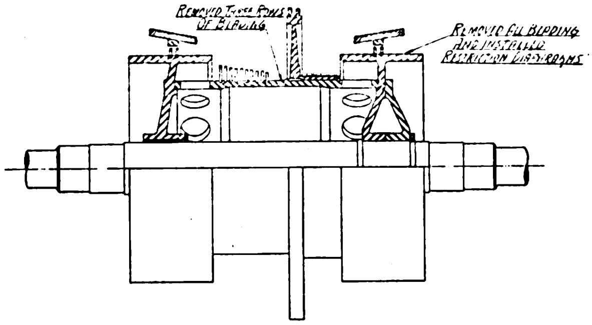
Removed Three Rows of Blading
Removed All Blading and Installed Restriction Diaphragms

FIG. 52—SPINDLE FOR 3000-KW. WESTINGHOUSE TURBINE CONVERTED INTO EMERGENCY HOUSE UNIT—BRUNOT ISLAND STATION, DUQUESNE LIGHT CO.

Water rate tests were made on the unit after the blading change, with and without the jet condenser in service. These tests show that the improvement in economy when operating condensing was not sufficient to warrant the use of the condenser. The condenser was removed, and the turbine exhaust connected to the auxiliary exhaust header to aid in maintaining the station heat balance.

When in service the unit either operates as an auxiliary generator, if exhaust steam is required, or it operates as a synchronous condenser. When operating as a synchronous condenser, a decrease in the auxiliary bus frequency will decrease the speed of the unit. The governor will respond, admitting steam to the turbine to maintain its speed, generating power for auxiliary use. When the load on the generator reaches 1600 kw., the 2300 volt bus is automatically separated from the 11,000 volt bus to prevent feed back. The auxiliaries are then supplied by this unit.

The power consumption of the unit when operating as a condenser is 300 kw.

When first placed in service, there was some doubt as to whether the turbine would heat up excessively when operating as a synchronous condenser, due to turbine windage. Readings taken at various points on the turbine casing showed a maximum temperature of 335 deg. fahr.

Due to the high steam consumption, the unit is operated only during abnormal station conditions, storms or when the station load reaches a value where the loss of the electrically driven auxiliaries would interrupt service.

STATEMENT BY THE KANSAS CITY POWER & LIGHT CO., KANSAS CITY, MO.

High Pressure Installation at North East Station

The 1200 lb. per sq. in. pressure turbo-generator installed at the North East Station is rated at 12,500 kv-a., 1800 r.p.m.

The complete installation will consist of one 12,500 kv-a., Westinghouse turbo-generator, two 16,950 sq. ft. Ladd boilers equipped with Elesco connection superheaters and shielded type radiant reheaters.

The turbine is of the Westinghouse parallel flow type, made up of a two velocity stage impulse element and about twenty rows of reaction blading. The turbine is designed to operate with throttle steam conditions at 1200 lb. per sq. in. gage pressure and 725 deg. fahr. total temperature. The pressure at the turbine exhaust is about 315 lb. per sq. in. gage. This unit, under complete control of the governor, can be contrasted with the high pressure units first operated when load was controlled by the boiler pressure.

Under the above steam conditions the unit will have a water rate varying from 45 lb. per kw-hr. to 34 lb. per kw-hr. at loads from 5000 to 10,000 kw., respectively. The exhaust steam from this unit will be reheated by a furnace type reheater to about 675 deg. fahr. for use in the main turbine operating at normal station pressure.

The design of this turbine is unique in many respects, departing radically from the standard type of unit. Particular attention has been given to the design, so the alignment of the unit will not be effected by expansion or by stresses applied by connecting high or low pressure piping.

The entire installation was designed and installed by engineers of the Kansas City Power & Light Co.

New Installation at Grand Avenue Station

This company recently acquired the 25 cycle generating plant of the Kansas City Street Railway Co., which contained boilers and generating equipment operated with steam at 185 lb. per sq. in. gage pressure and about 80 deg. fahr. superheat. Because the Street Railway Co. did not see fit to replace their substations with 60 cycle equipment that could be supplied with power from the present 60 cycle generating station, it became necessary to remodel the 25 cycle equipment. The fact that the 25 cycle system in all probability would not increase in size, and the further fact that this old station would be developed to contain ultimately around 150,000 kw. of modern 60 cycle generating equipment, did not warrant any extensive changes in the 25 cycle end of the plant.

In order to obtain a uniform high pressure boiler plant which would at the same time supply the low pressure 25 cycle units and the new 60 cycle units, it was decided to install at this time three 1500 h.p., 700 lb. per sq. in. gage pressure boilers and one 10,000 kw., 600 lb. per sq. in. gage non-condensing steam turbo-generator. This turbine will exhaust at 190 lb. per sq. in. gage and sufficient superheat to operate the required part of the present turbines and also to supply the necessary steam for a new connection to the present downtown heating system. All future 60 cycle units to be installed in this station will consist of 600 lb. per sq. in. gage condensing type units probably operating on a reheat cycle.

The turbine recently installed is a General Electric 12,000 kv-a. unit operating at 590 lb. per sq. in. gage and 740 deg. fahr. total temperature and exhausting into the present station header system at 190 lb. per sq. in. gage and approximately 100 deg. fahr. superheat. This turbine will have a water rate varying from 44 lb. per kw-hr. to 38 lb. per kw-hr. at loads from 5000 kw. to 10,000 kw., respectively.

Steam for operating this turbine will be supplied by three 15,000 sq. ft. Ladd boilers of a modified three drum Stirling design. Each boiler unit is designed for a normal evaporation of 150,000 lb. per hr. and a maximum evaporation of 225,000 lb. per hr.

The design of this station is being made by the Kansas City Power & Light Co., and the engineering and construction are being done by the United Light & Power Engineering and Construction Co.

STATEMENT BY THE MILWAUKEE ELECTRIC RAILWAY & LIGHT CO., MILWAUKEE, WIS.

Test of 7700 kw., 1200 lb. per sq. in. turbine

The second high pressure turbine at the Lakeside Station was placed in operation during January, 1929. This unit is rated at 7700 kw., which is 700 kw. higher than the first machine installed, because it operates with higher steam pressure and superheat. In all major respects it is identical with the first unit. Tests of the 7000 kw. unit are reported in the 1927 serial report on Higher Steam Pressures and Temperatures.

The unit was operated in compound with a 300 lb. per sq. in. pressure condensing turbine, both isolated from the remainder of the station. The condensate from the low pressure machines was weighed and corrected for condenser leakage, etc. Two three-hour tests were made on separate days. The unit was loaded at full capacity on all tests.

Possibility of high pressure extraction heater leakage was eliminated by using heaters on another recently installed condensing machine to heat feed water to the high pressure boiler. Other test details were similar to those reported for the tests of the 7000-kw. unit.

Test results in Table XXXV, show a water rate of 32.7 lb. per kw-hr. for the unit, with steam conditions at 1230 lb. per sq. in. gage, 750 deg. fahr. at throttle and 317 lb. per sq. in. gage at the exhaust. This corresponds to an efficiency ratio of 77.7 per cent computed on the electrical output basis. The efficiency ratio of the first machine was 75.5 per cent. The gain is principally the result of improved interstage leakage, though the blading is in better condition and low pressure seal leakage is slightly less.

The 77.7 per cent efficiency ratio compares favorably with that of large low pressure machines, showing that higher pressure stations are not handicapped by lowered turbine efficiencies.

STATEMENT BY THE PUBLIC SERVICE CO. OF COLORADO, DENVER, COLO.

This company, operating interconnected steam and hydro units, installed on the steam turbine an electric contact actuated by the throttle valve tripping mechanism so that it will trip the generator oil circuit breaker at the same time that the main throttle valve closes due to overspeed. This was done to prevent the hydro machine, when it loses its load, from motoring the steam-driven unit to a speed exceeding the desirable, 10 per cent, maximum for steam units.

Where hydro and steam plants operate on a system with long transmission lines, it is possible under some conditions for the hydro plant and the steam plant to be tied together at a time when the entire load is lost. The hydro machine, unable to reduce its speed at as fast a rate as the steam machine, will rise to a higher speed than is permitted for the steam unit.

STATEMENT BY THE UNION ELECTRIC LIGHT & POWER CO., ST. LOUIS, MO.

Frequency Regulator

A Leeds-Northrup frequency regulator was tried at Cahokia Station on the several main generators with the purpose of automatically controlling the system sixty cycle frequency over a narrower range than is possible with hand regulation. After correcting some minor deficiencies in the regulating instrument this has been accomplished. With hand regulation a range of 0.4 cycle (0.2 cycle too fast to 0.2 cycle too slow) is customary. Automatic regulation reduces this range to 0.1 cycle with a range of 0.05 being possible. The frequency record for both manual and automatic regulation is shown in Fig. 53.

This has been achieved, however, at the expense of a greatly increased fluctuation of load on the turbo-generator under regulation. Ordinarily the system regulation is cared for by regulation on one machine. Two machines have been placed under control of the regulator at one time, but even turbines of identical design do not parallel sufficiently well to maintain balanced loading. One or the other of the two units tends to take the greater portion of the load after a short period. With one 35,000 kw. unit controlling the frequency on the 60-cycle system, steam flow to the turbine has fluctuated from 240,000 to 340,000 lb. per hr., as often as eight times an hour. Single surges have changed the steam flow from 160,000 to 350,000 lb. per hr. and back to

TABLE XXXV.

SUMMARY OF TEST—7700-KW., 1200-LB. TURBINE AT LAKESIDE STATION.

1. Date	1/12/29
2. Generator output, kw	7,629
3. Steam pressure at throttle, lb. gage	1242
4. Steam pressure at first stage, lb. gage	1191
5. Steam pressure at exhaust, lb. gage	312
6. Steam temperature at throttle, °F.	740
7. Steam temperature at exhaust, °F.	448
8. High pressure seal leakage (1200 lb. - 300 lb.), lb. per hr.	1400
9. Low pressure seal leakage (300 lb. - atmosphere), lb. per hr.	2400
10. Steam supplied, lb. per hr.	250,360
11. Water rate (actual), lb. per kw-hr.	32.8
*12. Water rate (corrected), lb. per kw-hr.	32.7
**13. Efficiency ratio, %	77.7

*Corrected to 1230 lb. gage, 750 °F., 317 lb. gage.
**Electrical output, throttle pressure basis.

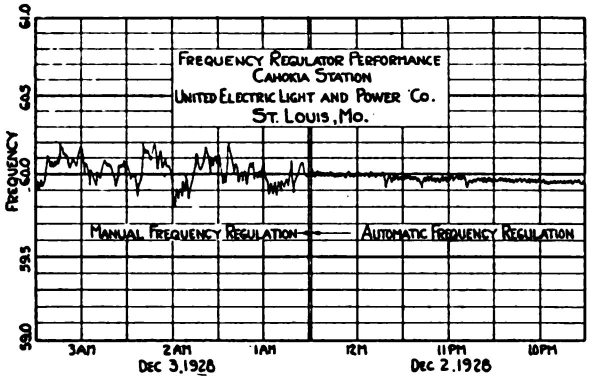

FIG. 53—FREQUENCY REGULATOR PERFORMANCE—CAHOKIA STATION, UNITED ELECTRIC LIGHT & POWER CO.

150,000 lb. per hr. in fifteen minutes. The steam flow record for one of the turbines when the frequency is controlled by manual and automatic regulation is shown in Fig. 54 and 55.

This wide variation is partly due to the fact that one unit is attempting to control the frequency for an electrical system which includes another steam plant. One 35,000-kw. unit is thus regulating a 60-cycle load of 210,000 kw. As governor characteristics differ on the various machines with two stations the problem cannot be readily solved by installing several regulators because of the tendency of one machine to take the entire load.

The wide fluctuation in turbine loading is not in line with desirable operation. It would cause undue strains on the blading because such a variation represents a wide range in load and in steam temperature, especially in the lower stages.

In addition to the effect on the turbine, the heat balance and auxiliaries are affected, especially units bleeding from more than one stage. Such a condition is encountered in connection with a 50,000-kw. unit, of which four stages are bled to heat feed water. Several of the adjustments on this heat balance system must be made by hand. These include adjustments to the boiler feed pump loads and the throttling of bleed line valves. As an example, steam extracted from the 12th stage is supplied to a deaerating

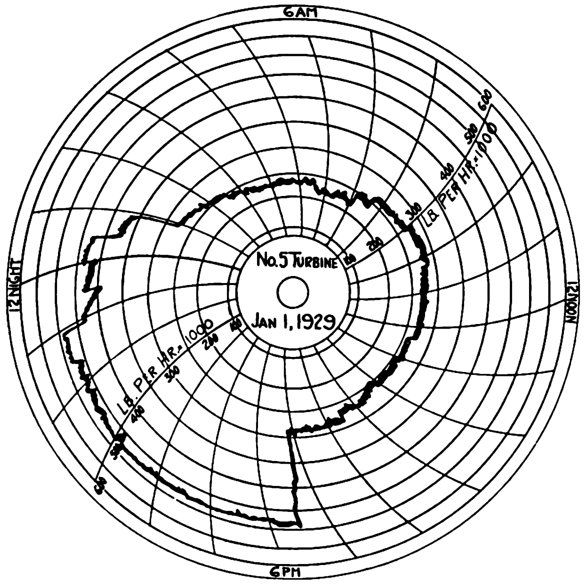

FIG. 54—STEAM FLOW TO TURBINE WITH MANUAL FREQUENCY REGULATION—CAHOKIA STATION, UNITED ELECTRIC LIGHT & POWER CO.

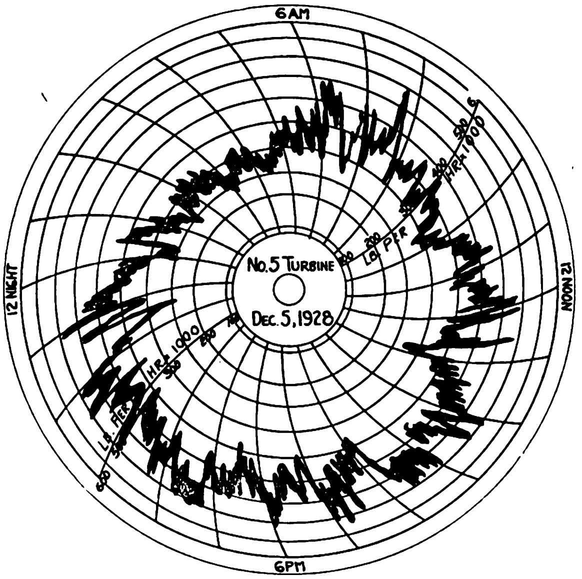

FIG. 55—STEAM FLOW TO TURBINE WITH AUTOMATIC FREQUENCY REGULATION—CAHOKIA STATION, UNITED ELECTRIC LIGHT & POWER CO.

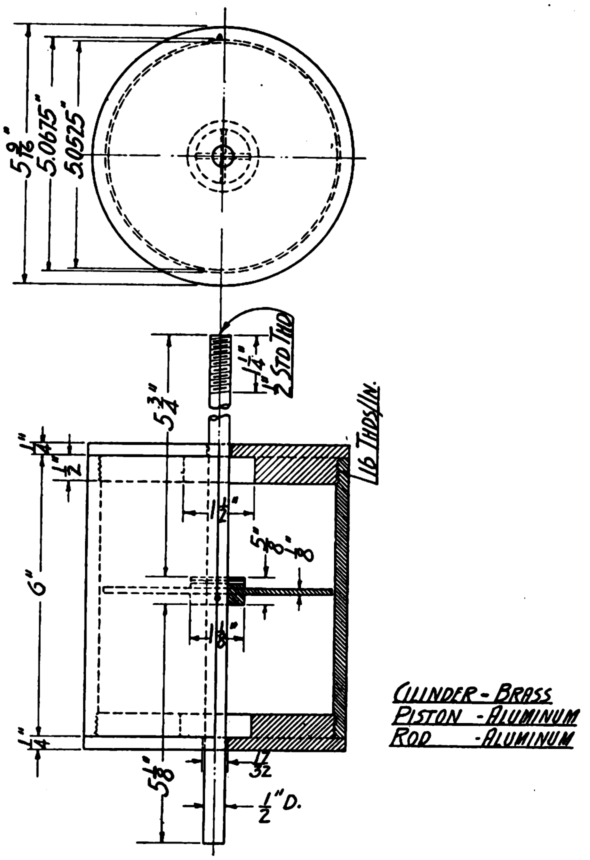

FIG. 56—DETAILS OF DASH POT INSTALLED ON TURBINE GOVERNORS—WEST END STATION, UNION GAS & ELECTRIC CO.

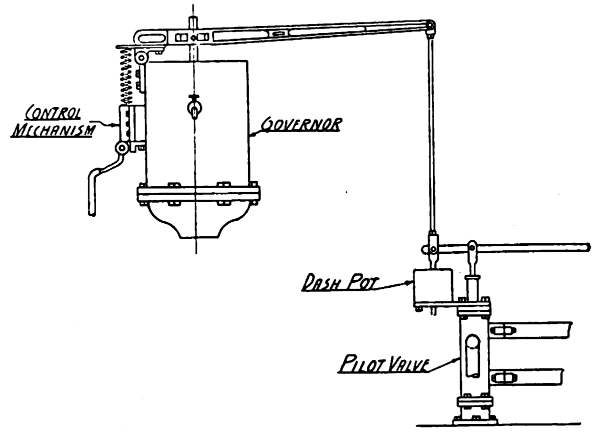

FIG. 57—DASH POT AS INSTALLED ON GOVERNOR LINKAGE—WEST END STATION, UNION GAS & ELECTRIC CO.

heater (steam to water contact). If the pressure is too high in this heater, water will not enter from the surge tank, and the boiler feed pump drains the heater, the pump becomes steam bound and the operation is interrupted. Consequently, the pressure of bleed steam to the heater must be controlled by hand throttling. With automatic frequency regulation the fluctuation in load and stage pressure is too rapid to permit reliable hand control of valves.

It may be concluded that in its present form the frequency regulator is not adaptable to Cahokia load conditions. The violent swings in load on individual units, and the inability of two units to parallel in regulation, cause fluctuation in turbine loads that would cause severe strains. On units with elaborate stage bleeding systems, the auxiliary operation is adversely affected.

STATEMENT BY THE UNION GAS & ELECTRIC CO., CINCINNATI, OHIO

Governor Dash-Pots

When the electrical tie connections between the three stations of the Columbia System were completed and put into operation it was found that system disturbances would in many cases start oscillations in the power output of the various generators. Under certain conditions, these oscillations would not dampen out, but would continue at a steady rate until checked by manual operation, which usually took the form of retarding the motion of the pilot valves on the governors.

It was observed on tests that a dash-pot installed in the governor linkage system would dampen the oscillations set up by system disturbances and would bring the turbines back to steady operation. The details of the dash-pots installed on the governors of the turbines at the West End Station are shown in Fig. 56 and the installation is shown in Fig. 57.

Since the installation of the dash-pots all the governors have been overhauled by the manufacturer in order to be certain that the regulation is correct. The governors of base load units have a regulation of 7 per cent at full load, while the governors on other units are set at 5 per cent. These governor settings have proven very satisfactory.

Changes Made in the Vertical Struts in Exhaust Casings

The exhaust casing of each turbine installed at the Columbia Power Station is designed with a vertical strut in the top and in the bottom half as shown in Fig. 58. The one face of the web strut was 11 in. from the leaving edge of the blades in the last stage and was 5 in. wide. It was believed that the blades were subjected to additional stresses as they pass the web faces, and that vibration could be set up which might result in blade failures.

In order to improve this condition, portions of the webs were cut away as shown in Fig. 58 and the clearance between the blade and the web faces increased to 20 in.

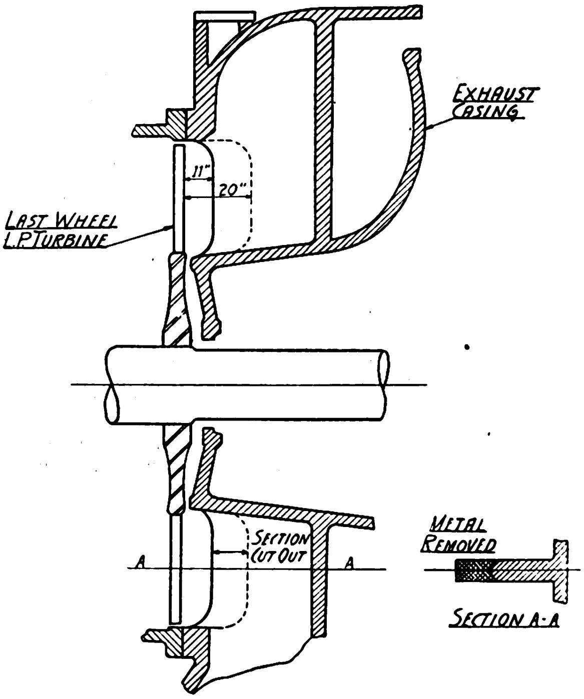

FIG. 58—SECTION OF VERTICAL STRUTS REMOVED FROM EXHAUST CASING—COLUMBIA STATION, UNION GAS & ELECTRIC CO.

MANUFACTURERS' STATEMENTS ON LARGE TURBINES

The Prime Movers Committee Does Not Accept Responsibility for Any Manufacturers' Statement

STATEMENT BY THE ALLIS-CHALMERS MANUFACTURING CO., MILWAUKEE, WIS.

To improve the steam turbine apparatus, this company observes the operation of its large turbines in the field studying the performance of the detail parts and the expansion movements of the machines under conditions encountered in service. This work is carried on with machines which are satisfactory in every respect and free from trouble. This is combined with a careful study of the operating and repair records of the machines, with the result that many of the essential details such as labyrinth packing, water seal, shaft glands, etc., were improved. The improvements, while of a minor nature, have contributed greatly to make the turbines reliable in operation, making them largely immune to difficulty in case of reasonably quick starting. This company found that making an engineering study of successful operating machines has enabled it to obtain a better insight into the operating problems.

Work is continued, perfecting the details of manufacturing processes on all parts of the turbine. Appreciable headway has been made in this company's plan of perfecting

TABLE XXXVI

SUMMARY OF TESTS—50,000-KW. ALLIS-CHALMERS TURBO-GENERATOR UNIT—STEAM EXTRACTED AT FOUR STAGES OF THE TURBINE.

1. Run No.	2	7	9	10
2. Date	8/24/27	8/30/27	8/31/27	9/2/27
3. Barometer, in. Hg	29.62	29.43	29.50	29.31
4. Net generator output, kw.	49,060	43,410	23,730	33,230
5. Steam pressure at throttle, lb. gage	586	619	615	630
6. Steam pressure at inlet, lb. gage	577	566	341	456
7. Steam pressure at secondary valve, lb. gage	435	352	307	286
8. Steam pressure at exhaust, in. Hg. abs	1.17	1.21	1.25	1.27
9. Steam temperature at throttle, °F	675	677	677	660
10. Steam temperature at exhaust, °F	82.6	83.7	85.0	85.7
11. Condensate from hotwell, lb. per hr	396,080	343,910	207,970	275,600
12. Total bleed steam, lb. per hr	78,640	62,830	38,140	52,790
13. Total steam to turbine, lb. per hr	474,720	406,740	246,110	328,390
14. Feed water temperature leaving high pressure heater, °F	261	260	263	263
15. Heat consumption of unit (actual), B.t.u. per kw-hr	10,680	10,330	11,420	10,760

the manufacture of the turbine shaft, so that it will be in approximate balance when completely assembled, and before any balancing is done.

The 50,000-kw., 1800-r.p.m. tandem compound turbo-generator unit installed in the Waukegan Station of the Public Service Co. of Northern Illinois, has now operated for approximately two years and has proven entirely satisfactory. This unit operates with 600 lb. per sq. in. gage steam pressure, 725 deg. fahr. total temperature and 29 in. of mercury vacuum. No troubles or delays were encountered in erection or subsequent starting of the unit. No balancing of either the turbine or generator rotors was necessary. The machine has operated without detectable vibration during its starting periods.

At the end of the first year of service the unit was opened for annual inspection. The interior of the turbine was found in good condition, and very little work was necessary other than the cleaning processes usual after a year's operation. Up to the time of this inspection the cylinder covers have not been lifted since the unit was assembled during erection.

The unit was started 48 times during its first year of operation. The longest time taken to bring it up to speed was 59 minutes, the shortest time 26 minutes. The average starting time for 44 starting periods was 48 minutes. For a period of approximately a month the unit was taken out of service daily.

Results of the test of the 50,000-kw. unit at Waukegan Station are shown in Table XXXVI. The economy was found better than guaranteed.

During the past year, two 30,000-kw. units were placed in operation. The first, for the Consumers Power Co., Jackson, Mich., operated with a steam pressure of 350 lb. per sq. in. gage at the turbine throttle, superheated to a total temperature of 700 deg. fahr. with 29 in. of mercury vacuum at the exhaust. The second unit, for the Oklahoma Gas & Electric Co., Harrah, Okla., operates with a steam pressure of 275 lb. per sq. in. gage at the turbine throttle, superheated to a total temperature of 700 deg. fahr. with 28.5 in. of mercury at the exhaust. Both of the above units are single flow with uni-directional double flow exhaust blading. The results of the test on the 30,000-kw. unit for the Consumers Power Co. also showed an economy better than guaranteed.

Three 15,000-kw. units were installed since the 1927 report. The first, for the Florida Public Service Co., Avon Park, Fla., operates with 400 lb. per sq. in. gage steam pressure at turbine throttle superheated to a total temperature of 715 deg. fahr. with 28.5 in. of mercury vacuum at the exhaust. The second, installed for the city of Pasadena, Cal., operates with the same steam pressure, but with a total steam temperature of 725 deg. fahr. and 28.0 in. of mercury vacuum at the exhaust. The third, for the Madison Gas & Electric Co., is to operate with a steam pressure of 205 lb. per sq. in. gage at the turbine throttle, 100 deg. fahr. superheat and 28.5 in. of mercury vacuum at the exhaust. The third unit is designed for future operation with 250 lb. per sq. in. gage steam pressure and a total steam temperature of 650 deg. fahr. The design of these units is shown in Fig. 59. The first two units have been operating successfully for some time. The erection of the third unit is completed and will be placed in service in the near future.

This company has under construction a 20,000-kw. unit for Riverside Power Manufacturing Co., Davenport, Iowa. This unit will operate with 400 lb. per sq. in. gage steam pressure with a steam heat content of 1362 B.t.u. per lb., vacuum at turbine exhaust nozzle 28.5-29.0 in. of mercury. This unit is scheduled to be in operation in the early fall of this year.

STATEMENT BY THE AMERICAN BROWN BOVERI ELECTRIC CORP., CAMDEN, N. J.

The 160,000-kw. cross-compound turbo-generator unit installed at the Hell Gate Station of the United Electric Light & Power Co., was placed in operation during the latter part of 1928.

This company has a turbine under construction, designed

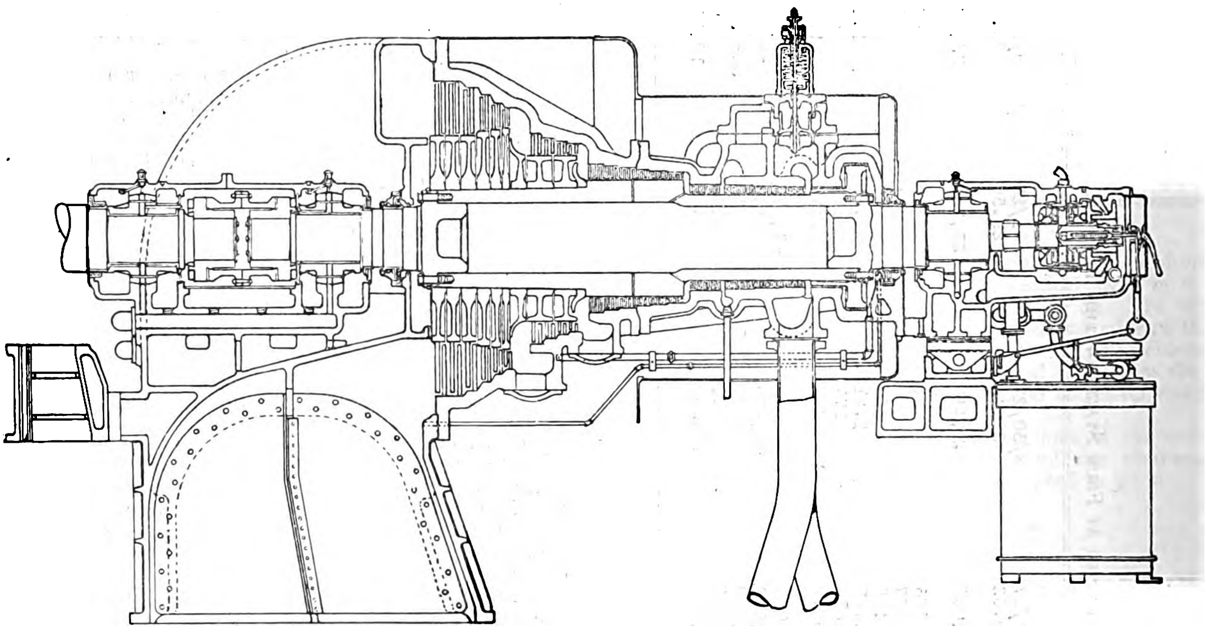

FIG. 59—CROSS-SECTION OF 15,000-KW., 1800-R.P.M. TURBINE—ALLIS-CHALMERS MFG. CO.

to operate with throttle steam conditions of 1400 lb. per sq. in. gage pressure, and 700 deg. fahr. total temperature, exhausting at a back pressure of 360 lb. per sq. in. gage. This unit is rated at 3700 kw., at 3600 r.p.m.

STATEMENT BY THE GENERAL ELECTRIC CO., SCHENECTADY, N. Y.

Steam turbine development during the past two years followed two major trends, one toward units of larger capacity and the other toward the extensive use of 1200 lb. per sq. in. pressure.

The trend toward larger units is clearly indicated by Fig. 60, which shows the maximum rating of different types of steam turbines manufactured by this company. The relatively recent compound units increased in capacity to 208,000 kw. and the tandem compound units, with double flow exhaust having a single shaft and driving a single generator, increased in size to 160,000 kw. While Fig. 60 shows only the units of maximum rating, an analysis of all units on order show a progressive movement toward turbines of larger average unit capacity.

The trend toward higher pressure is indicated by the selection, after exhaustive calculations, of 1200 lb. per sq. in. as the most economical turbine pressure for the new stations at Deepwater, N. J., and at Holland, N. J. The generating equipment at the Deepwater Plant, the first station to be designed for 1200 lb., will consist of a 12,500-kw. high back pressure unit and two 53,000-kw. cross-compound condensing units. The unit for the Holland Station is of the cross-compound, condensing type rated at 55,000-kw. capacity. Turbines with a total capacity in excess of 300,000 kw. manufactured by this company have been shipped or are on order, and there is every indication that the use of 1200 lb. per sq. in. pressure will continue to increase.

The 208,000-kw., triple cross-compound turbine for the State Line Generating Co. has been shipped and will soon be in operation.

The 165,000-kw., triple compound set is in service in the Philo Station of the Ohio Power Co.

Fig. 61 shows the ventilating housing of the 160,000-kw., 1500-r.p.m., 11,400-volt generator for the large tandem compound turbine which has been shipped to the East River Station of the New York Edison Co. The turbine is of tandem compound construction with double flow in the low pressure end and is designed for 375 lb. per sq. in. gage and 700 deg. fahr.

Fig. 62 shows the stator frame of welded steel plate construction. The rocking trunnions facilitate tipping the frame

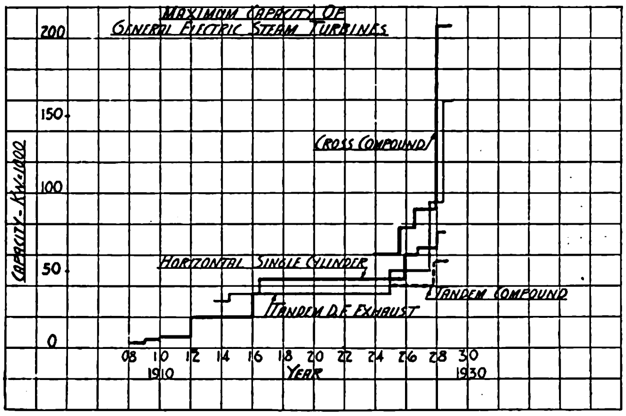

FIG. 60—MAXIMUM RATING OF GENERAL ELECTRIC STEAM TURBINES—GENERAL ELECTRIC CO.

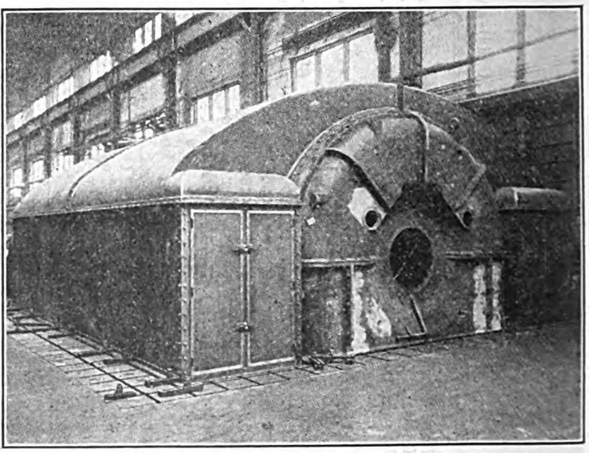

FIG. 61—VENTILATING HOUSING FOR 160,000-KW. GENERATOR—GENERAL ELECTRIC CO.

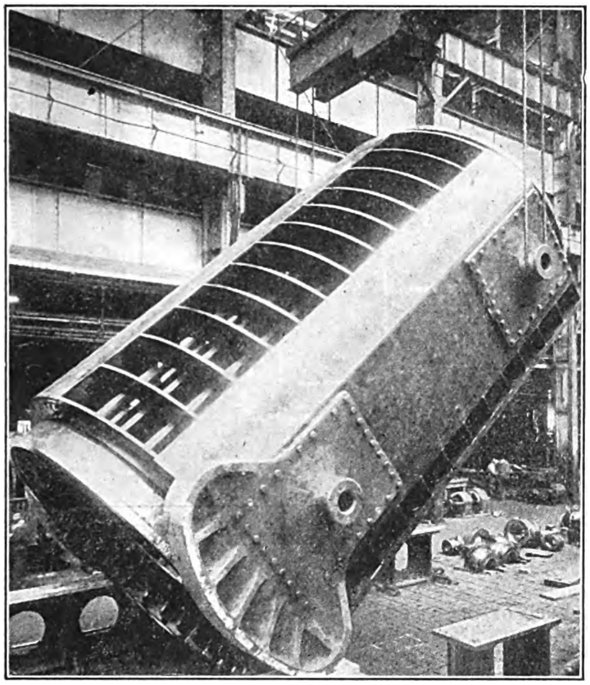

FIG. 62—WELDED STATOR FRAME FOR 160,000-KW. GENERATOR—GENERAL ELECTRIC CO.

on end. An unusual feature in the construction of this generator is the stator winding. It is composed of two separate windings which are identical in all respects, but are electrically independent so that the capacity of each is 80,000 kw. The two sets of windings are connected through two generator breakers to adjacent bus sections thereby affording the following advantages:

1. The possibility of obtaining half load from one of the windings without regard to the other half.
2. The reduction in generator circuit breaker capacity by the use of two generator circuit breakers.
3. The elimination of bus reactors made possible by the transfer of power taking place through the coupling effect of the two separate windings.
4. The increased stability obtained by omitting the bus reactors.

The 94,000-kw. unit of the Southern California Edison Co. is shown partially installed in Fig. 63. The operation of this unit has been very satisfactory since installation, and it has carried maximum load practically continuously except for 3 or 4 hours at night. The generator is the largest now operating and was the first to be wound for 16,500 volts. It is rated 90,000 kw., 100,000 kv-a., 50 cycle, 1500 r.p.m. The stator has a frame of welded steel plate construction and was assembled, wound and tested at the factory and shipped complete.

The largest 1800 r.p.m. single-cylinder turbine under construction is a 75,000-kw., 17 stage unit for the Cahokia Station at St. Louis. It is designed for steam pressure of 315 lb. and 725 deg. fahr. total temperature. The unit has four bleed points and will supply feed water heating for a total of 110,000-kw. capacity. It will occupy no more space than now occupied by a 35,000-kw. unit.

A 75,000-kw., 1500-r.p.m., single-cylinder turbine was recently installed in the Huntley Station of the Buffalo General Electric Co. The steam conditions are 250 lb. per sq. in. and 660 deg. fahr.

Fig. 64 shows the 65,000-kw., 1800-r.p.m. unit in the Edgar Station of the Edison Electric Illuminating Co., Boston, described in the statement by this company in the 1927 report. This unit was one of the first to be equipped with a service generator, which is shown clearly in the photograph.

A 55,000-kw. tandem-compound single-flow reheat turbine is operating in the Pekin Station of the Super Power Co. of Illinois and a duplicate unit is on order. The generators of these machines were the first to be wound for 22,000 volts.

Three more 50,000-kw., 1500-r.p.m. turbines have been shipped to the Detroit Edison Co., who now have six units

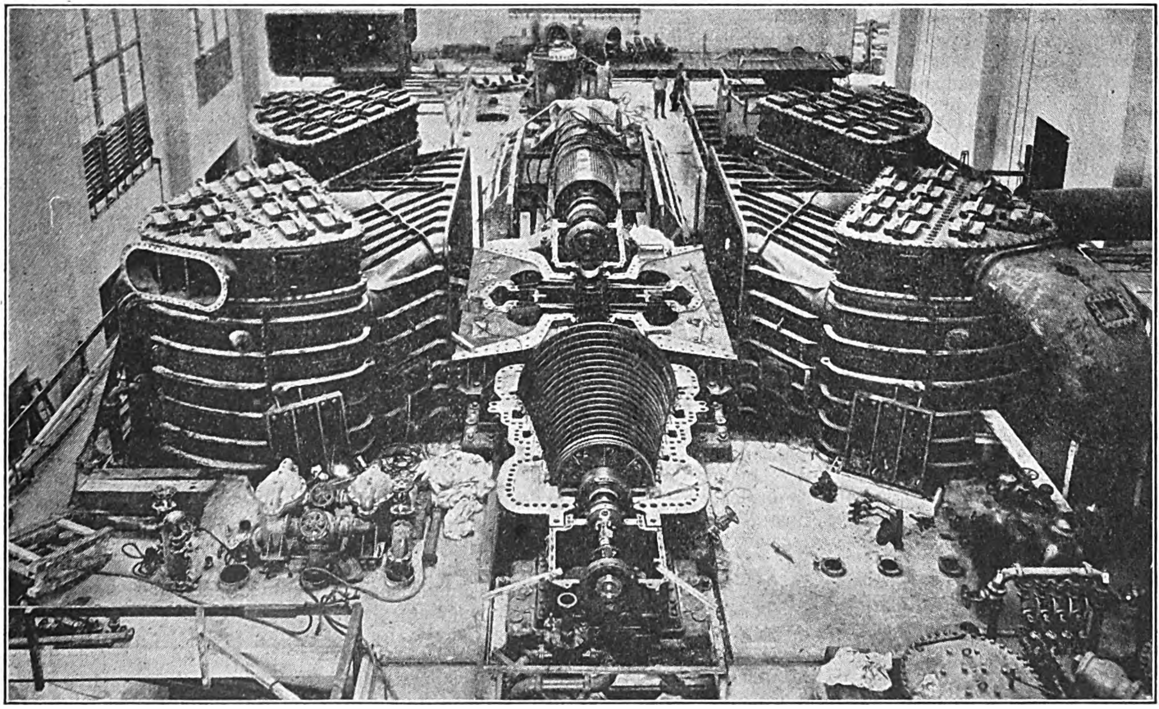

FIG. 63—94,000-KW. TURBO-GENERATOR PARTLY INSTALLED IN LONG BEACH STATION NO. 3 OF SOUTHERN CALIFORNIA EDISON CO.—GENERAL ELECTRIC CO.

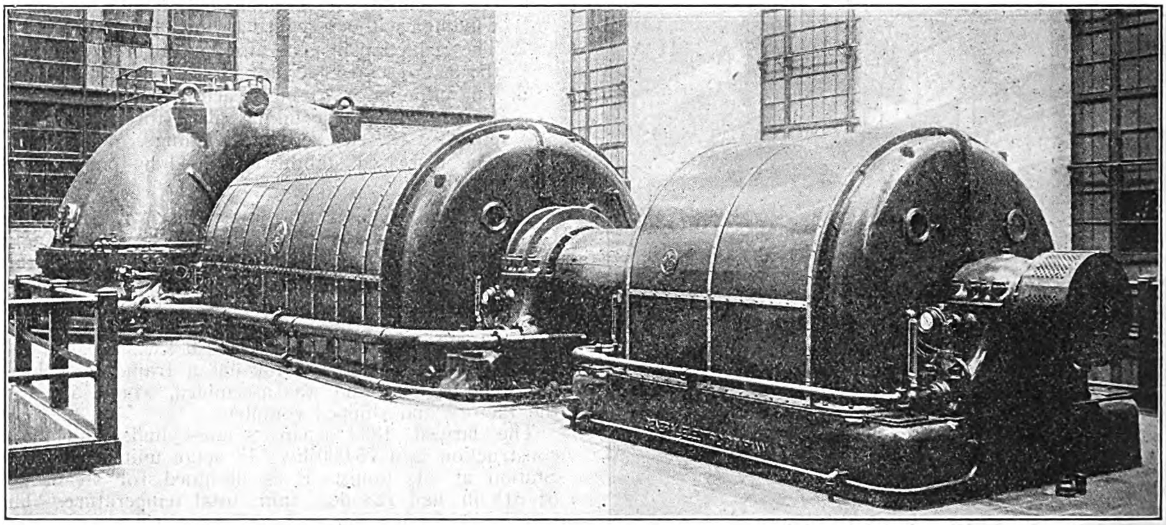

FIG. 64—65,000-kw., 1800-r.p.m. Turbine in Edgar Station of Edison Electric Illuminating Co.—General Electric Co.

of this type in their Trenton Channel Station and two in their Delray Station.

During the past two years the use of generator surface air coolers has increased to such an extent that practically all turbo-generators of 1000-kw. capacity and larger are now equipped with air coolers. This company has in operation surface air coolers serving more than 8,000,000 kw. of turbo-generator capacity.

The mercury vapor plant equipment installed in the South Meadow Station at Hartford, Conn., was put into commercial service during October, 1928, and operated in the most satisfactory manner. The first runs have indicated the desirability of certain modifications that will require a few weeks, meanwhile it should be appreciated that no fundamental changes are involved, but merely minor adjustments. The preliminary results indicate that the fuel economy of the process is better than predicted because of a high mercury turbine efficiency.

Research work is being carried on today as intensively as at any time in the past in order that this company may continue to meet the demands of the industry. This company has been able to design new units with every confidence that the expected efficiency and performance would be realized. That this expectation is well founded is proved by the results of complete turbo-generator tests that have been made during the past two years on a large number of representative turbines of different ratings that thoroughly cover the range in capacity. It is significant that machines tested, more than met their guarantees.

Statement by the Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

Turbo-Generator Development

During the year 1928 eight large turbo-generator units, manufactured by this company, were placed in service. The capacities of these units range from 15,000 kw. to 110,000 kw., representing a total of 397,000 kw. During the same period eleven units of 15,000-kw. capacity or larger, totaling 414,000 kw., were sold. Two of these are already installed and are included in the number in service as reported above.

Among the units which were placed in service during the year the following are worthy of special note:

104,000-kw. unit in the Crawford Avenue Station of the Commonwealth Edison Co.
60,000-kw. unit in the Lakeside Station of the Milwaukee Electric Railway & Light Co.
110,000-kw. unit in the Hudson Avenue Station of the Brooklyn Edison Co.

Each of these large units passed the preliminary stage in operation. They were placed in commercial operation without troubles of any consequence and are showing excellent performance. The designs of these units were covered in this company's statement of the 1927 report.

A test, made by the Milwaukee Electric Railway & Light Co. on the 60,000-kw. unit showed results approximately 1½ per cent better than the guaranteed performance.

Three units were inspected in which it was found the blade rings had moved excessively in the cylinders. Steps were taken to avoid any recurrence. The supports were altered and dowels provided so as to allow only radial movement of the rings with respect to the rotor.

Vibration troubles have not presented any entirely new problems and, by continuing our investigations along the same lines as reported for preceding years, very gratifying results have been obtained. It is interesting to note that of the eleven large spindles which were placed in service during the year, only one required any considerable amount of field balancing.

There have been no developments to indicate the necessity or desirability of any decided change in our standard blading practice. Consequently, our position on this subject remains unchanged. The sources of supply of stainless steel material are now adequate and the manufacturing processes for working this material have been developed so that stainless steel blades can now be produced in any quantities desired.

In the 1927 report this company referred to the oil operated governors on the 40,000-kw. units at the Colfax Station of the Duquesne Light Co. as the first governors of this type to be applied to large, central station units. During the past year two additional units, namely, the 104,000-kw. unit at Crawford Avenue and the 65,000-kw. unit at Lakeside, were placed in operation and the oil-operated governors are performing as satisfactorily as those on the Colfax units. The governor on the unit at Lakeside is greatly simplified and the desirability of this oil-operated type for large central station units is now established beyond question.

A new turbine was developed that operates at 3600 r.p.m. and bears a nominal rating of 10,000 kw. This is a single-cylinder, single-flow, complete expansion unit of the combination impulse and reaction type.

Four openings are provided in the cylinder, at different pressure stages, for extracting steam to heat feed water.

The cylinder consists of a base and cover, bolted together in the horizontal plane of the centerline, each being made in two parts joined by a vertical flange. The high pressure section is made of cast steel while the low pressure section is of cast iron. The vertical joint is made up permanently during the erection and, thereafter, the base and cover each can be handled as a single piece.

The cylinder is supported and anchored to the foundation at the low pressure end by two feet, one on each side of the exhaust chamber. These feet are bolted to the cylinder proper and can be removed to facilitate handling during shipment and erection.

The thrust or high pressure end is supported on an I-beam section which is placed transversely so that the elasticity of the web allows free movement axially to take care of expansion and contraction of the cylinder parts.

The rotor consists of a solid nickel steel forging. The use of this material allows higher working stresses and consequently reduces the length of the rotor considerably. The turbine rotor is coupled directly to the generator rotor by means of a solid flanged coupling and only three main bearings are used for the complete turbo-generator unit.

A dummy or balance piston is provided to counterbalance the major part of the axial thrust which results from the pressure drop across the reaction blading. The remainder of the thrust is carried by a thrust bearing of the standard Kingsbury type. This thrust bearing includes a worm and wheel adjusting feature similar to that provided on the 1800 r.p.m. machines, by means of which the rotor can be moved axially to obtain correct setting without dismantling any turbine parts.

The steam chest is mounted on top of the cylinder cover and carries four valves which control the flow of steam to the nozzles. The valves are operated by a standard oil-operated governor of the same design as has been used on the 3600 r.p.m. turbines during the past five years. The throttle valve is of the oil-operated, quick-closing type. Other features, such as the main bearings, overspeed automatic trip, glands, etc., are of standard design according to past practice.

MANUFACTURERS' STATEMENTS ON SMALL TURBINES FOR AUXILIARY DRIVE

Statement by the Allis-Chalmers Manufacturing Co., Milwaukee, Wis.

The Allis-Chalmers 3600 r.p.m. steam turbine is designed primarily for service as a prime mover in smaller and isolated power stations. The design is similar in general detail to that used for large central station machines. This company has not developed what might be termed an "industrial type of turbine" for sizes larger than 750 kw.

Auxiliary steam turbines and generators for large steam power plants are supplied by this company from a standard type of 3600 r.p.m. turbines. In general, the capacity of these machines varies from 2500 kw. to 6000 kw. for use with steam pressures up to 350 lb. per sq. in. gage and 400 lb. per sq. in. gage; and in capacities from 6000 kw. to 10,000 kw. for steam pressures up to 500 lb. per sq. in. gage.

There are available machines at 3600 r.p.m. of the non-condensing and high back pressure type designed for high efficiencies. These have shown remarkably good operating efficiencies and great reliability.

Fig. 65 shows the similarity between 6000-kw., 3600-r.p.m unit and the large central station 20,000-kw., 1800-r.p.m. unit. The single-cylinder construction is used with small diameter at inlet where the pressure and temperature are high and with an ample exhaust casing in which is provided a rigid support for the bearing and coupling structure between the turbine and generator. Such machines have had excellent operating records with the minimum repairs, with the greatest blading reliability. The larger unit in Fig. 65 is rated at 20,000 kw., operating with steam at 400 lb. per sq. in. gage pressure.

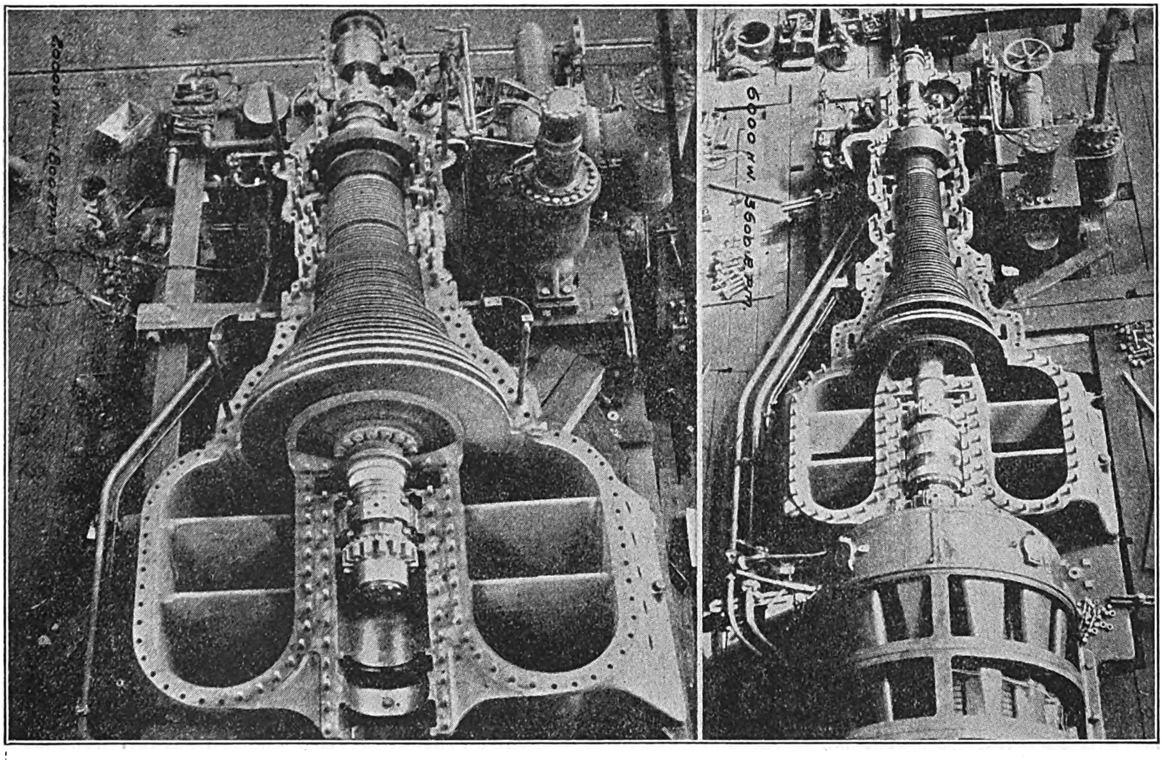

FIG. 65—6000-KW., 3600-R.P.M. AND 20,000-KW., 1800-R.P.M. TURBINES, SHOW SIMILAR CONSTRUCTION—ALLIS-CHALMERS MFG. CO.

STATEMENT BY THE DE LAVAL STEAM TURBINE CO., TRENTON, N. J.

This company is engaged in the development of turbines for auxiliary drives operating at high steam temperatures and pressures.

The principal departure from other types of turbines, for this class of service, is that the steam chest is placed in the cover of the turbine instead of in the lower half. This particular feature has proved very valuable in high pressure, high temperature steam plants as it eliminates the need for water cooling and permits the use of ring oiled bearings. This is a feature that cannot be satisfactorily accomplished when the steam chest is placed below the center line of the shaft.

This company has made particular efforts to locate all valve parts or other parts requiring adjustment above the center line of the turbine, where they are in open view of the operator and are consequently much more liable to receive attention than when these parts are inaccessibly located.

The regulating valve and the trip valve are entirely separate, but the housing for both valves is cast integral with the steam chest. This eliminates a number of joints that would exist if separate valve bodies were used.

The support of the turbine has also been located near the center line so that sudden changes in temperature will not affect the alignment. This is particularly important in turbines operating at high temperatures.

The auxiliary turbines can be furnished with steel casings. Fig. 66 illustrates a standard turbine of this type direct connected to a 950 gal. per min., 800 lb. per sq. in. boiler feed pump. The turbines are provided with large internal clearances.

A turbine driven circulating pump is shown in Fig. 67. This turbine is designed to operate with steam at high pressure and temperature.

Several direct current, geared, generating units of capacities as high as 6000 kw. were placed in operation during the past year. These units are of the compound geared type and of a construction similar to that used on the house turbines in the Trenton Channel plant of the Detroit Edison Co.

With high temperatures and superheats, the use of the compound turbine is very desirable as the high pressure, high temperature steam can be confined in a relatively small, steel turbine casing.

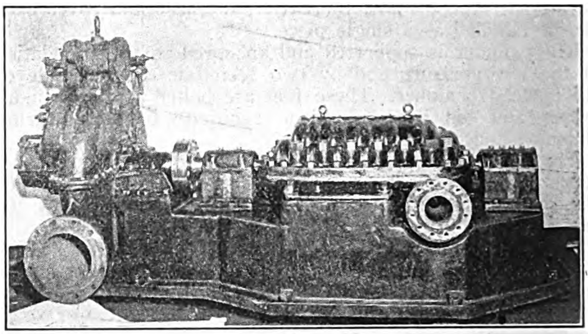

FIG. 66—STEAM TURBINE, DIRECT CONNECTED TO 950-G.P.M., 800-LB. BOILER FEED PUMP—DE LAVAL STEAM TURBINE CO.

STATEMENT BY THE GENERAL ELECTRIC CO., SCHENECTADY, N. Y.

Small turbines are used for auxiliary drive as well as motors supplied with current by low voltage generators coupled to the shaft of the main unit. The difference in overall economy between one system and the other, taking into consideration the fixed charges, as well as the thermal economies, is so small that the final decision as to which system should be used can be made for one or the other depending upon the particular cycle employed or the assumptions made.

Since the statement in the 1927 report this company shipped three 2500 kw. and one 4000 kw. quick starting turbo-generators that are used as standby units for the service generator connected to the main unit. These turbines are non-condensing and are arranged to come to full speed and full voltage from a cold stationary start in a period of

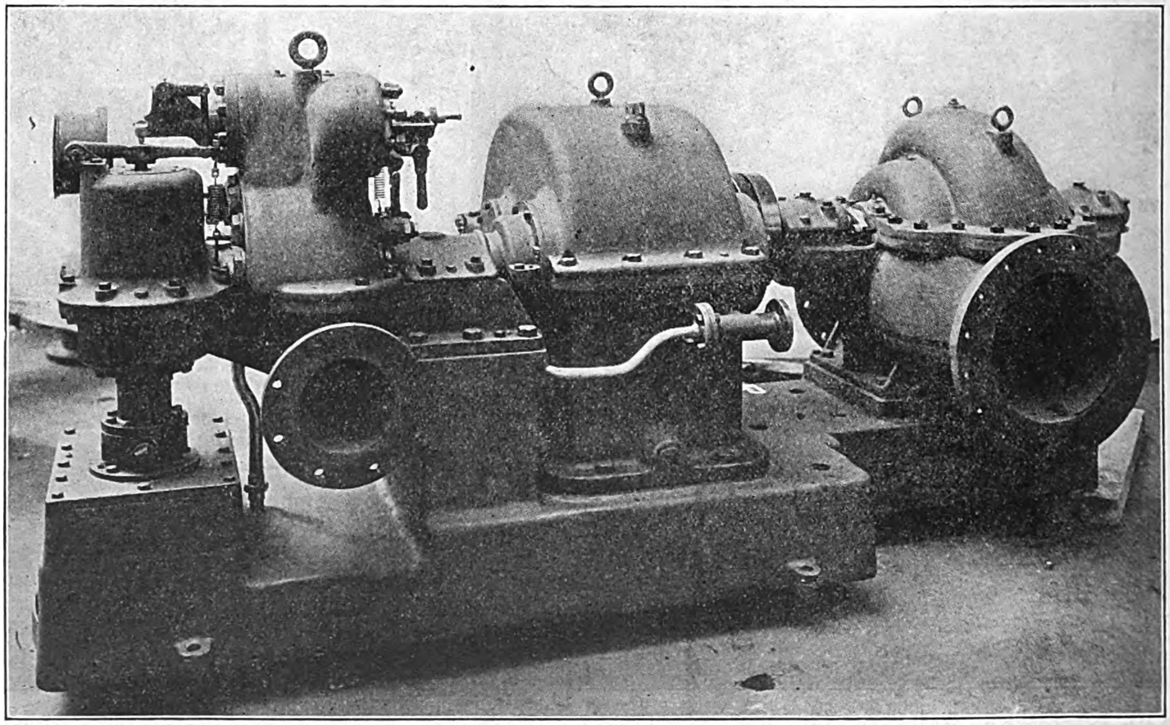

FIG. 67—GEARED TURBINE DRIVING CIRCULATING PUMP—DE LAVAL STEAM TURBINE CO.

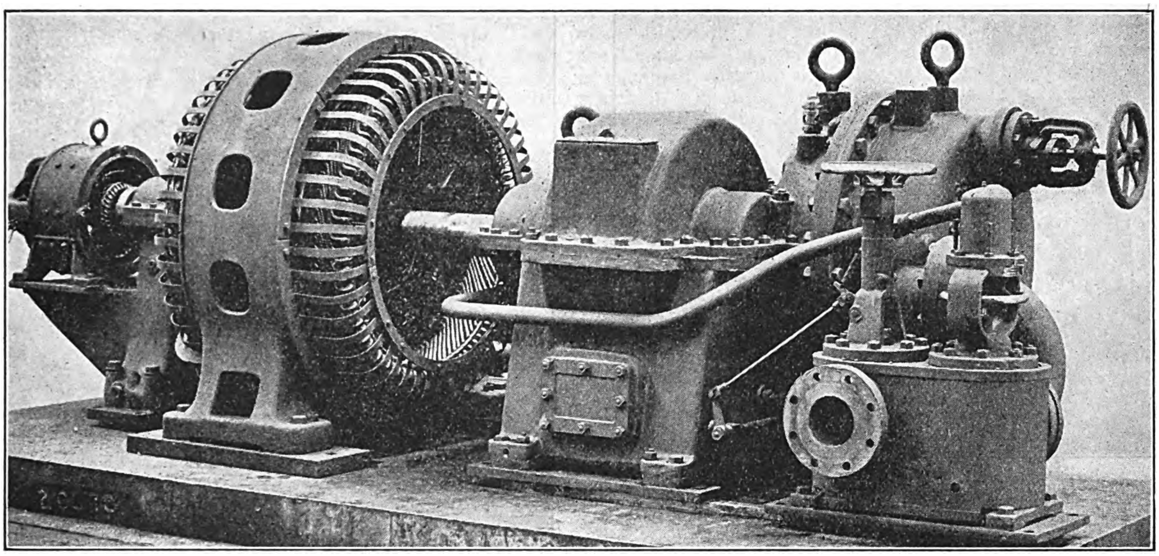

FIG. 68—HIGH-SPEED, GEARED, SINGLE-WHEEL, IMPULSE, REENTRY TYPE TURBINE—WESTINGHOUSE ELECTRIC & MFG. CO.

less than 15 seconds. The turbines can also operate as synchronous condensers, ready to pick up the auxiliary load as soon as the frequency on the system falls below a predetermined value.

Low voltage generators coupled to the shaft of the main unit for driving station auxiliaries are used in a large number of present day plants. This keeps the operation of the station auxiliaries quite separate from the main transmission system and the effective size of the main generator is not reduced, as is the case when the auxiliaries are driven from the main generator. The service generator can be installed without increasing building dimensions, since the space required for drawing the field of the main generator is always longer than the house service generator with its exciter.

STATEMENT BY THE MOORE STEAM TURBINE CORP., WELLSVILLE, N. Y.

This company is prepared to build turbines in capacities from 100 kw. to 2000 kw. with bleed connections at several stages of the turbine for use with stage water heating. These turbines, operating on a highly efficient cycle, may be arranged to use either high pressure or low pressure steam or both and generate power in proportion to the water heating requirements.

These turbines offer a means of increasing the thermal efficiency of stations not fully equipped for stage bleeding of the main units. In some new installations they deserve consideration as a possible alternate to bleeding of the main turbines because of the lower cost and favorable cycle efficiency. Control devices can be furnished to suit conditions.

This company has turbines with integral, helical reduction gears to drive slow speed apparatus and can equip these drives with hydraulic type, variable speed governors if so desired. The standard reduction gears have also been extended to cover the full range of turbine capacities.

Variable speed governors of the hydraulic type can be applied to any turbines when desired, giving a speed range up to about 10:1.

An auxiliary drive unit of a type suitable for use with stokers is built by this company. It consists of a turbine and worm gear combined, having a wide range, variable speed hydraulic governor.

The efficiency of the smaller multi-stage turbines of this company has been greatly improved during the past two years. Much better economy is obtainable by using multi-stage turbines rather than single stage turbines for driving auxiliaries of the boiler feed and circulating pump type.

STATEMENT BY THE TERRY STEAM TURBINE CO., HARTFORD, CONN.

During the past year, no radical changes were made in the design of the steam turbines and reduction gears. The efforts have been directed mainly toward increasing the efficiency of both the single stage and multi-stage turbines and now machines are available that have a lower steam consumption.

Turbines are also built for auxiliaries requiring special drives. A number of turbines of this type are equipped with new and improved governors. In some cases the governors are of the variable speed design, suitable for a speed range of 1 to 10. Provision can be made to control these variable speed machines from some remote point.

STATEMENT BY THE WESTINGHOUSE ELECTRIC & MANUFACTURING CO., EAST PITTSBURGH, PA.

The standard turbines for auxiliary drives can be divided for convenience of description into two types or groups, both of which embody unusual features of simplicity and reliability.

High Speed, Non-Condensing Type

This unit consists of a single wheel, impulse reentry type turbine which is connected to the driven apparatus by a reduction gear. It is built in sizes ranging in capacity from 35 kw. to 500 kw. The normal turbine speeds range from 5000 r.p.m. to 8400 r.p.m. thus realizing the inherent advantages of high speed turbines such as better economy, less floor space requirements and less weight per h.p. developed. Reduction gears are available with ratios to give speeds of the driven apparatus ranging from 750 r.p.m. to 1500 r.p.m.

Fig. 68 and 69 illustrate this unit. The turbine rotor is overhung on the end of the pinion shaft and the turbine and gear form a compact self-contained unit. The cylinder is of unusual construction in that it is split vertically in a plane normal to its centerline, the outer part being a single casting bolted to a machined surface on the ends of the upper and lower halves of the gear case. Other important features in this design include: centrifugal impeller type oil governor of the same reliability as those furnished on large turbines, rotor restraining feature by virtue of which the rotor cannot rupture the casing in case of accidental extreme overspeeding, self contained ejector lubricating system with ejector motive oil supplied by the impeller mounted on the pinion shaft similar to the systems used on the large turbines, external oil cooler and duplex strainer, standard automatic stop governor and automatic quick closing type throttle valve.

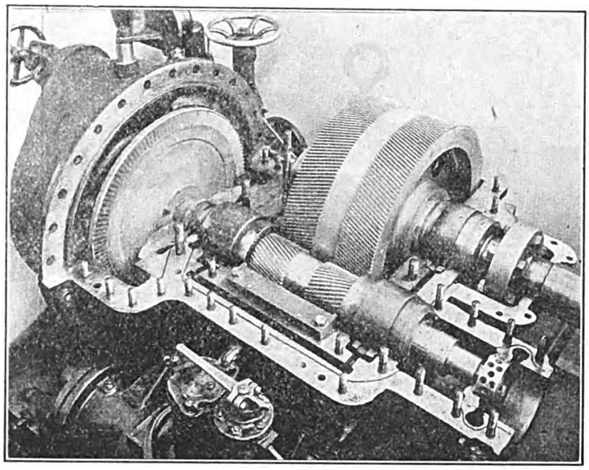

FIG. 69—HIGH-SPEED, GEARED, AUXILIARY TURBINE WITH COVER REMOVED—WESTINGHOUSE ELECTRIC & MFG. CO.

Mechanical Drive Type

The so-called "Mechanical Drive" unit designed primarily as a drive for pumps, fans, etc., consists of a single wheel, impulse, re-entry type turbine which has two bearings and, therefore, constitutes a complete unit. It can be connected to the driven apparatus either directly or through a reduction gear, the method being determined by the class of service. This type is built in sizes ranging in capacity up to 1400 h.p. The normal turbine speeds range from 800 r.p.m. to 4500 r.p.m. and when used with a reduction gear, speeds of 250 r.p.m. to 1500 r.p.m. can be obtained for the driven apparatus.

Fig. 70, 71 and 72 show shop views and a longitudinal section of this turbine. The cylinder base is supported in a cradle-like soleplate in such a manner that it hangs suspended at approximately the center of the turbine shaft. This construction allows the cylinder to expand vertically in either direction from the centerline and eliminates the possibility of this expansion causing any misalignment of the rotating shafts. Other features in this design include: ring-oiled bearings, horizontal weight centrifugal governor, water sealed glands and automatic stop governor.

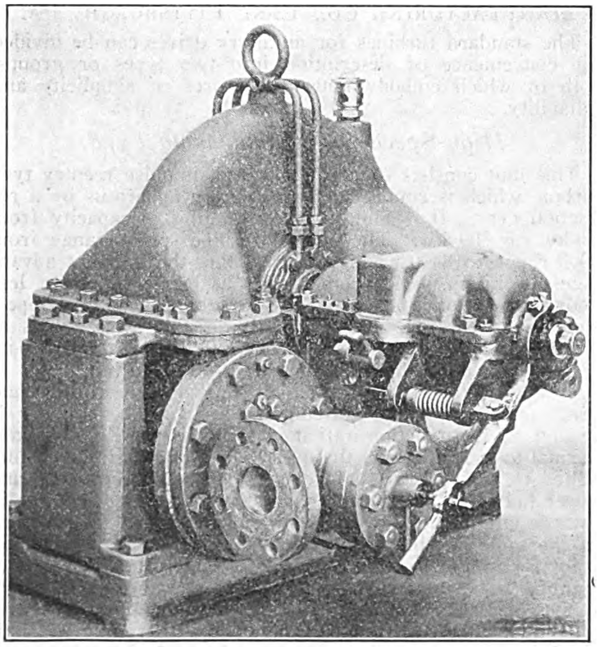

FIG. 70—SINGLE-WHEEL, IMPULSE, REENTRY TYPE TURBINE—WESTINGHOUSE ELECTRIC & MFG. CO.

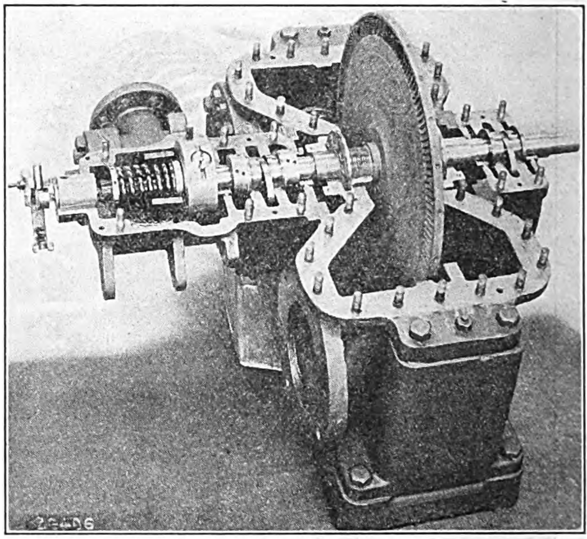

FIG. 71—SINGLE-WHEEL, IMPULSE, REENTRY TYPE TURBINE WITH COVER REMOVED—WESTINGHOUSE ELECTRIC & MFG. CO.

The units described above are built for standard central station pressures and, for special applications, can be designed for higher steam conditions. One application of the mechanical drive type operates with inlet steam at 800 lb. per sq. in. gage pressure and discharges against 150 lb. per sq. in. gage exhaust pressure.

Either type is equally well adapted to dual driven sets and many such applications are now in service. When used for this purpose, it is not necessary to bleed steam through the turbine for cooling as was previously the practice. The governor regulation is such that with proper adjustment the turbine will pick up the load, if the motor speed drops 2 per cent below normal. Also by either manual or automatic control, the turbine speed can be regulated to carry any portion of the load in order to maintain the desired heat balance of the plant.

Another unit which is rapidly gaining popularity as a

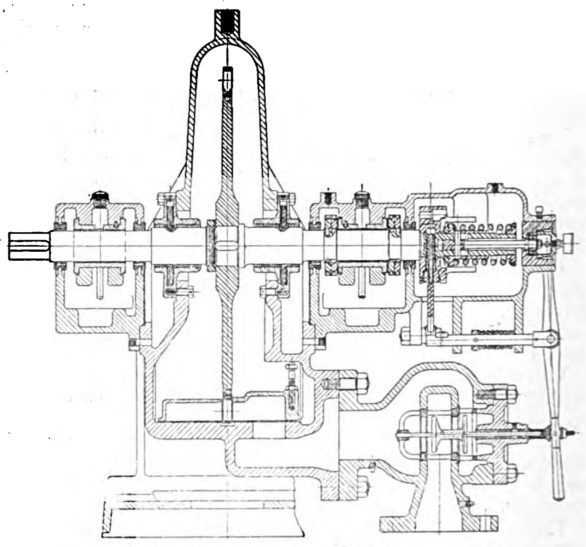

FIG. 72—CROSS-SECTION OF SINGLE-WHEEL, IMPULSE, REENTRY TYPE TURBINE—WESTINGHOUSE ELECTRIC & MFG. CO.

house generator drive consists of a single wheel, impulse re-entry type turbine directly connected to a generator. The normal operating speed is 3600 r.p.m. and it is built in sizes ranging in capacity from 500 kw. to 2000 kw. Due to its extremely sturdy construction, this unit is particularly well adapted to emergency service. In such cases it is either floated on the line or provided with means for unusually quick starting. One unit of 2000 kw. capacity installed at the Richmond Station of the Philadelphia Electric Company is equipped with an automatic starting device by means of which it is brought from a cold, standing condition to full speed in approximately 22 seconds.

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Features that must be considered in design of modern power plants.

POWER. Another Largest Turbine. Vol. 65, p. 832-3, May 31, 1927.

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POWER. Combined Operation of Steam and Hydro System. Vol. 68, p. 575-6, Oct. 2, 1928.

Problems of operation reviewed that are encountered on interconnected system of Northern States Power Co.

POWER. Cottland Plant, Sweden, Designed for High Pressure. Vol. 66, p. 86-9, July 19, 1927.

High pressure Ljungstrom turbines used.

POWER. Design and Operation of the Gould Street Plant. Vol. 67, p. 742-3, April 24, 1928.

Abstract of subject for American Institute of Electrical Engineers' meeting at Baltimore.

POWER. Ford Motor Company Designs and Builds Its Own Small Turbines. Vol. 66, p. 232-4, Aug. 16, 1927.

Description of design of 5000 kw. unit and indicates the main design features of smaller units.

POWER. Forestalling Trouble by an Annual Inspection of Steam Turbines. Vol. 65, p. 401-3, March 15, 1927. Outlines significant points covered during annual inspection, and method used.

POWER. Generating Power with Mercury Vapor. Vol. 66, p. 566-7, April 12, 1927.

Abstract of discussion at meeting of the American Society of Mechanical Engineers.

POWER. High Pressure Turbines in Industrial Plant. Vol. 66, p. 51, July 12, 1927.

POWER. Kip's Bay Plant of the New York Steam Corporation. Vol. 65, p. 808-12, May 31, 1927.

A general plant description.

POWER. Largest Tandem Compound Turbine Under Construction. Vol. 65, p. 697, May 10, 1927.

Pictures with description of a 94,000 kw. unit.

POWER. Live Steam Reheater for 90,000 kw. Generating Unit at Crawford Avenue Plant. Vol. 66, p. 288-90, Aug. 23, 1927.

POWER. Magnet Reveals Hidden Flaws in Rotor. Vol. 65, p. 825, May 31, 1927.

Illustrated description of tests made on turbine disk forgings for hidden defects.

POWER. The Mercury Vapor Plant at Hartford. Vol. 65, p. 818-9, May 31, 1927.

An illustrated discussion of the latest design.

POWER. Mixed Pressure Turbine Installed in Industrial Plant. Vol. 68, p. 897-9, Nov. 27, 1928.

Savings produced by installing a mixed pressure turbine by an automobile manufacturer.

POWER. Morrell Street Plant. Vol. 68, p. 402-3, Sept. 4, 1928.

Equipment installed at this Detroit Municipal Power Plant and its cost.

POWER. New Coventry Power Station Opens with 40,000 kw. Vol. 68, p. 856, Nov. 20, 1928.

A British base load plant.

POWER. New East River Station of the New York Edison Co. Vol. 65, p. 390-7, March 15, 1927.

Illustrated description of the plant put in operation in Nov., 1926.

POWER. The 160,000 kw. Turbo-Generator for Hell Gate. Vol. 65, p. 226, Feb. 8, 1927.

A description with illustrations.

POWER. Power Station of the Holland State Mine "Maurits." Vol. 68, p. 122-3, July 17, 1928.

An abstract of the description of this plant, with a discussion of design details.

POWER. Progress in 1928. Vol. 69, p. 4-9, Jan. 1, 1929.

Some outstanding turbine installations.

POWER. Reciprocating Engine Using 600 Deg. Fahr. Steam Gives Excellent Results. Vol. 66, p. 291-3, Aug. 23, 1927.

POWER. Reheaters and Reheating. Vol. 65, p. 960, June 21, 1927.

POWER. Relation of Steam to Water Power. Vol. 67, p. 39, Jan. 3, 1928.

The relation between the two power sources involve many factors brought out in the economic study presented.

POWER. Reliability and Safety Outstanding Features in New Stand by Plant. Vol. 65, p. 154-8, Feb. 1, 1927.

Description of the Harbor Point Plant of the Utica Gas & Electric Co., Utica, N. Y.

POWER. Stanton Base Load Plant Burning Anthracite Culm. Vol. 66, p. 312-6, Aug. 30, 1927.

Description of plant.

POWER. Steam Pressure Regulator for Extraction Engines. Vol. 65, p. 342, March 1, 1927.

POWER. Steam Turbine Nozzles. Vol. 65, p. 450, March 22, 1927.

POWER. Turbine Guarantees with Bleeding. Vol. 65, p. 174, Feb. 1, 1927.

POWER. Using the Same Steam Three Times. Vol. 65, p. 732-6, May 17, 1927.

Steam bled from turbine supplied to steam driven auxiliaries that return steam to turbine exhausting into condenser.

POWER. Wet Steam in Turbines. Vol. 66, p. 257, Aug. 16, 1927.

POWER PLANT ENGINEERING. Analysis of Present Day Turbine Installations. Vol. 31, p. 42-5, Jan. 1, 1927.

Turbine arrangement and extraction for feed water heating. Comments made on pressures and temperatures and use of reheat.

POWER PLANT ENGINEERING. Binghamton Station Adds 30,000 kw. Unit. Vol. 32, p. 544-51, May 15, 1928.

A complete description of plant of Binghamton Light, Heat & Power Co.

Power Plant Engineering.. Bleeding Large Turbines Practically Universal. Vol. 32, p. 453-4, April 1, 1928.

New units designed for bleeding. Casing of old units drilled for steam extraction.

Power Plant Engineering. Capacity in Dixon Station Increased. Vol. 32, p. 492-3, April 1, 1928.

12,500 kw. turbine installed to operate at 212 pounds but will be increased to 375 pounds.

Power Plant Engineering. Columbia System Increases Generating Capacity. Vol. 32, p. 970, Sept. 15, 1928.

Description of two units rebuilt at Columbia Station of Columbia Power Co., increasing rating of each from 50,000 to 76,800 kw.

Power Plant Engineering. Crawford Avenue Station Adds Two Units. Vol. 31, p. 1137-9, Nov. 1, 1927.

Description of the 75,000 kw. and 88,000 kw. units.

Power Plant Engineering. Development in Steam Turbine Construction. Vol. 31, p. 45-6, Jan. 1, 1927.

Types and changes made in blading, staging and bleeding. Changed steam conditions.

Power Plant Engineering. Edgar Extension Confirms High Pressure Claims. Vol. 32, p. 784-5, July 15, 1928.

Cross-section and description of new turbine.

Power Plant Engineering. Excitation Systems for Turbo-Generators. Vol. 31, p. 58-60, Jan. 1, 1927.

Schemes in use, types of drives, voltages and methods of control.

Power Plant Engineering. Good Turbine Foundations Decrease Maintenance. Vol. 31, p. 982-3, Sept. 15, 1927.

Power Plant Engineering. Gould Street Generating Station. Vol. 32, p. 575-8, May 15, 1928.

Plant described before American Institute of Electrical Engineers' regional meeting.

Power Plant Engineerig. Heat Balance Tend Toward Increased Extraction. Vol. 32, p. 1314-6, Dec. 15, 1928.

Larger percentage of bled steam used.

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Factors to be considered in its selection.

Power Plant Engineering. Record Breaking Turbines Now in Service. Vol. 32, p. 1317-9, Dec. 15, 1928.

Power Plant Engineering. Reeves Avenue Station at Norfolk Adds 30,000 kw. Unit. Vol. 32, p. 733-4, July 1, 1928.

Equipment of plant of Virginia Electric & Power Co.

Power Plant Engineering. Riverside Station Adds a 15,000 kw. Unit. Vol. 32, p. 304, March, 1928.

Recent addition to plant at Savannah, Ga.

Power Plant Engineering. Some Operating Troubles with Turbo-Generators. Vol. 31, p. 458, April 15, 1927.

Operating troubles with 17 different turbines reported by a German magazine.

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Power Plant Engineering. Super-Pressure Turbine Built in Sweden. Vol. 31, p. 1077, Oct. 15, 1927.

DeLaval turbine built for 1500 lb. initial pressure with multiple nozzle governing.

Power Plant Engineering. Turbine and Turbo-Generator Equipment. Vol. 32, p. 109-14, Jan. 15, 1928.

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Description of unit installed at Waukegan Station of Public Service Co. of Northern Illinois.

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A complete description with curves.

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III—Operating Mechanisms. The Electric Journal, Vol. 25, p. 303-6, June, 1928.

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A general description of this plant.

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The Engineer. Tests of a 12,000 kw. Zoelly Steam Turbine. Vol. 145, p. 177, Feb. 17, 1928.

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Description of plant.

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A description of the Kalamazoo steam plant of the Consumers Power Co.

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Test results of a 20,000 kw. turbo-generator.

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A way to plan such schedules is described.

STOKER EQUIPMENT AND FURNACES

Summary

During the past few years there has been a growing tendency on the part of users of stoker fired boiler plants to increase the sizes of stokers and also to increase the input of coal per square foot of grate area. This has brought about the introduction of improvements in furnace construction, in methods of introducing air at the proper place and, in the proper proportion for satisfactory combustion. These tendencies are in line with the real effort on the part of operating companies to reduce boiler plant costs.

Stokers

Experience of member companies, especially with long stokers, has indicated that air distribution has not yet been satisfactorily worked out. Some improvements have been made along this line, and the coming year promises a very marked advance toward the solution of these problems.

For a particular kind of coal the secondary rams or pushers on the long stokers apparently require a different ratio of adjustment from that used on the smaller stokers. To obtain satisfactory operation has, in some cases, required considerable experimental work before the final adjustment was secured. In the future, manufacturers will undoubtedly have more definite knowledge on which to base their adjustment of stokers for a new installation.

Stoker manufacturers have introduced a number of improvements in stoker design during the past year, which are described under manufacturers' statements. These indicate the realization of the importance of continuing the improvement of stoker design to reduce maintenance costs and to increase efficiencies.

Furnaces

Experience of the operating companies with water-cooled walls appears to have been satisfactory and the troubles encountered have been mostly of a minor nature. The use of water-cooled walls has continued to increase along with the tendency to increase furnace combustion rates. An effort is being made on the part of some operating companies to secure a definite comparison of the value of refractory lined as compared to bare water-cooled wall surfaces. Sufficient data, however, are not available at the present time to include them in this report. The manufacturers have continued with an effort to improve circulation in boiler wall surfaces in order to eliminate possible tube failures which might result from improper circulation.

Fans

A number of installations have been made with roller and ball bearings, and while results to date have been satisfactory, except for a few very minor troubles, the companies using them feel that they have not had sufficient operation to indicate the real results.

A very small number of the operating companies report that fans have been tested for performance before installation. Other companies accept the fans as delivered and the only check obtained on performance in many cases is calculated from maximum boiler output test. The inclusion in the contract of a clause calling for shop tests before delivery would tend to eliminate any controversy between manufacturer and purchaser regarding the satisfactory performance of fans, especially in cases where it would be extremely difficult to make tests after installation.

Last year a propellor type fan was developed, for use on a generator cooling system. This fan is capable of developing very high pressures, and can be installed in a comparatively small floor area. However, while they require only a small amount of floor space, their height is somewhat greater than that required by the usual type of fan.

Air Preheaters

The data submitted indicate that there has been continued trouble with corrosion on preheaters, particularly at the exit end of the gas passes. In some cases the trouble has been concentrated on certain portions of the preheater and in other cases it has been general corrosion. The chemical composition of the coal and its moisture content appear to have considerable bearing on this feature. Attention of the operating companies is, therefore, called to the necessity of careful design in the distribution of the gas flow throughout the entire cross-section of the preheaters and also where coals high in sulphur and moisture are used, considerable care should be exercised in the installation and the method of cleaning selected.

OPERATING COMPANIES' STATEMENTS

STATEMENT BY THE BROOKLYN EDISON COMPANY

In connection with the installation of unit No. 5 at Hudson Avenue, four B. & W. cross drum boilers, having 23,764 sq. ft. of heating surface each, and four B. & W. return tubular economizers, with 14,975 sq. ft. of heating surface each, were erected during 1928. In order to reduce slagging alternate boiler tubes being eliminated in the lower row. A sketch of one of the boiler units is shown in Fig. 1.

Bituminous coal with a heating value, as fired, of 13,810 B.t.u. and a proximate analysis as follows:

	Per cent
Fixed carbon	72.5
Volatile matter	19.2
Ash	8.3
Moisture	3.3

is fired on Westinghouse underfeed stokers having 15 retorts and 33 tuyeres. Each stoker is driven by 20-h.p., 250-volt d-c. motors.

Publication No. 289-71, Serial Report, Prime Movers Committee.

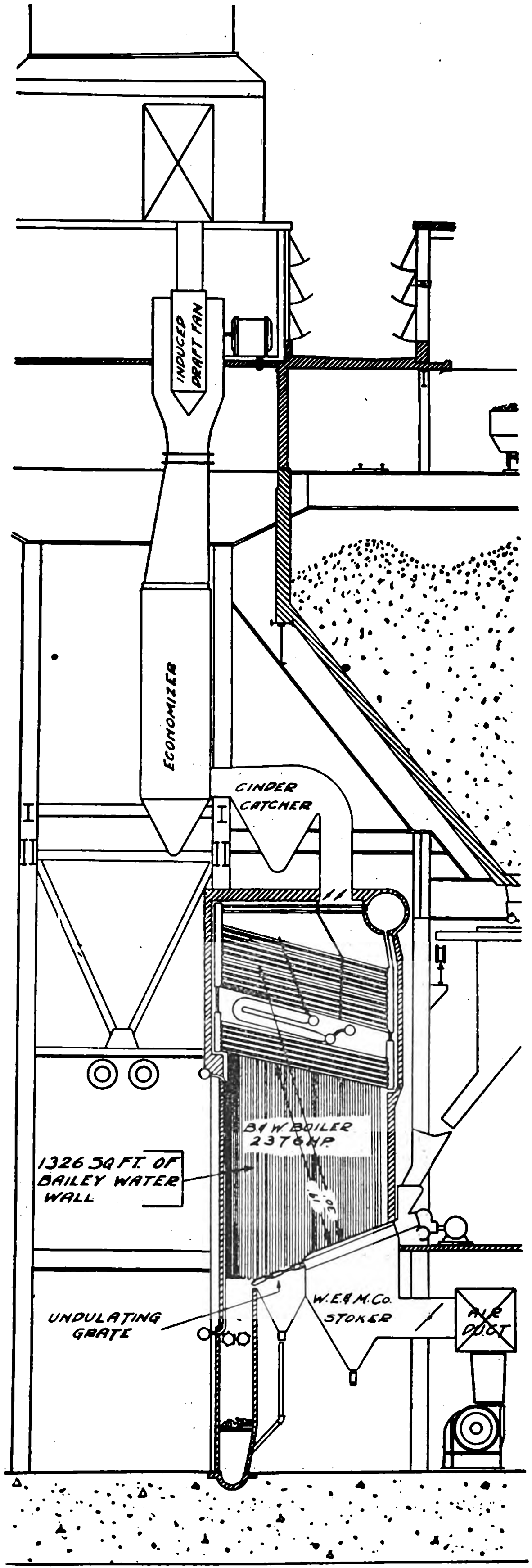


FIG. 1—Boiler Installation, Unit No. 5—Brooklyn Edison Co.

Bailey water walls are used on the sides and rear of the furnace, which has a volume, including ash pit, of 9220 cu. ft. Each side wall has a cooling area of 313 sq. ft., while the rear wall has 700 sq. ft. The walls are covered with bare cast iron blocks in the ash pit and slightly above the fire line on the sides; above this, refractory faced blocks are used.

The forced and induced draft fans are of the B. F. Sturtevant vane control type, motor driven.

Steam is generated at 415 lb. gage at approximately 700 deg. fahr. The maximum rating at which these boilers have been operated is 450 per cent. The stokers and boilers have given satisfactory service.

Air Preheaters

No air preheaters were used on unit No. 5 boilers. With unit No. 4, described in 1927-28 Report of the Subcommittee on Stokers and Furnaces (N. E. L. A. Publication No. 278-49), two Combustion Engineering Company's plate type preheaters, of 21,648 sq. ft. heating surface each, were installed on each boiler. When cleaning the preheaters, the first step is washing down with water while the unit is still hot. An air lance and chain are then employed to remove the caked deposits. Cleaning is done when the boiler is taken off the line after approximately 2000 steaming hours.

Contract curves for these preheaters are shown in Fig. 2.

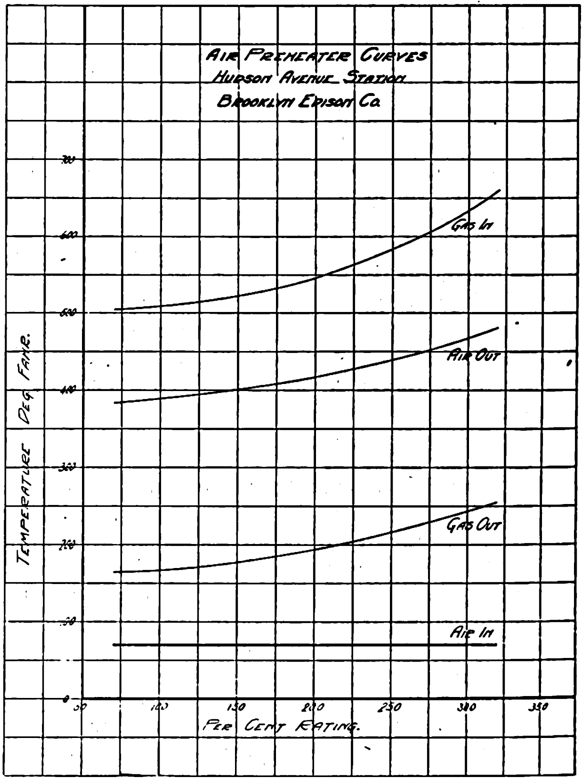


FIG. 2—Preheater Performance Curves—Broooklyn Edison Co.

Statement by the Commonwealth Edison Company

The installation of the last two units (No. 5 and No. 6) at Crawford Avenue Station during 1927 and 1928 involved no radical changes in the steam generating equipment over that of the earlier installations which have been described in previous reports.

The two changes in design as related to combustion conditions were the more extensive use of water screens and more open spacing of the tubes in the lower 3¼-in. tube

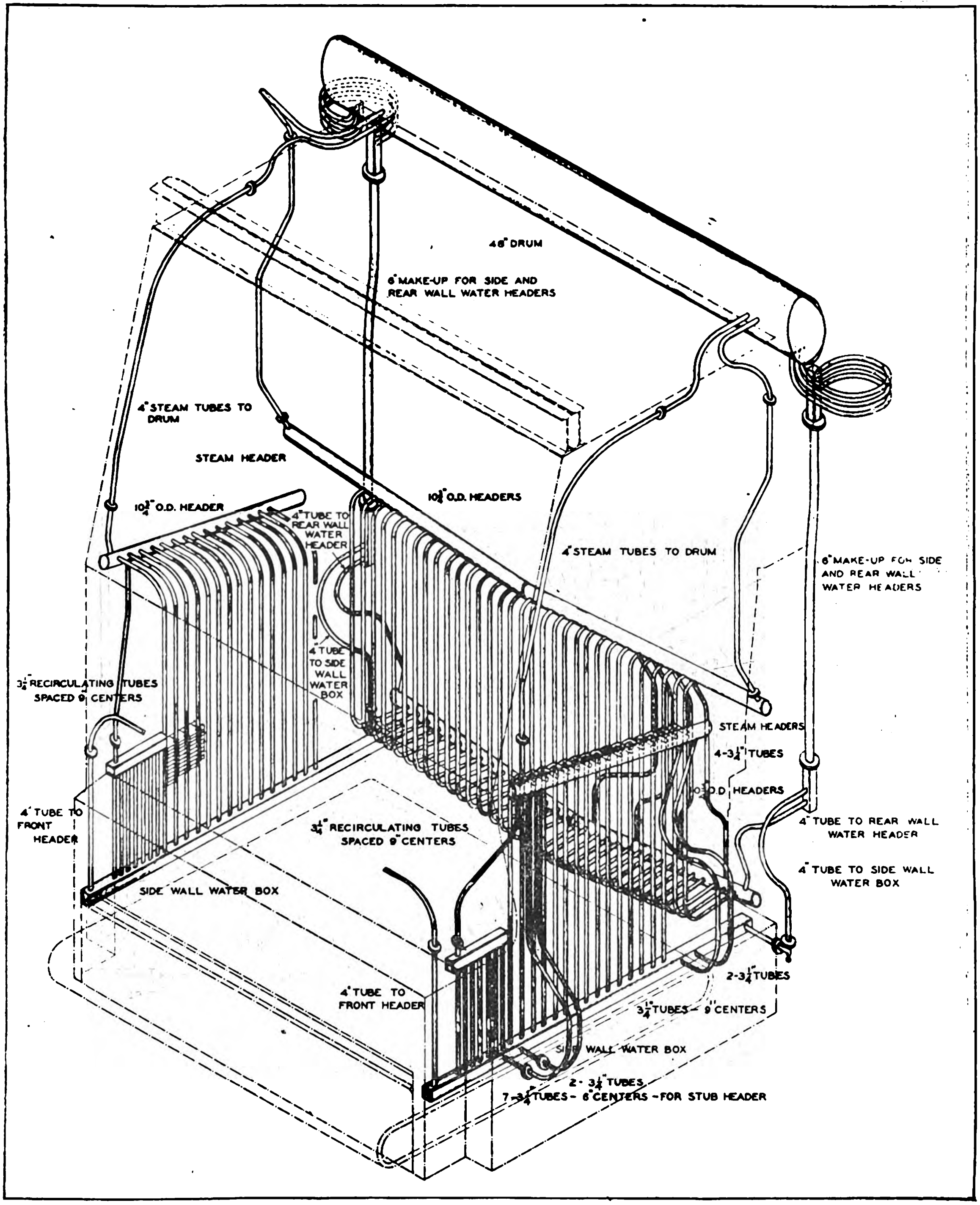

48" DRUM
6" MAKE-UP FOR SIDE AND REAR WALL WATER HEADERS
4" STEAM TUBES TO DRUM
STEAM HEADER
10¼" O.D. HEADER
4" TUBE TO REAR WALL WATER HEADER
10¼" O.D. HEADERS
4" STEAM TUBES TO DRUM
6" MAKE-UP FOR SIDE AND REAR WALL WATER HEADERS
4" TUBE TO SIDE WALL WATER BOX
3¼" RECIRCULATING TUBES SPACED 9" CENTERS
STEAM HEADERS
4-3¼" TUBES
10¼" O.D. HEADERS
4" TUBE TO FRONT HEADER
3¼" RECIRCULATING TUBES SPACED 9" CENTERS
4" TUBE TO REAR WALL WATER HEADER
4" TUBE TO SIDE WALL WATER BOX
SIDE WALL WATER BOX
2-3¼" TUBES
4" TUBE TO FRONT HEADER
3¼" TUBES - 9" CENTERS
SIDE WALL WATER BOX
2-3¼" TUBES
7-3¼" TUBES - 6" CENTERS - FOR STUB HEADER

FIG. 3—ARRANGEMENT OF WATER-COOLED WALLS—UNIT NO. 5 BOILERS—CRAWFORD AVE. STATION—COMMONWEALTH EDISON CO.

bank. The general design of the boiler is about the same as described in the 1926-27 Report of the Subcommittee on Stokers and Furnaces (N. E. L. A. Publication No. 267-59). The increase in the heating surface was due to that added in the form of furnace screens.

The two different furnace screen arrangements are shown in Fig. 3 and 4. Previous experience on trial screen installations indicated the necessity of extending the side screening so as to protect a part of the side wall below the arch. This required a short screen as shown, but connected into the circulation of the main side screen. The effect of this screen system gave such gratifying results in reducing furnace maintenance costs that it was decided to extend the general idea further and completely screen the furnace as shown by the arrangement of Unit No. 6 boilers. The side tubes are more closely spaced (6-in. centers) at the primary part of the furnace as the service is particularly severe at this point. The curtain wall was also included in the screen arrangement. The horizontal forward portion of this screen serves as the support for a special arch construction. This arch is not water cooled in the sense ordinarily understood. The arch blocks are supported by iron clips clamped to tubes and extend only for the horizontal distance, thus retaining the heat radiation function of the arch so necessary to chain grate operation.

Except as stated, screen tubes are all on 9-in. centers and covered with tile to fit. The refractory facing soon erodes due to the action of slag. The tubes, however, are rarely exposed to direct action of the furnace as they are more or less protected by adhering slag. When the brick erodes between the tubes to any extent these spaces are gunnited.

Ample recirculation has been provided for in these screen systems to avoid possibilities of stagnation of flow. Since the installation of these recirculators no failures have occurred.

The increased vertical spacing of the lower boiler tube bank has made this portion of the heating surface more accessible and this facilitates the cleaning and rodding out of the slag deposits. These boilers are usually operated for 35-day periods, which means that frequent rodding and water lancing is necessary to keep passages clear. The cleaning of boilers, particularly as it applies to the lower bank and superheater, still remains one of our main difficulties in boiler room operation. These conditions are, of course, largely due to the character of the fuel. Rather a rapid decrease in boiler efficiency occurs during an operating period in spite of rodding and soot blower cleaning.

The use of preheated air has been the cause of faulty operation and increased maintenance on our chain grates. The apparent limit appears to be about 300 deg. fahr. The cooling of the chain by rear water-cooled drums has met the situation fairly well, but much exists that is still unsatisfactory. Local heating of the chain with resulting "streaking" still persists. This condition can be minimized by draft regulation, even distribution of coal and increased air spacing, but none of these has resulted in a final satisfactory solution of this problem. Trougle has been experienced with the "growth" of cast iron links, necessitating removal of several rows to accommodate expansion. We have made it our regular practice to use steel drive links to eliminate tearing due to jamming.

Turbulence is produced in the furnace by means of overfire air injection. This has resulted in increased efficiency and has reduced smoking considerably. This also has the effect of reducing flame travel where, if turbulence were not used. flames would extend well into the second pass. Under normal operation at average capacity the flame tips out at the inter-deck superheater. Slagging begins to be serious at ratings above 200 per cent, which is lower than plant requirements.

The removal of the compartment siftings by means of screw conveyors proved unsatisfactory. Much better operation is now being obtained by means of the star dumping arrangement which drops sifting to the return chain and to be eliminated through this chain as it rounds the sprockets at the stoker front.

Under normal conditions the operation of the preheaters offers little difficulty except for the problem of cleaning. Preheaters are cleaned by washing when down. No other means has been found satisfactory. The deposit is generally more pronounced at the entrance.

No particular innovations in fan equipment have been made except the use of one forced draft and one induced draft fan instead of two per boiler. Draft control is accomplished by push button with auxiliary control by hand damper.

STATEMENT BY THE LUZERNE COUNTY GAS & ELECTRIC CORPORATION, KINGSTON, PA.

A cross-section of one of the Hunlock Creek 17,260 sq. ft. B. & W. boilers designed to burn steam sizes of anthracite coal, is shown in Fig. 5.

The front and rear arches are so designed that the rich gas rising under the front arch and passing to the throat is met by the lean gas and excess air coming from under the rear arch, in a blast which is strong enough to thoroughly mix the gases at the throat.

After passing through the throat and rising, the gases are again mixed and rolled over by the right angle direction change provided by the horizontal baffle, which extends across the bottom of the second and third passes, and is supported by the second row of tubes. The first and second rows of tubes are separated from the third row in order to form a slag screen.

The boiler was set backwards in order to provide the change in direction of gas flow, since this design has been found to be very efficient in another somewhat similar installation. This horizontal baffle provided a protected third arch effect, with very low maintenance costs. Some other companies had previously used a similar scheme except that the arch was built into and supported by the furnace wall and was located below the boiler tubes. This arrangement resulted in excessive maintenance costs and was, therefore, not satisfactory.

It has been found in the operation of the Hunlock Creek boilers that the gas is so thoroughly mixed at the throat that the third arch is not required except possibly at very low ratings. It is probable, therefore, that future installations in this plant will be made without the third arch and with the boiler turned in the opposite direction to facilitate cleaning and removal of cinder.

The average yearly maintenance cost of furnaces per ton of coal burned since their installation is as follows:

1926	$0.005
1927	0.062
1928	0.023

The above are based on tons of 2000 lb. The year 1926 is not a normal average. During part of that year operation and some maintenance work were carried on by the manufacturer.

STATEMENT BY THE PHILADELPHIA ELECTRIC COMPANY

Richmond Station

In the 1927-28 Report of the Subcommittee on Stokers and Furnaces a figure of $25 per year per boiler was given for maintenance of the Bailey water-cooled wall blocks at Richmond Station. While this figure is still very low, it has increased somewhat during the past year so that taking the complete period of operation of approximately three years, the maintenance cost is now slightly over $30 per boiler per year. The repairs or replacements have been practically all confined to bare blocks located at the clinker line in the side walls. The original blocks installed were rolled steel, and these have been replaced by cast iron. Up to the present time none of the cast iron blocks has given any trouble, although some of them have been installed for more than a year.

Willow Station

The Willow Station is a central heating plant in which are installed three B. & W. cross drum boilers, each having

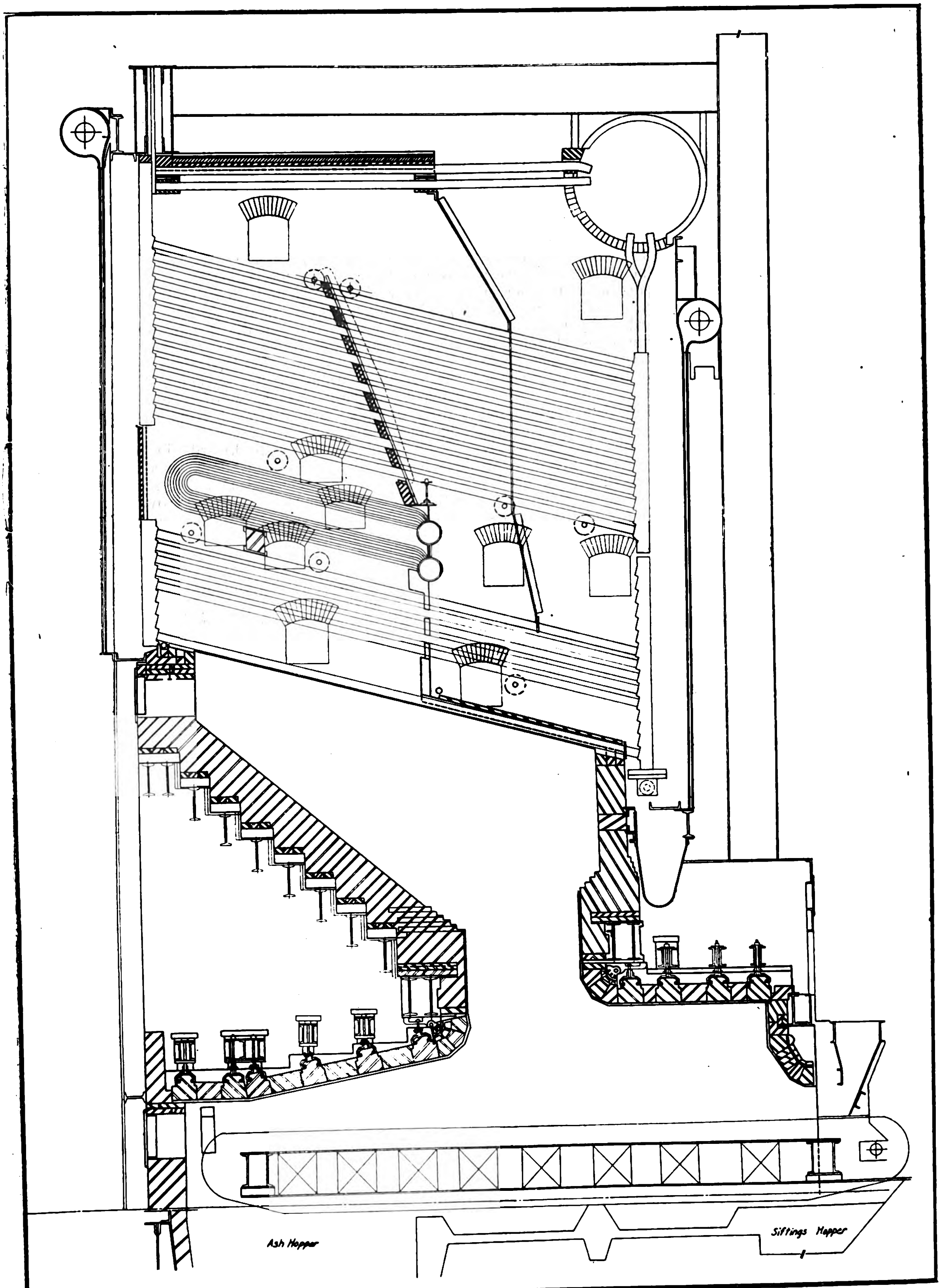

Ash Hopper
Siftings Hopper

FIG. 5—CROSS SECTION OF BOILER UNIT—HUNLOCK CREEK STATION—LUZERNE COUNTY GAS & ELECTRIC CORP.

a heating surface of 11,296 sq. ft. Bailey water-cooled walls are installed on the complete surface in two sides and the rear wall. The front wall over the stoker is of standard firebrick construction. Bituminous coal is fired by Taylor 7-retort, 41-tuyere, underfeed stokers.

With the original arrangement of air supply to the stoker it was impossible to secure the expected rating without experiencing serious difficulty in burning out of tuyeres on the lower end of the stoker and with very excessive smoking at about two-thirds of the guaranteed maximum rating. There was apparently too great a jet action by the direct impact of air at the lower end of the stoker. This, combined with the original adjustment of the pushers, caused the fire to thin out at the lower end and frequently resulted in bare places on the stoker. Baffles were installed in one of the stokers, and after considerable experimenting with various locations, a satisfactory arrangement was finally worked out. The work with the baffles was carried on parallel with various adjustments to the pushers so that before the end of the first season's heating load, it was possible to carry the maximum load on the boiler with the experimental baffle. Permanent baffles have now been installed which, it is believed, with the adjustment of the pushers, will solve the difficulties, so far as capacity and smoking are concerned. Fig. 6 is a sketch of the boiler installation, and Fig. 7 illustrates the arrangement of the baffles used for obtaining better air distribution.

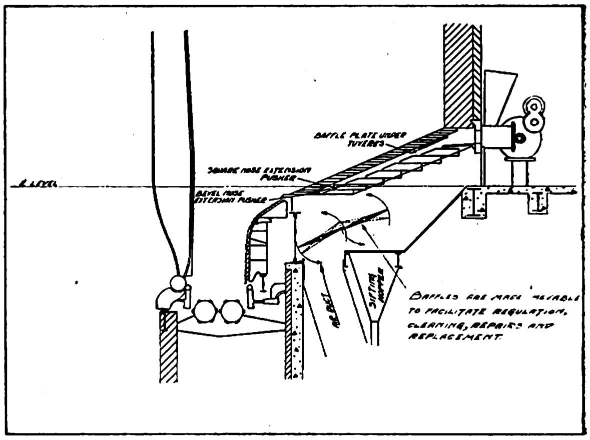

BAFFLE PLATE UNDER TUYERES
SQUARE NOSE EXTENSION PUSHER
BEVEL NOSE EXTENSION PUSHER
AIR DUCT
SIFTING HOPPER
BAFFLES ARE MADE ADJUSTABLE TO FACILITATE REGULATION, CLEANING, REPAIRS AND REPLACEMENT.

FIG. 7—STOKER WIND BOX BAFFLES FOR AIR DISTRIBUTION—WILLOW STATION—THE PHILADELPHIA ELECTRIC CO.

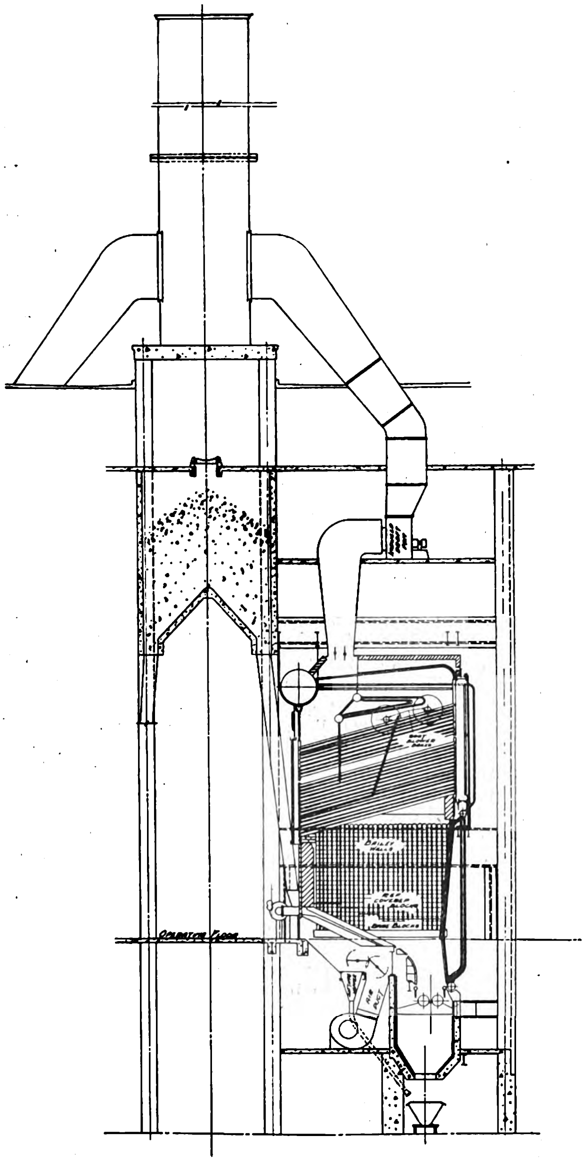


FIG. 6—BOILER INSTALLATION—WILLOW STATION—THE PHILADELPHIA ELECTRIC CO.

The water walls consist of refractory covered blocks, except for the portion extending along the line of the fuel bed. At this point the blocks are of bare cast iron construction. The only trouble has been with certain exceptionally large cast iron blocks which were secured to the lower side wall headers. Several of these blocks burned excessively on the thicker part of the casting and also cracked at the point of minimum thickness. The manufacturer has replaced some of them with a new design which is filled in on the surface of the block at the points where the metal is excessively thick, with a refractory surface. This new design has shown considerable improvement over the orig-

TABLE I

DATA REGARDING BAILEY WALLS FROM DATE OF INSTALLATION TO AUG. 15, 1928

	12 Boilers at Richmond Station Ref. Faced Blocks	Boiler No. 7 at Chester Station Ref. Faced Blocks	Boiler No. 8 at Chester Station Bare Blocks	3 Boilers at Willow Station, Refractory Blocks
Date of installation......	Oct., 1925	July, 1926	Aug., 1927	Sept., 1927
1. Total number of boiler service hours.........	178,562*	15,252	5,737	17,183*
2. Avg. temperature of air for combustion, °F..	300	450	550	No preheat.
3. Millions pounds coal burned during elapsed period..............	1,520	73.9	34.2	48.6*
4. Per cent excess air at which boiler furnace is operated............	25	30	30	30
5. (a) Avg. fusing temperature of ash, °F.†.	2,500	2,500	2,500	2,500
(b) Avg. heating value of coal B.t.u.....	13,900	13,800	13,800	13,800
6 Number Bailey wall blocks replaced since installation..........	276	None	18	None
7. Maintenance charges against Bailey walls...	$1,108.69*	None	$198.59	None

*Total for entire installation.
†Based on test samples only.

inal, but they have not been in use for a sufficient period of time to form a definite conclusion.

Water Wall Maintenance

Table I gives the total maintenance expense from the time of installation to Aug. 15, 1928, for water walls in Richmond, Chester and Willow Stations. Attention is called to the maintenance cost for boiler No. 8 at Chester Station. While this boiler had a shorter period of service than boiler No. 7, there is almost a $200 maintenance charge for the walls as compared to no cost on No. 7. A probable explanation is that the brick work adjacent to the edge of the water-cooled wall has spalled and eroded to such an extent that the edge of the blocks was exposed to the furnace and the additional heat from exposure of two surfaces of the block could not be transmitted to the water tubes rapidly enough to prevent burning along the edge. The above figure includes some cost for replacing brick work which was removed to allow access to the blocks.

At Willow Station no cost is shown for maintenance of walls although a few blocks have failed and were replaced by the manufacturers.

STATEMENT BY THE WEST PENN POWER COMPANY

During the year 1924, eight 16,400 sq. ft. B. & W. boilers and two 35,300-kw. turbines were installed at the Springdale Station. These boilers are all equipped with 10,700 sq. ft. steel tube economizers. Fourteen retort Westinghouse stokers with 27 tuyeres per retort were installed under seven of these boilers. During the year 1926 an additional turbine of 47,100-kw. capacity was installed without additional boilers. This gave an installed main turbine capacity of 167,000 kw. based upon the manufacturers' ratings.

With twelve of the thirteen boilers in the station in operation at maximum advisable capacity, an average output of only 140,000 kw. can be maintained over the daytime period. This is the base load plant of the system. As the installed turbine capacity is considerably in excess of the boiler capacity, the boilers have been operated so as to obtain the highest possible yearly output without excessive increase in maintenance.

Difficulties Resulting from Type of Coal Used

The coal burned in these boilers is obtained from a mine located at the power station. The coal is very friable and is considerably broken up by the time it reaches the bunkers, giving a very large amount of fines. The fineness of the coal, together with its tendency to soften before the carbonization takes place, makes it very difficult to burn efficiently. Trouble is experienced due to the tendency to coke on the stoker, thus restricting the flow of air. As a result, most of the air passes through the fuel bed along a line just above the ridge of tuyeres where deep furrows are burned into the fuel bed, while the coal in the retort is fused into a solid pencil which is not broken up until it reaches the agitator section of the stoker.

Excess air enters the furnace along the ridge of tuyeres, since it is difficult to keep the tops of the tuyeres adequately covered with fuel. Due to the coking of the coal in the retorts, more coke reaches the overfeed section than can be efficiently burned. The high average resistance of the fuel bed, together with the thin covering of the tuyeres, results in a large number of small particles of coke being blown from the fuel bed. These flying particles settle mostly on the overfeed section and tend to increase the amount of coke to be burned on this section or in the clinker-grinder pit.

The ash in the coal contains approximately 13 per cent of iron oxide, and the fusion temperature is 2350 deg. fahr. Large quantities of coke and ash are blown from the fuel bed against the rear furnace wall. These particles stick and fuse, and the resulting slag flows down the wall at temperatures in excess of 2500 deg. fahr., forming a shelf just above the air box castings in the rear wall. This shelf throws the air away from the surface of the rear wall, and as a result the temperature of the wall is increased and the flow of slag augmented.

In order to remove accumulations of slag at the base of this wall and to dispose of any large formations in the clinker pit, it has been found necessary to bank each boiler for a period of about one hour every night. During this period, the level of ash in the clinker pit is lowered, if necessary, and the shelf of slag is removed by the use of hooks and bars, together with applications of water. The output of each boiler is reduced below normal for an average period of about 75 min. each night until this process is completed.

It was found that the flow of slag could be somewhat retarded by admitting large quantities of air through the air box castings at the bottom of the rear wall. In order the keep the wall cool enough to prevent the flow of slag, it was necessary to keep the ashes in the clinker pit below the level of the air box castings, so that a maximum of cool air could be obtained and a non-reducing atmosphere could be maintained at the wall surface.

The admission of this excess air resulted in an appreciable loss, and was not entirely effective in preventing troubles from slag. These losses were increased due to the burning of the covers of the air box castings, which allowed excessive quantities of air to enter the furnace at some points.

During the first two years of operation of these stokers somewhat more trouble was experienced with the formation of slag deposits even though the ratings were lower at that time. The improvement in these conditions results mainly from the limiting of the maximum CO_2. This has been accomplished without affecting the average CO_2 values.

The average performance data for the year 1928 are as follows:

Average rating while operating, per cent......	273
Average steam output while operating, lb./hr..	145,000
Average CO_2 in boiler outlet gases, per cent....	11.6
Average temperature of boiler outlet gases, deg. fahr.	655
Average combustible in the refuse, per cent....	28
Average temperature of superheated steam, deg. fahr.	703
Time in service, per cent..................	79.0
Time banked, per cent*......................	5.8
Time out of service, per cent................	15.2
Average efficiency of boiler and furnace, per cent	72.0
Average efficiency of boiler economizer and furnace, per cent............................	79.8

---

*This includes the time when the boiler output is reduced below 25,000 lb. per hr. to remove clinker formations. These boilers are practically never banked except over week-ends.

Rates of Combustion

The average output per boiler for each of the seven 16,400 sq. ft. boilers while in service is 145,000 lb. per hr. This average excludes the time necessary to remove clinker formations. The average output during the daytime of week-days is approximately 150,000 lb. per hr. Outputs of approximately 175,000 lb. per hr. have been obtained for periods of 1 hr. on individual boilers. Although the maximum continuous output is limited to approximately 150,000 lb. per hr., outputs of from 160,000 to 165,000 lb. per hr. could be carried over a 3-hr. daily peak. The rates of combustion corresponding to these outputs are as follows:

	Coal burned per sq. ft. of active grate surface. (Projected surface minus ash pit surface but inclusive of agitator)	Coal burned per sq. ft. of projected combustion chamber area
Average output	62.3 lb. per hr.	44.8 lb. per hr.
Average output during the daily peak period	66.0 lb. per hr.	47.6 lb. per hr.
Maximum outputs obtained for periods of 1 hr	80.0 lb. per hr.	58.0 lb. per hr.

The average output for the 8760 hr. of the year is 115,000 lb. per hr. This corresponds to 217 per cent rating.

Stoker Maintenance

During the past year it was the practice to keep twelve of the thirteen available boilers in service during the three days of the week when the load was the greatest. During two of the remaining week-days, eleven boilers were kept in service. Additional boilers were taken from service over the week-end when the system load was low, to make repairs to the stokers.

During the year 1928 the costs of labor and material for stoker maintenance were $0.02 and $0.052 per ton, respectively. During the same period the labor and material costs for the stokers of the five original boilers were $0.015 and $0.032 per ton, respectively. These boilers have duplex Westinghouse stokers of thirteen retorts and are seventeen tuyeres in length. Nearly all of the castings used in stoker replacements are obtained from a local foundry.

Improvements

During the past year several changes have been made which have resulted in improved operation. The largest gain in efficiency has resulted from the construction of ducts to permit drawing the air from the top of the boiler room. As originally constructed, the air for half of the eight boilers in the second section of the station was taken from the discharge of the main turbo generators; the forced draft fans for the other four boilers were located on the boiler room floor and were arranged so that air could be taken either from outside or inside the building. As it has been found from experience that substantially better results were obtained with the warmer air, air ducts were extended to the top of the boiler house.

These ducts have been in use for only a few months, and data are not available over the full range of outside air temperatures. With an outside air temperature of 0 deg. fahr., an average temperature of 80 deg. fahr. is obtained, and with 40 deg. fahr. outside air an air temperature of approximately 100 deg. fahr. is obtained. All of the air for these four boilers is taken from the boiler room except in the very coldest weather.

A marked improvement in performance has been obtained by the use of castings which are bolted to the bottom of the aprons in the clinker pit. These castings fit under the clinker-grinder rolls and extend from the apron to under the center line of the clinker grinder. Their use results in more even grinding and lessens the trouble experienced with holes forming in various sections of the clinker pit. The clinker pit can also be more quickly filled after having been emptied.

“A connection has been made between the forced draft duct and the ash pit below the clinker grinders. As these stokers have water-sealed ash pits, it is possible to maintain the full forced draft pressure under the ash pits. It is believed that the additional air that is caused to pass upward through the ash pit in this way results in a lowered percentage of combustible in the refuse.

As trouble has been experienced with the burning of air box castings that were exposed to the radiation of the furnace, these castings are now being made with ribs on the unexposed side. The holes in these castings are also being enlarged in the exposed side, so as to give a greater surface of contact with the entering air. As a result of these changes the cost of maintaining these parts has been reduced.

Orifices have been installed in the steam line to the stoker agitator rams, in order to reduce the speed with which they are moved and prevent too great a disturbance to the fuel bed.

Water Walls

As a result of the slagging troubles and consequent heating of the rear wall, it was decided to install water-cooled tubes on this wall in one of the furnaces in order to determine if the cooling of the wall would not result in increased capacity and improved efficiency. A water wall of 4-in. tubes placed on 7⅝-in. centers was installed on the rear wall of boiler No. 8.

This installation was made in the fall of 1926. It has been found that, as a result of this procedure, the slagging troubles, are eliminated. The increase in capacity, however, was not found to be as great as expected. The maximum continuous capacity is limited to approximately 160,000 lb. per hr. When an attempt is made to increase the output above this value, trouble is experienced due to disturbances of the fuel bed and the blowing of small particles of coke over against the rear wall and into the clinker pit. This results in losses due to excessive combustible in the refuse.

The following are average performance figures for boiler No. 8 and for all of the other boilers of the same design during the year 1928:

	Boiler No. 8	Boilers No. 7-14 Inclusive
Average rating while in service, per cent...	284	273
CO_2 at boiler outlet, per cent..............	12.6	11.6
Combustible in the refuse, per cent.........	34	28
Temperature of gases at boiler outlet, deg. fahr.	653	655
Temperature of superheated steam, deg. fahr.	667	703
Efficiency of boiler and furnace based upon 70 deg. fahr. inlet air temperature, per cent.	71.6	71.9

It will be seen that the average rating of boiler No. 8 is but slightly higher than that of the other boilers of the same design. The increase in capacity is approximately proportional to the increase in CO_2, indicating that the amount of gas passed through the boiler is approximately the same. The combustible in the refuse has been increased sufficiently to increase the boiler losses by 1.5 per cent of the heat in the fuel burned. This loss, however, is largely offset by the gain due to the increase in CO_2 percentage. The temperature of the outlet gases is slightly lower in the case of boiler No. 8. If compared at the same rating a still lower outlet gas temperature would have been obtained. The superheaters in these boilers are located just above the sixth row of tubes, and consequently the superheat is greatly affected by a change in furnace temperature. The above comparison indicates that the superheat has been reduced by 36 deg. fahr. as a result of the installation of the water wall.

Approximately the same boiler efficiency has been obtained, although the average rating has been increased by 4 per cent. Due to the effect of the increased CO_2 on the economizer performance, the combined efficiency will be somewhat lower for boiler No. 8 than for the others of the same design. The effect of the 34 deg. fahr. reduction in superheat will be to still further reduce the economy of power generation with steam from boiler No. 8 by slightly more than 1 per cent.

These comparisons indicate that the installation of the water wall has made it possible to obtain 7 or 8 per cent increase in boiler capacity with a reduction in economy of approximately 1.5 per cent. This increase in capacity, especially when accompanied by an appreciable reduction in economy, is not sufficient to justify the installation of water walls in the remaining boilers. The failure to secure appreciable benefit from the use of water cooling of the rear wall was due to the fact that the capacity and economy performance was limited by other conditions than those which could be affected by additional cooling of the walls.

MANUFACTURERS' STATEMENTS

The Prime Movers Committee does not accept responsibility for any manufacturers' statement in this report.

Statement by the Air Preheater Corporation

As a result of an improved form of heating element adapted after about one year of routine work in actual installations, all models of the Ljungstrom air preheater have been redesigned during the past year so that they are now capable of giving the same thermal performance with apparatus having a smaller volume, weight and cost. It, therefore, follows that the installation of this type of preheater in plants operating with low load factor can be more easily justified.

The design of the new heating element differs from the older type in that undulating partition sheets marked "B" in Fig. 8 have been substituted for flat partitions. The undulations in the partition sheet are installed in a transverse direction to the flow of gases, causing an increased turbulence and considerably accelerating heat transfer.

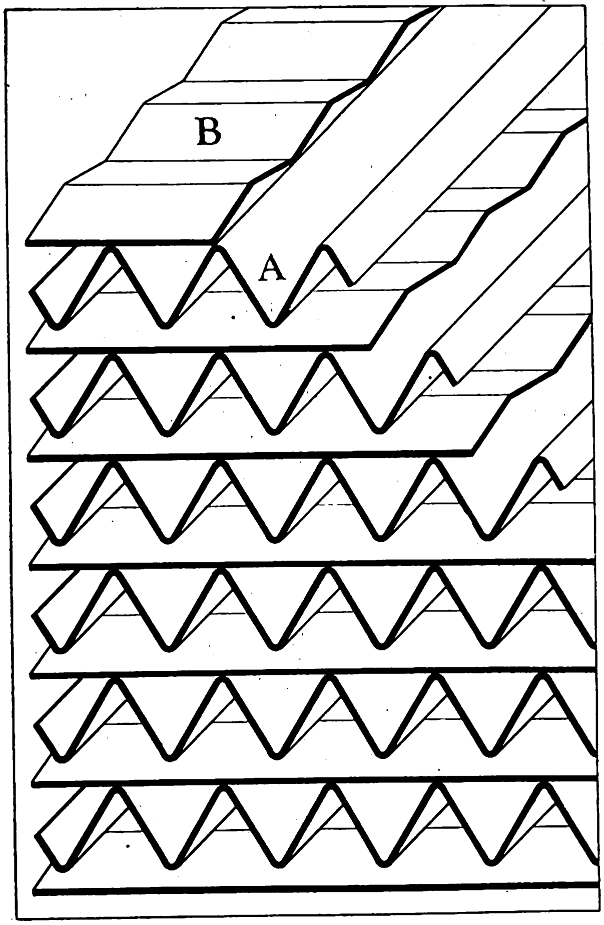


FIG. 8—The New Design of Ljungstrom Heating Surface.

The air and gas channels in this new design have about twice the area of the channels in the older type. This increase in areas, in addition to the greater turbulence, has greatly facilitated cleaning with the simple and effective soot blower provided with the preheater.

Coincident with the adoption of the new type heating element, smaller inlet and outlet chambers were introduced, so that the resulting arrangement requires considerably less vertical space, with no increase in the horizontal dimensions.

The rack and pinion motor drive in all models has been simplified by the substitution of a motor-driven speed reducer for the former chain and sprocket arrangement.

Models up to size No. 16 were formerly provided with a friction drive. All preheaters are now constructed with rack and pinion drives, with the rack made in sections so that it can be easily renewed. The tracks on which the preheaters revolve have also been made in sections, so that they can be readily replaced.

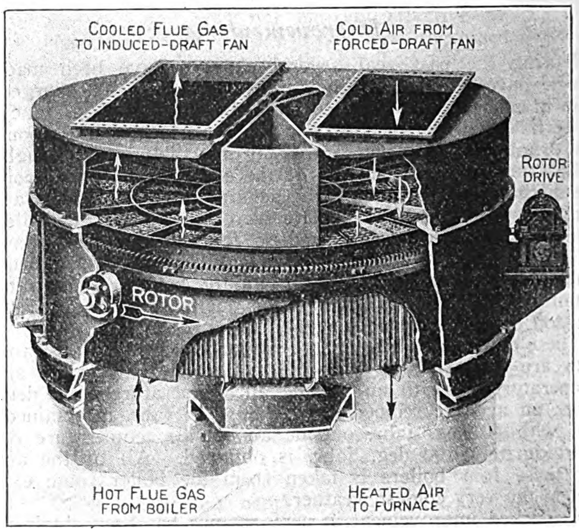

Cooled Flue Gas to Induced-Draft Fan
Cold Air from Forced-Draft Fan
Rotor Drive
Rotor
Hot Flue Gas from Boiler
Heated Air to Furnace

FIG. 9—Ljungstrom Air Preheater for Use with Independent Fans.

Ljungstrom air preheaters are now made in two principal types for use with independent fans and in one type for integral fans. The larger of the independent fan types, shown in Fig. 9, averages about 20 per cent less in vertical height than the corresponding previous model, and the model for use with boilers of less than 10,000-sq. ft. capacity has an overall height scarcely more than that of the rotor. This latter type is the most compact Ljungstrom air preheater ever offered.

The integral fan type, Fig. 10, is now constructed with outboard bearings, which result in much cooler bearing operation and gives greater accessibility for oiling, adjustment and repair.

The fan blades have been altered in design and are now bolted to the hub through plates which are riveted to the fan blading. The fans are so balanced in the new design, and the power input curves for both forced and induced draft fans are such, that working throughout the entire range of boiler ratings the fan driving unit will not be overloaded.

After a considerable experimental period, the air leakage has been decreased by use of sealing strips, illustrated in Fig. 11.

All racks, pinions, tracks, guides and carrying rolls, as well as fan blades are now constructed of steel best suited for the particular service, and a special heat treating department is maintained where the manufacture of these parts is controlled.

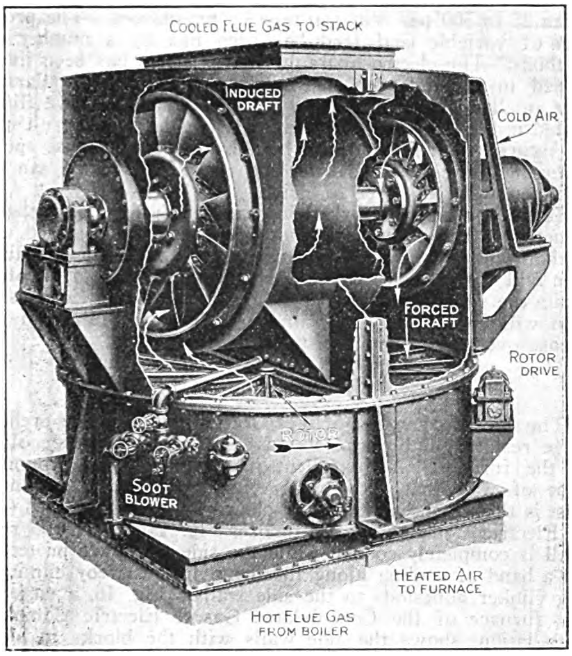

COOLED FLUE GAS TO STACK
INDUCED DRAFT
COLD AIR
FORCED DRAFT
ROTOR DRIVE
ROTOR
SOOT BLOWER
HEATED AIR TO FURNACE
HOT FLUE GAS FROM BOILER

FIG. 10—LJUNGSTROM AIR PREHEATER WITH INTEGRAL FANS.

STATEMENT BY THE AMERICAN ENGINEERING COMPANY, PHILADELPHIA, PA.

Stokers

The outstanding development during the last year has been the increased use of stokers for large steam outputs and the selection of steam units for greater steam generating capacities. The double-ended Taylor stokers at the Beacon St. plant of the Detroit Edison Company have shown their ability to evaporate half a million pounds of water per hour. They will also put into service this year in their new Delray plant 15-retort, 57-tuyere, single-ended stokers of about the same capacity.

The Taylor stokers firing the high-pressure boilers at the Edgar station of the Edison Electric Illuminating Company of Boston are 16-retorts wide and 45-tuyeres deep.

Abroad equally rapid developments are taking place. The results obtained with smaller Taylor stokers at the Deptford East plant of the London Power Company have been so successful that a second installation of much larger stokers is being made. These new stokers will be 17-retorts wide and 49-tuyeres long. In both cases preheated air is applied.

For the extension to the power system of Berlin, Germany, eight Taylor stokers, 20-retorts wide and 49-tuyeres long, have been purchased. These will be equipped with American Engineering Company water walls and ash handling system. The units, arranged for single-ended firing, will have a capacity of 600,000 lb. of steam per hr.

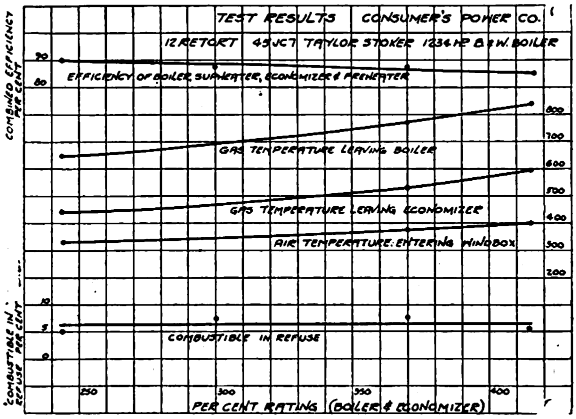


FIG. 12—CURVES SHOWING EFFICIENCY OF TAYLOR STOKER—SAGINAW RIVER STATION—CONSUMERS POWER CO.—ZILWAUKEE, MICH.

Other stokers of much greater length and width are under consideration. There is no reason why stoker-fired units with a capacity of 1,500,000 lb. of steam per hr. will not be realized shortly.

In spite of the tremendous strides made in generating capacity, efficiency has been maintained. For example, at the Saginaw River Station of the Consumers Power Company, Zilwaukee, Mich., where highly preheated air is used,

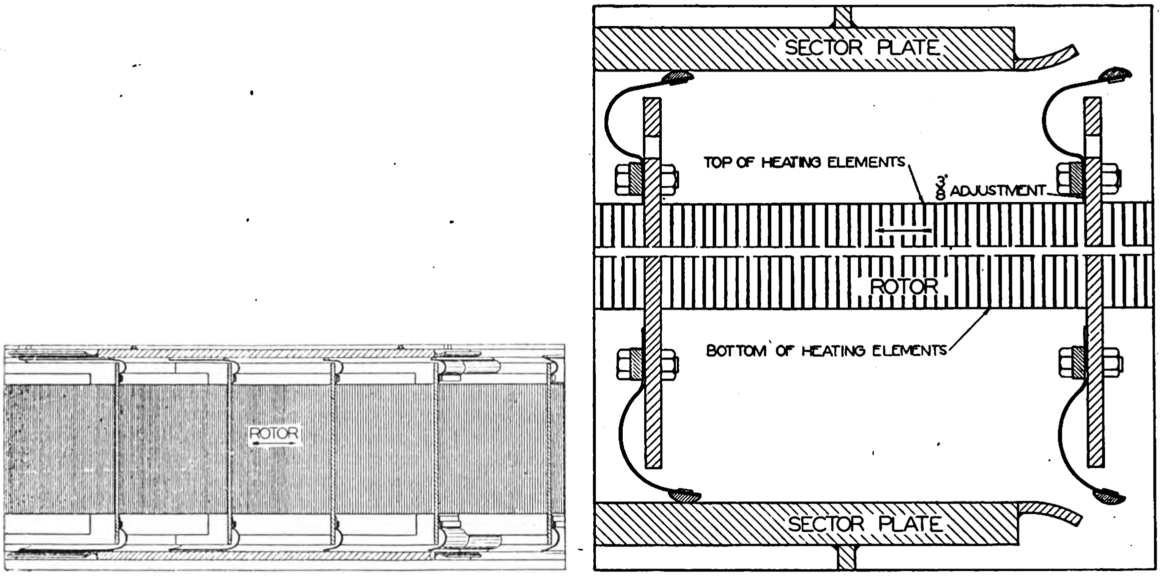

ROTOR
SECTOR PLATE
TOP OF HEATING ELEMENTS
3/8 ADJUSTMENT
ROTOR
BOTTOM OF HEATING ELEMENTS
SECTOR PLATE

FIG. 11—ARRANGEMENT OF SEALING STRIPS—LJUNGSTROM AIR PREHEATER.

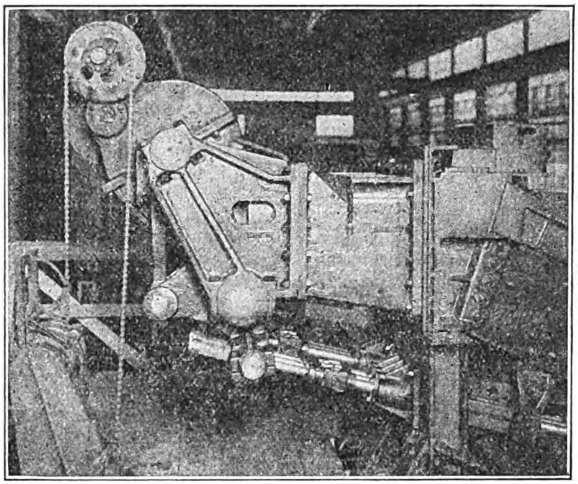


FIG. 13—STRAIGHT LINE MOTION FOR DRIVING RAMS—AMERICAN ENGINEERING CO.

Taylor stokers during a test showed an efficiency of over 84 per cent at 415 per cent of boiler rating, including economizer. The full data are shown by the curve, Fig. 12.

The increase in fuel burning capacity of stokers necessarily involves careful consideration of the mechanical details. The rapid increase in the rate of coal feeding per retort has been taken care of, from the mechanical standpoint, by greatly improved coal-feeding devices, which provide much greater protection from wear than was offered in the small stokers with their much more limited fuel-feeding rates.

Fig. 13 illustrates the straight line motion which is used for driving the rams on the new stokers for the second extension of the Edgar station. Here the drive for the coal feeding ram is entirely independent of the distributing pushers. Moreover, the elimination of the direct connection between the crankshaft and the coal feeding ram eliminates the angular thrust on the ram, resulting in almost complete elimination of the eccentric loading of the ram. It also provides increased bearing surface and greatly prolongs the life of all parts. The same straight-line effect is secured for the pusher drive.

A still further development of this drive is being applied to the 57-tuyere stokers for the Delray plant of the Detroit Edison Company, where the stroke of each individual distributing pusher can be separately controlled.

The large capacities of modern stokers has resulted in a very wide range of steam generation, and boiler ratings from 25 to 500 per cent can now be maintained. The problem of variable coal feed has been met by a number of methods. The electro-hydraulic drive, which has been mentioned in previous reports, has won increased popularity. For smaller plants the direct connected turbine drive illustrated in Fig. 14 is most effective, while the same result can be secured with motor drive by the use of additional speed changing devices. A coal feeding range of 24 to 1 can be obtained with this type of drive.

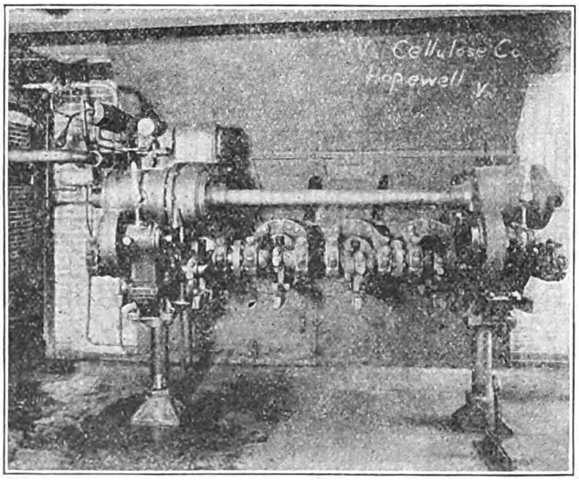


FIG. 14—DIRECT CONNECTED TURBINE DRIVE ON TAYLOR STOKER.

There has been a marked increase in the use of preheat. Practically no large installations now being considered are without this feature. The stokers for the Berlin installation will operate with air at a temperature of 500 deg. fahr., while the stokers for the second extension to the Edgar station will be supplied with air up to 600 deg. fahr., an increase over the previous installation.

Water Walls

The increased rates of evaporation and higher preheat have resulted in the almost universal use of water cooling in the furnace. An excellent illustration of an economic type of wall that provides maximum benefit at minimum cost is that of the new heating plant of the Consolidated Gas & Electric Company of Baltimore, Fig. 15, where the rear wall is completely cooled, while the side walls are protected by a band of cooling along the firing line, thereby eliminating clinker adhesions to the side walls. Fig. 16, a view of the furnace of the Consolidated Gas & Electric Company installation, shows the side walls with the blocks in place on the tubes and the rear wall before the blocks were bolted on. These blocks on the rear wall are carried up high enough to protect the tubes.

Water cooling of the front wall is especially important where the ash fuses at a low temperature and contains a large amount of iron oxide. A complete water cooling of the front and rear walls with the economic type of side wall, has given perfect protection at the plant of the Anglo-Canadian Pulp & Paper Company.

The side wall protection, which has been found very satisfactory, is illustrated in Fig. 17 and 18, where a section three tubes high is shown. Here the brickwork is supported on steel, while the bolted-on blocks of machined cast iron are accessible from the aisle by removing the insulation plates and the plastic insulation immediately back of the tubes.

STATEMENT BY THE COMBUSTION ENGINEERING CORPORATION

Stokers

There has been a definite tendency toward the studied correlation of fuel burning equipment, steam generating equipment and accessories, such as air preheaters and water walls. There is increasing evidence of the advantages of unity of design and responsibility.

Multiple Retort Underfeed Stoker

This new stoker is the outgrowth of many ideas and improvements resulting from years of experience with this machine.

Practically the entire area of each retort is active underfeed area giving even fuel distribution over the entire grate surface. The strength and power of this stoker are self-evident throughout the mechanism and its sturdiness is illustrated in Fig. 19. Parts subject to wear, such as ram box liners, lower section of ram, lower section of ram box and upper section of auxiliary rams, are easily renewable. Likewise, parts subject to burning, such as upper sections of retorts, tuyeres, side wall tuyeres and grate bars, can be easily replaced.

Gear Box

The two-speed gear box is proportioned to the heavy construction of the main part of the stoker and is machined throughout. The hand lever on the front of the gear box

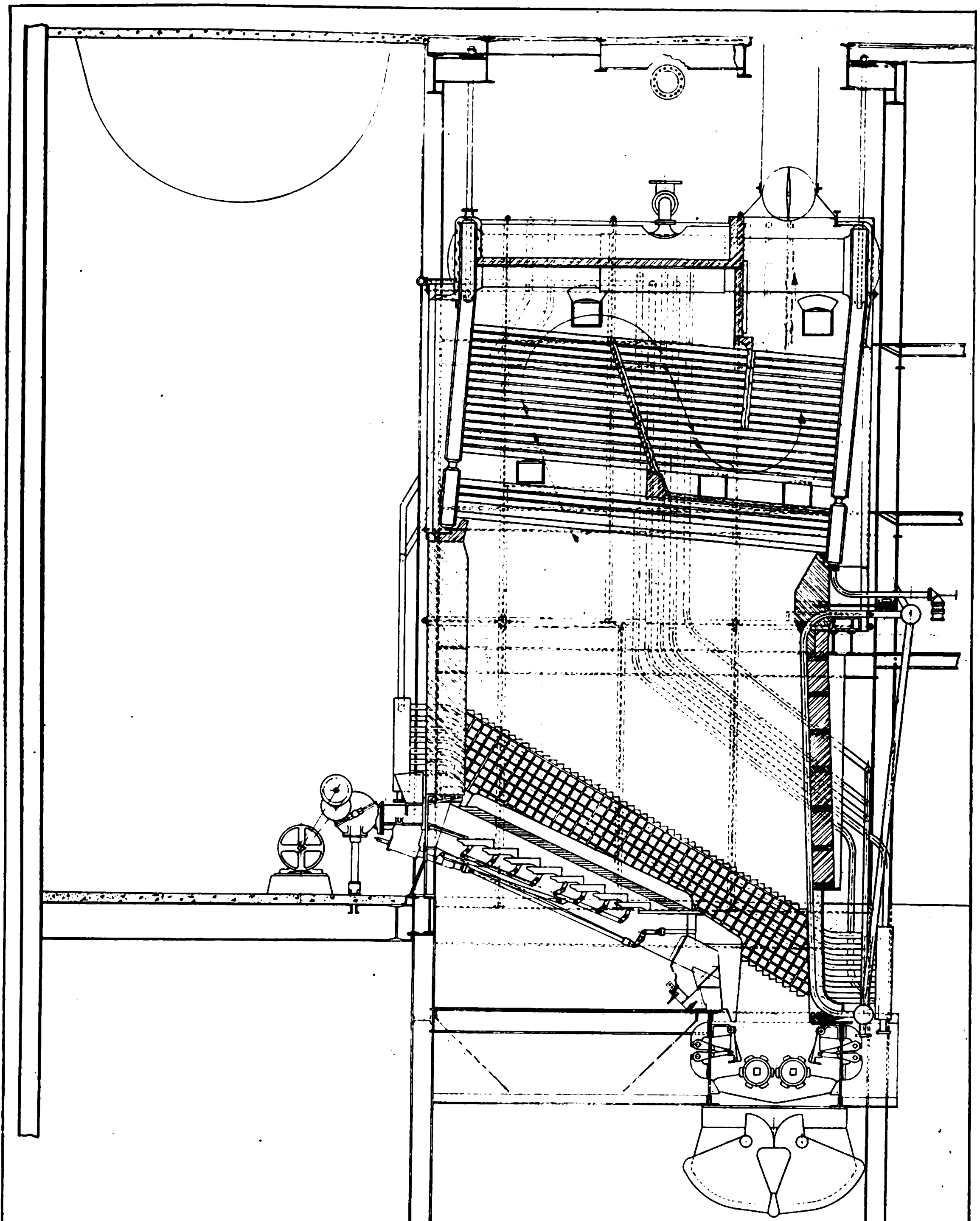


FIG. 15—Water Wall Installation—New Heating Plant—Consolidated Gas & Electric Co.

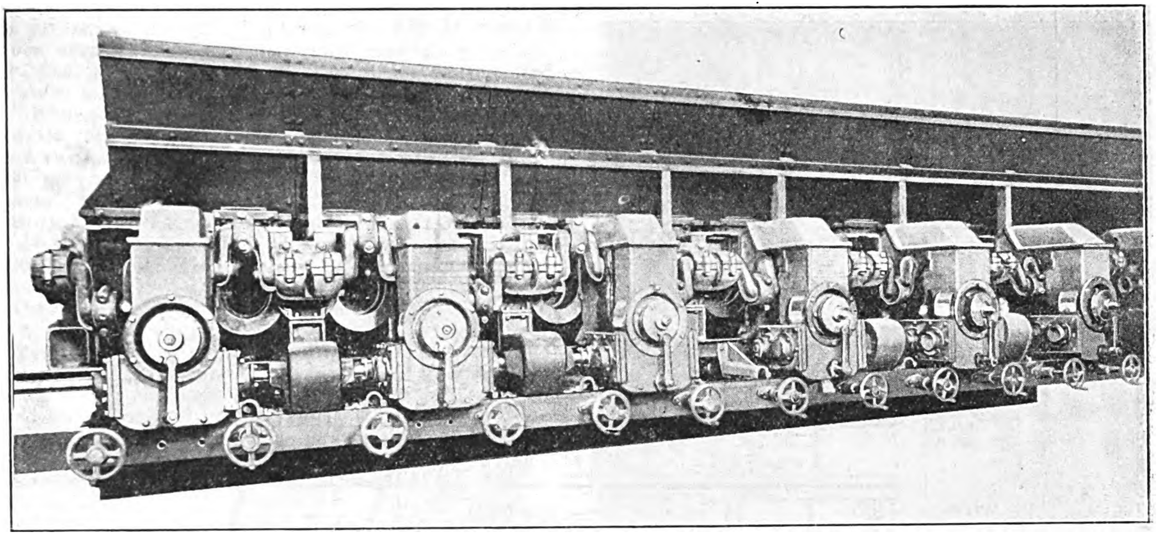


FIG. 19—MECHANISM OF MULTIPLE RETORT UNDERFEED STOKER—COMBUSTION ENGINEERING CORP.

bed when the fresh charge is being forced in and distributes and levels the fuel bed, rather than forming the characteristic furrows usually existing in the fuel bed on an underfeed stoker.

The motion of the grate bars at the end of the stoker is opposite to that of the auxiliary rams, and thus serves to clear the ash from the end of the stoker, so as to be ready to receive the next increment of ash upon the change in direction of motion of the auxiliary rams.

Grate Surface

Each retort is built up so as to provide for expansion and to minimize the possibility of cracking.

The tuyere design gives streamline flow of air and delivers the greater part of the air sidewise into the retort which results in improved operation.

Ash Pit

The ash pit may have either grinder rolls or dump grates. Dump grates are usually installed on the smaller sizes, while clinker grinders are standard for the larger sizes of stokers. These rolls are made up of semi-circular cast iron sections having replaceable teeth and fitted around a square steel shaft which is operated by a pawl and ratchet arrangement. Ordinarily two grinder rolls are furnished in the ash pit, both being reversible and having variable speed.

In Fig. 20, which shows the installation at the Allegheny County Steam Heating Company plant at 12th St., Pittsburgh, Pa., it will be noted that three grinder rolls are installed. This installation represents the first three roll clinker grinder to be built by any company, the arrangement being such that one or both outside rolls can operate separately or in conjunction with the center roll which can operate in either direction.

Front Wall Supporting Casting

The ram box, stoker driving mechanism, hopper and retort sides are bolted to the casting which supports the front wall. The entire stoker body subjected to heat is free to expand and cannot cause any disturbance of the front wall. Also in case of necessary replacement of any parts, the front wall does not have to be disturbed.

Air Control

Zone control of air pressure is afforded by the use of separate air compartments extending across the width of the stoker. The amount of air pressure may be suited to the thickness of the fuel bed directly over any particular air compartment which, with intelligent operation, will result in the best combustion conditions. Without zone control, the air follows the path of least resistance and passes to the lower portion of the fuel bed where it is not needed, resulting in low CO_2 and high flue gas temperature.

Air may be admitted through tuyeres, grate bars, side wall tuyeres and either through dump grates or walls of grinder pit.

The Multiple Retort Underfeed Stoker is recommended for burning all grades of coking bituminous coal, and may be applied to the largest units, as well as those of medium and small sizes. Bituminous coals having high ash content or low fusion temperature of ash are more suitable to burn on chain grate stokers.

Air Preheaters

In respect to thermal performance and lack of operating troubles, the most effective arrangement of air path through the heater has been found to be what is known as the "S" flow, shown in Fig. 21, illustrating the C. E. Air Preheater.

In this design the flue gas flows directly up or down through the heater and the air flows in the opposite direction in an "S"-shaped path, which provides approximately equal length for all air lanes, gives more uniform flow and a more uniform heat transfer rate across the heater.

The latest design provides sectional cleanout doors across the entire heater for the insertion of steam or air lances, which makes it possible to clean the heater during operation.

A further improvement has been made in welding the elements to sealing strips at the air inlet and outlet instead of using bolts, thus eliminating leakage at these points. The elements themselves are electrically welded, as usual.

STATEMENT BY THE FOSTER-WHEELER CORPORATION, NEW YORK, N. Y.

Water Walls

During the year 1928 little has developed that is new so far as the principles in water wall design are concerned. The most important results of the year's activity are the experiences gained from the performances of different wall constructions under various furnace conditions. The knowledge of causes and effects has been increased so that simplicity in design and certainty of results have greatly increased.

Typical results which have a strong bearing on future

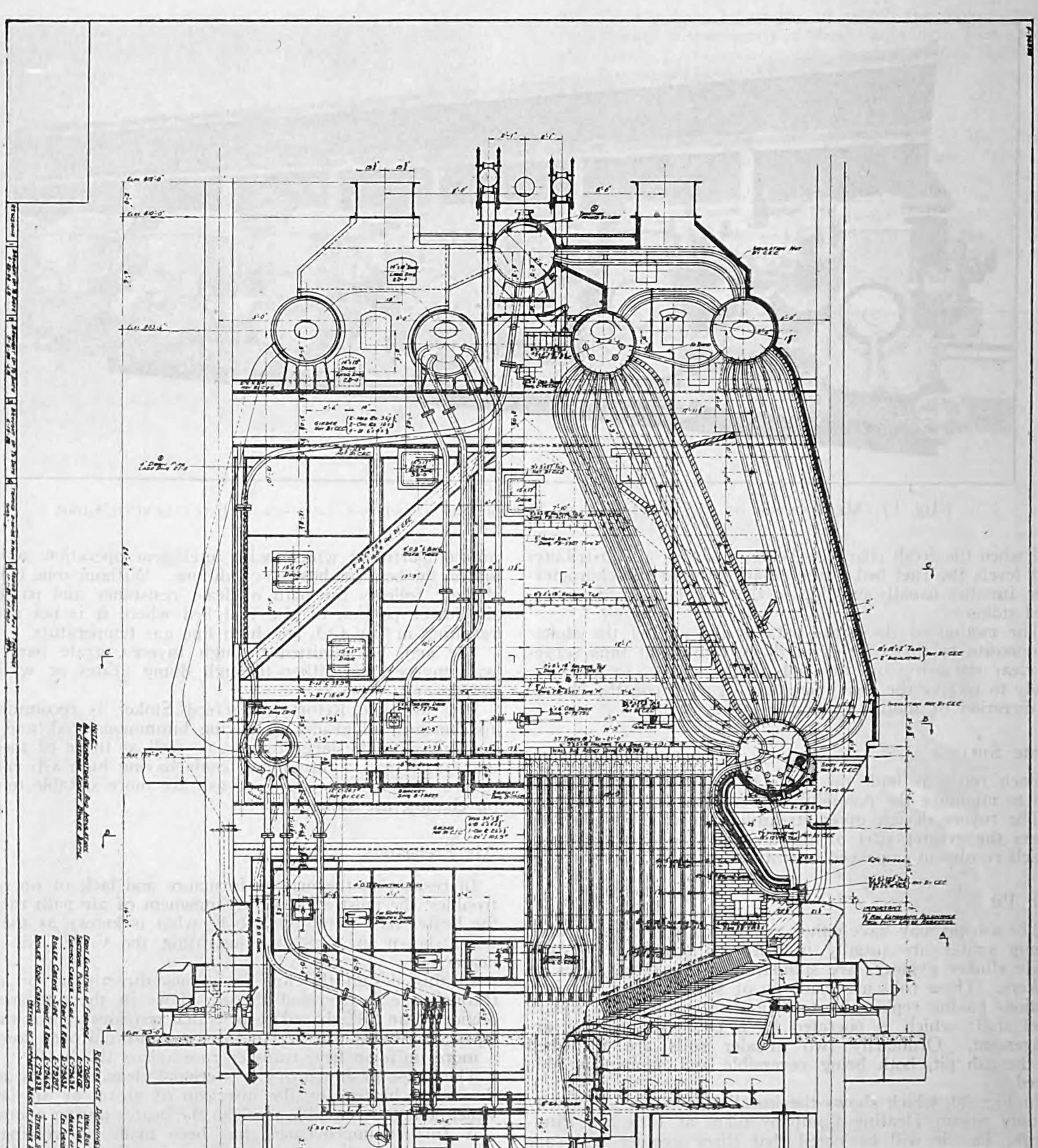

REFERENCE DRAWINGS
ELEV. 763'-0"
ELEV. 748'-0"
HALF SIDE ELEVATION
HALF SECTION
SIDE ELEVATION OF BOILER & FURNACE
ALLEGHENY COUNTY STEAM HEATING CO.
PITTSBURGH, PA.
DRAWING NO. F-70098-5

FIG. 20—INSTALLATION OF COMBUSTION ENGINEERING CORP. UNDERFEED STOKER WITH THREE GRINDER ROLLS—ALLEGHENY COUNTY STEAM HEATING CO.

designs are shown in Fig. 22, 23 and 24. Fig 22 shows a bare tube rear wall, backed with solid refractory, as applied to 5120 sq. ft. Edge Moor cross drum boilers fired by the Aero unit system for pulverized fuel. The settings include Foster Bare tube side and rear walls, with air-cooled refractory panels in each side wall toward the front. This is a two-pass boiler for operation at 385 lb. per sq. in. and 300 per cent rating. Fig. 23 shows the same wall construction after several months of operation. Eminently satisfactory results have been obtained.

Fig. 24 shows the side wall of one of the furnaces for the 9000 sq. ft. Edge Moor boilers, as described on pages 70 and 71 of the 1926-27 Report of the Subcommittee on Stokers and Furnaces. The construction of the wall is that shown as "D" on page 69 of the Report and consists of bare tubes to the back of which are bolted wing castings designed to effect the greatest absorption of radiant heat by the tubes. At the right of the picture is the rear wall composed of refractory faced tubes. The relative freedom of the bare tubes from accumulation and its self-cleaning tendency are well shown.

Fig. 25 illustrates the rear wall and portion of side wall during construction of the furnace for 10,150 sq. ft. cross drum Babcock-Wilcox and Goldie-McCulloch boiler. This is a good example of the modification of construction as dictated by experience. Here the side wall and upper portion of the rear wall are of bare tubes with bolted-on wing back castings for the absorption of radiant heat. The unit is fired by Aero unit system and has an air-cooled refractory wall at the front of the furnace. The lower portions of the rear wall tubes are covered with flat faced cast iron blocks, bolted to the furnace side of the tubes. This gives a smooth, virtually indestructible surface to withstand high temperature and the wear of slag removal.

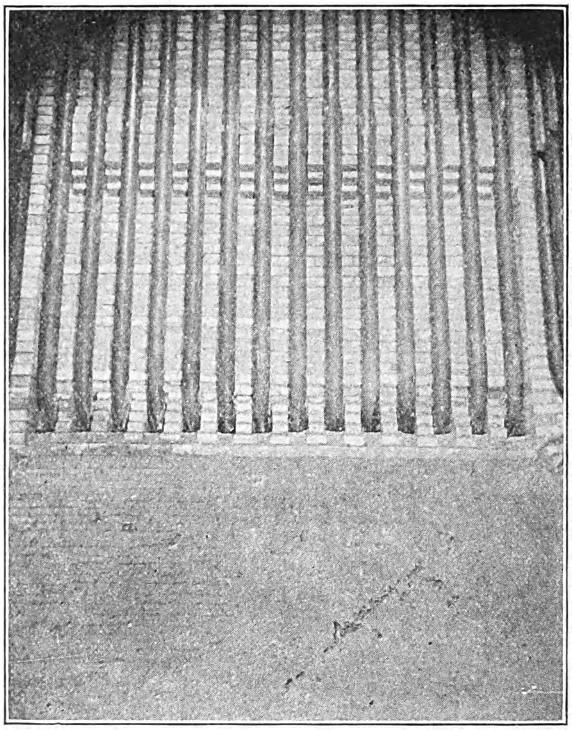


FIG. 22—BARE TUBE REAR WALL — FOSTER-WHEELER CORP.

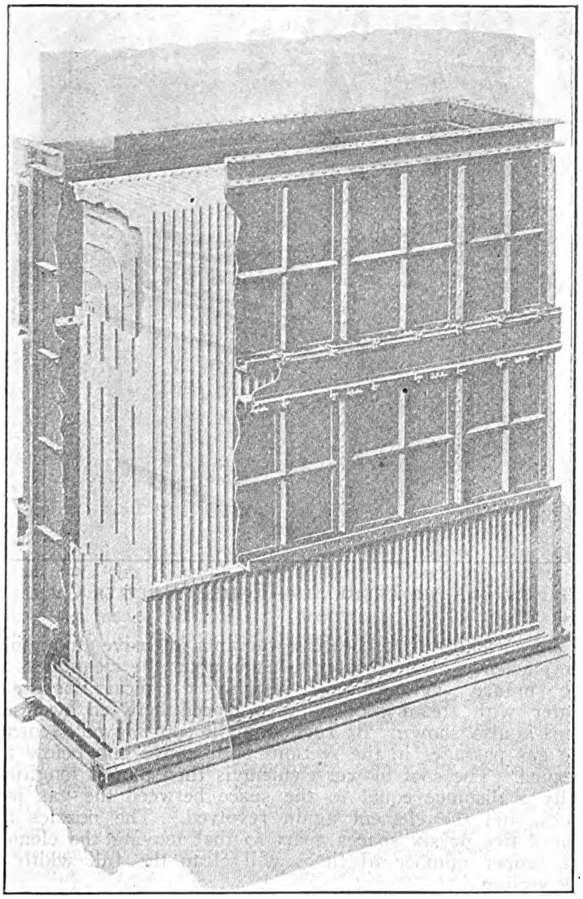


FIG. 21—COMBUSTION ENGINEERING CORP. AIR PREHEATER—PLATE TYPE.

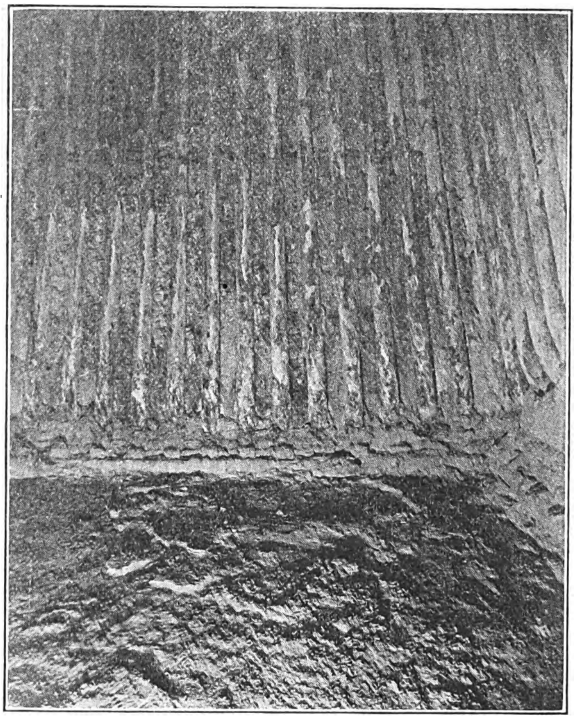


FIG. 23—FOSTER WATER WALL AFTER SEVERAL MONTHS' OPERATION.

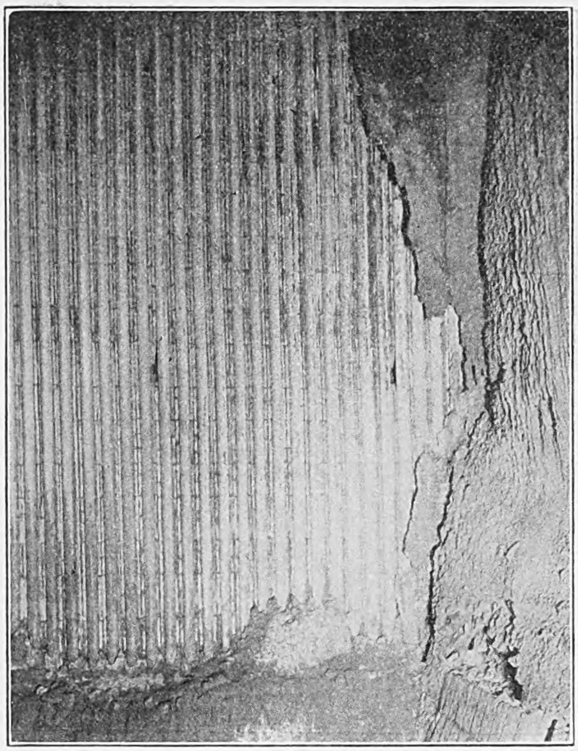


FIG. 24—WATER-COOLED SIDE WALL—FOSTER WHEELER CORP.

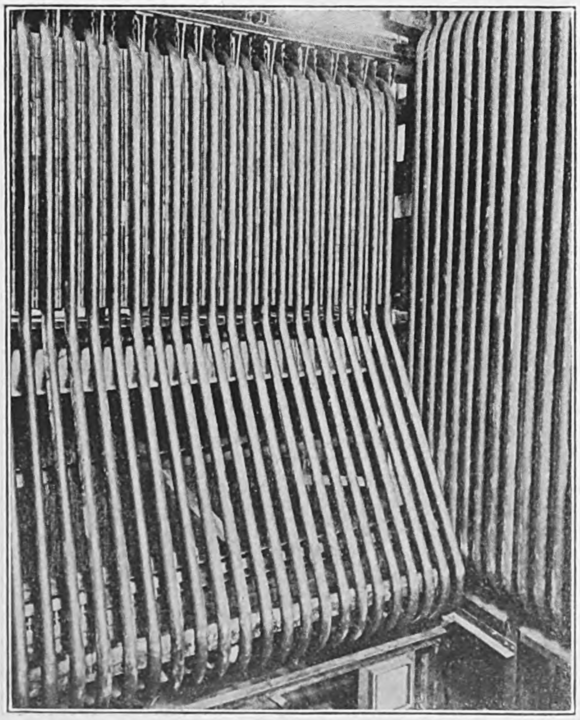


FIG. 25—WATER WALL DURING CONSTRUCTION—FOSTER WHEELER CORP.

Air Preheaters

The application of the new plate type sectional air heater manufactured by the Foster-Wheeler Corporation constitutes one of the interesting developments in the work of air preheating for 1928. Several of these air heaters are now in operation and are giving highly satisfactory results.

Fig. 26 shows a typical arrangement of four sections of an air heater arranged one above the other so that gases may pass vertically either upward or downward, while air passes horizontally through each section and through all of the sections in series, passing from one section to another through connecting ducts.

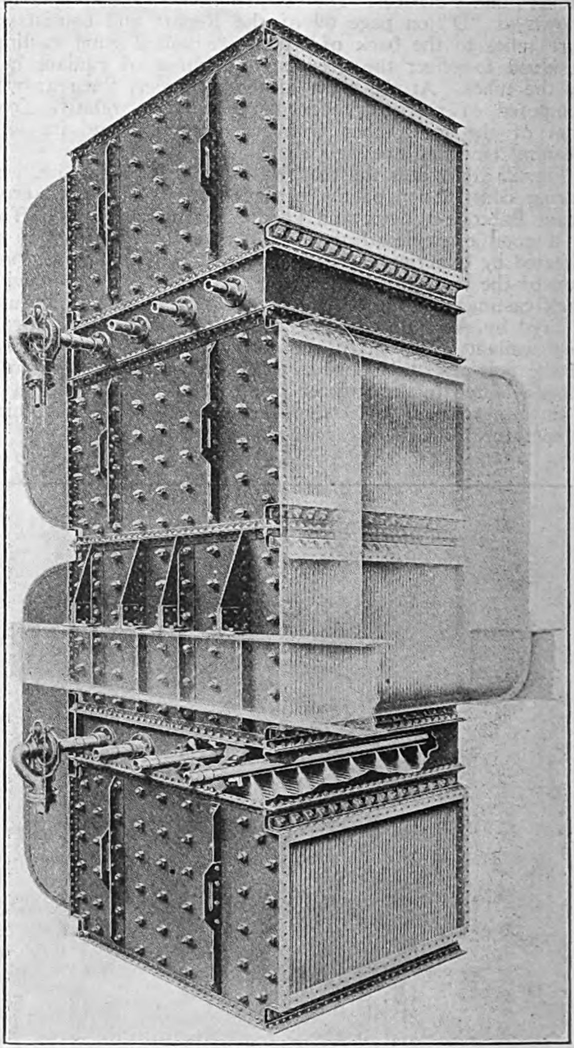


FIG. 26—AIR PREHEATER—FOSTER WHEELER CORP.

The cleaning of air heaters warrants intensive study since the efficiency of the heater depends upon the cleanliness of the surface. A means of cleaning a typical Foster air heater with steam soot blowers placed between two sections is also shown. By revolving the soot blower elements the gas passages in the sections both above and below are cleaned. The soot blower element is then moved longitudinally a distance equal to the space between the gas passages, and the element again revolved. The nozzles are placed five or six spaces apart so that moving the element the proper number of times will clean the full width of the section.

Fig. 27 shows a 51,000 sq. ft. air heater with the ducts partially completed. It should be noted that in this installation the gases pass downward through the air heater so that the lowest sections constitute the cold end of the air heater.

Referring to Fig. 26 it will be seen that should the cold end sections deteriorate from corrosion they may easily be replaced by unbolting at the top; the construction is designed so that this may be accomplished with minimum difficulty.

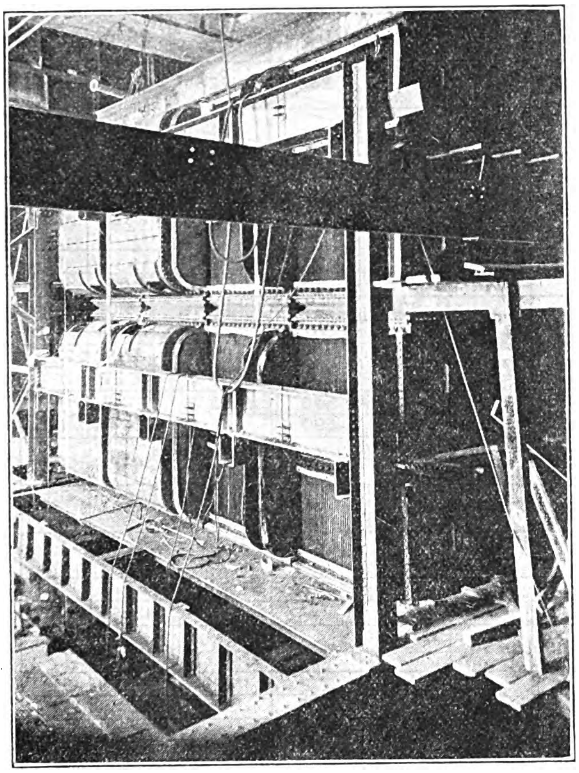


FIG. 27—AIR HEATER DURING CONSTRUCTION—FOSTER WHEELER CORP.

The performance of smaller air heaters in the same plant have given the following results:

Air heater surface	13,580 sq. ft.
Boiler surface	14,086 sq. ft.
Steam production	110,000 lb. per hr.
Flue gases	230,000 lb. per hr.
Air heated	170,000 lb. per hr.
Temperature of air increased from 87 deg. fahr. to 285 deg. fahr.	
Fuel saving effected	6.15 per cent

Fig. 28 shows another arrangement of sections and illustrates the flexibility of design. These air heaters are placed in a low head room. The gases pass up through one air heater section and through a horizontal duct across to the other section and down through the second section to the flue. The air to be preheated enters one air heater section flowing horizontally, is connected by a horizontal duct to the other section and flows through it also horizontally before being discharged to the furnace. This arrangement made it possible to install a moderate size air preheater in conjunction with an economizer where the space was unusually limited.

Fig. 29 shows a line drawing of the boiler unit for the new Holland 1400 lb. station, including five section high air heaters, economizer, etc. In this case there will be two groups of air heater sections each five high, the forced draft fan delivering air to each of the two bottom sections, the air flowing upward through the air heater while the gases flow downward to the induced draft fan.

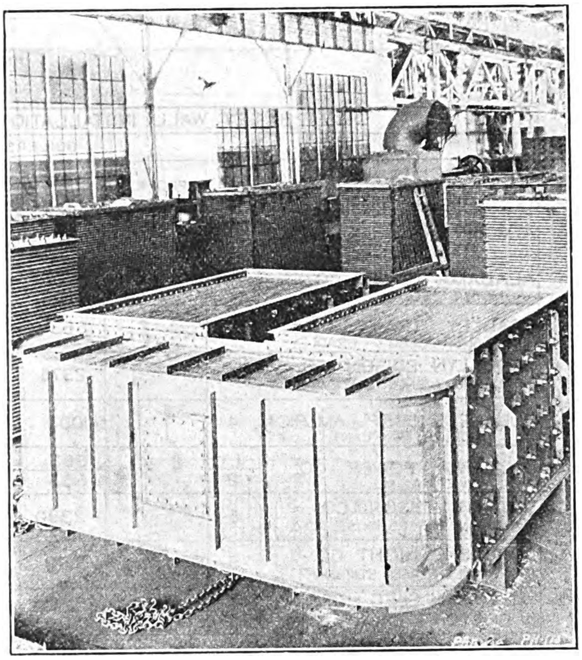


FIG. 28—AIR HEATER FOR LOW HEAD ROOM—FOSTER WHEELER CORP.

STATEMENT BY THE FULLER LEHIGH COMPANY, FULLERTON, PA.

The past year has been one of marked progress toward a better knowledge of the requirements and design possibilities of water cooling of stoker-fired furnaces and also in the number of notable installations placed in service.

For large furnaces operated at high ratings, the probability of brick work trouble or slag dripping down on the

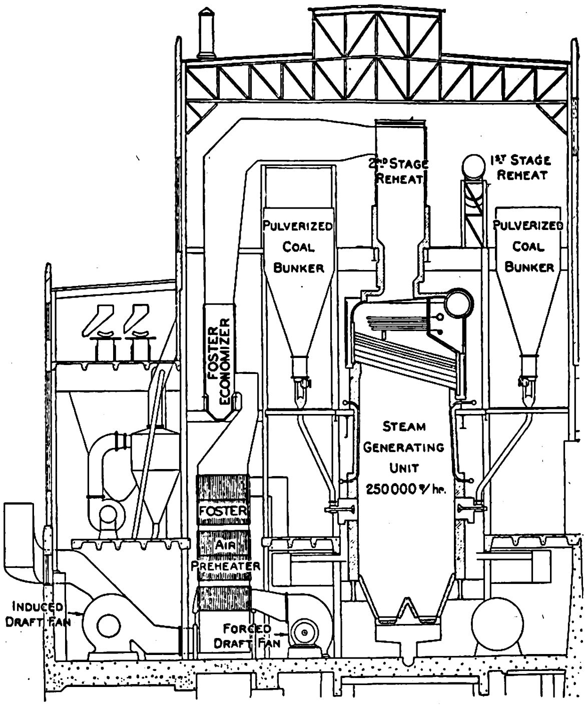
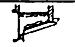
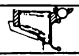
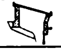
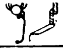
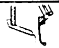
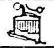
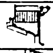
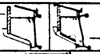
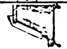
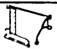
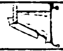
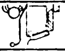
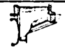
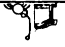
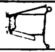
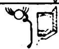
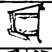
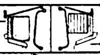
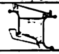
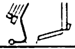
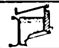
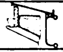
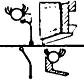
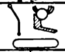
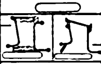
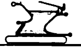
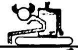
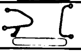
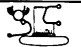
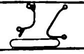


FIG. 29—BOILER UNIT FOR 1400 LB. INSTALLATION—HOLLAND STATION

TABLE II.

BAILEY WALL INSTALLATIONS ON STOKER-FIRED JOBS

COMPANY	BOILERS					WATER-WALL AREA (SQ. FT.)				
	NO.	PROFILE	PER BOILER		DESIGN PRESS.	PER BOILER			TOTAL JOB	MONTHS SERVICE TO 2-1-29
			HORSE POWER	MAX. CAPACITY LBS. STEAM/HOUR		FRONT	SIDES	REAR		
ATMOSPHERIC NITROGEN CO. HOPEWELL STATION	3		1284	200,000	450	—	312	380	2076	7
ALABAMA POWER CO. MOBILE STEAM PLANT	3		1310	90,000	475	—	266	172	1314	—
BRADLEY TRANS. CO. STEAMER "CARL D. BRADLEY"	2		563	30,000	325	—	—	54	108	19
BROOKLYN EDISON CO. HUDSON AVENUE STATION	4		2376	350,000	465	—	646	676	5288	6.5
CELANESE CORP. OF AMERICA AMCELLE, MD. PLANT	4		1000	114,400	450	—	—	232	928	—
DELMARVA POWER CO. VIENNA, MD.	1		663	60,000	350	—	—	133	133	1
	2		663	60,000		—	—	133	266	9
DETROIT EDISON CO. DELRAY POWER HOUSE NO. 3	5		2390	340,000	470	* 808	402	312	7610	—
						† —	570	337	4535	
DUQUESNE LIGHT CO. JAMES H. REED STATION	3		3179	350,000	448	* 192	396	647	3705	—
						† 1430	544	—	5922	
THE EDISON ELEC. ILL. CO. OF BOSTON EDGAR STATION	2		697	300,000	1400	—	596	610	2412	—
	2		1509	225,000		—	590	632	2444	16.5
LYNN GAS & ELECTRIC CO. LYNN, MASS	2		1582	184,000	450	—	404	342	1492	3
MEMPHIS GAS & ELEC. CO. FOURTH ST. STATION	3		1512	100,000	350	—	—	156	468	22
NATIONAL SUGAR REFG. CO. LONG ISLAND, N.Y.	5		1213	110,000	317	—	329	334	3315	—
PENN CENTRAL LGT. & POWER CO. SAXTON STATION	1		1112	144,000	300	—	244	210	454	39
	3		1112	144,000		—	244	210	1362	32
PEOPLES GAS & ELEC. CO. MASON CITY, IOWA.	1		874	135,000	450	—	432	211	643	—
PHILADELPHIA ELECTRIC CO. RICHMOND STATION	10		1570	185,000	410	—	272	328	6000	39
	2		1570	185,000		—	272	328	1200	37
PHILADELPHIA ELECTRIC CO. WILLOW STATION	3		1129	125,000	200	—	314	273	1761	17
PHILADELPHIA ELECTRIC CO. CHESTER STATION	1		1422	140,000	267	—	157	331	488	17.5
	1		1422	140,000		—	157	331	488	32
POTOMAC EDISON CO. WILLIAMSPORT STATION	1		1658	200,000	375	—	402	515	917	19
STATEN ISLAND EDISON CO. LIVINGSTON STATION	1		1450	171,500	310	—	455	404	859	19
	1		1385	175,000		—	—	450	450	5
STAMFORD GAS & ELEC. CO. STAMFORD, CONN.	2		1576	180,000	425	220	418	284	1844	2
TOLEDO EDISON CO. ACME STATION	1		1464	193,000	260	—	—	278	278	31
VIRGINIA ELEC. & POWER CO. REEVES AVE. STATION	3		1530	120,000	450	—	432	416	2544	16
VACUUM OIL CO. PAULSBORO, N. J.	3		1732	190,000	450	—	224	429	1959	14
WARE SHOALS MFG. CO. WARE SHOALS, S.C.	1		1001	80,000	225	—	103	66	169	10
CLEVELAND ELEC. ILL. CO. LAKESHORE STATION	1		687	40,000	275	—	—	175	175	52
COMMONWEALTH EDISON CO. CRAWFORD AVE. STATION	1		1661	208,000	650	457	348	450	1255	28.5
	6		1728	200,000		457	—	—	2742	9.5
EL PASO ELECTRIC CO. EL PASO, TEX.	1		1066	128,000	450	302	260	326	888	16
GLEN ALDEN COAL CO. NANTICOKE PLANT	1		668	50,000	300	—	144	—	144	1
NEBRASKA POWER CO. OMAHA STEAM ELECTRIC STATION	1		1945	250,000	385	521	—	465	986	—
WESTERN UNITED GAS & ELEC. CO. AURORA, ILL.	1		1001	118,000	325	272	127	158	557	38
WAUKEGAN GEN. CO. WAUKEGAN STATION	1		1437	200,000	700	—	—	529	529	11.5

* BAILEY WATER WALL

† TUBE & TILE WATER WALL

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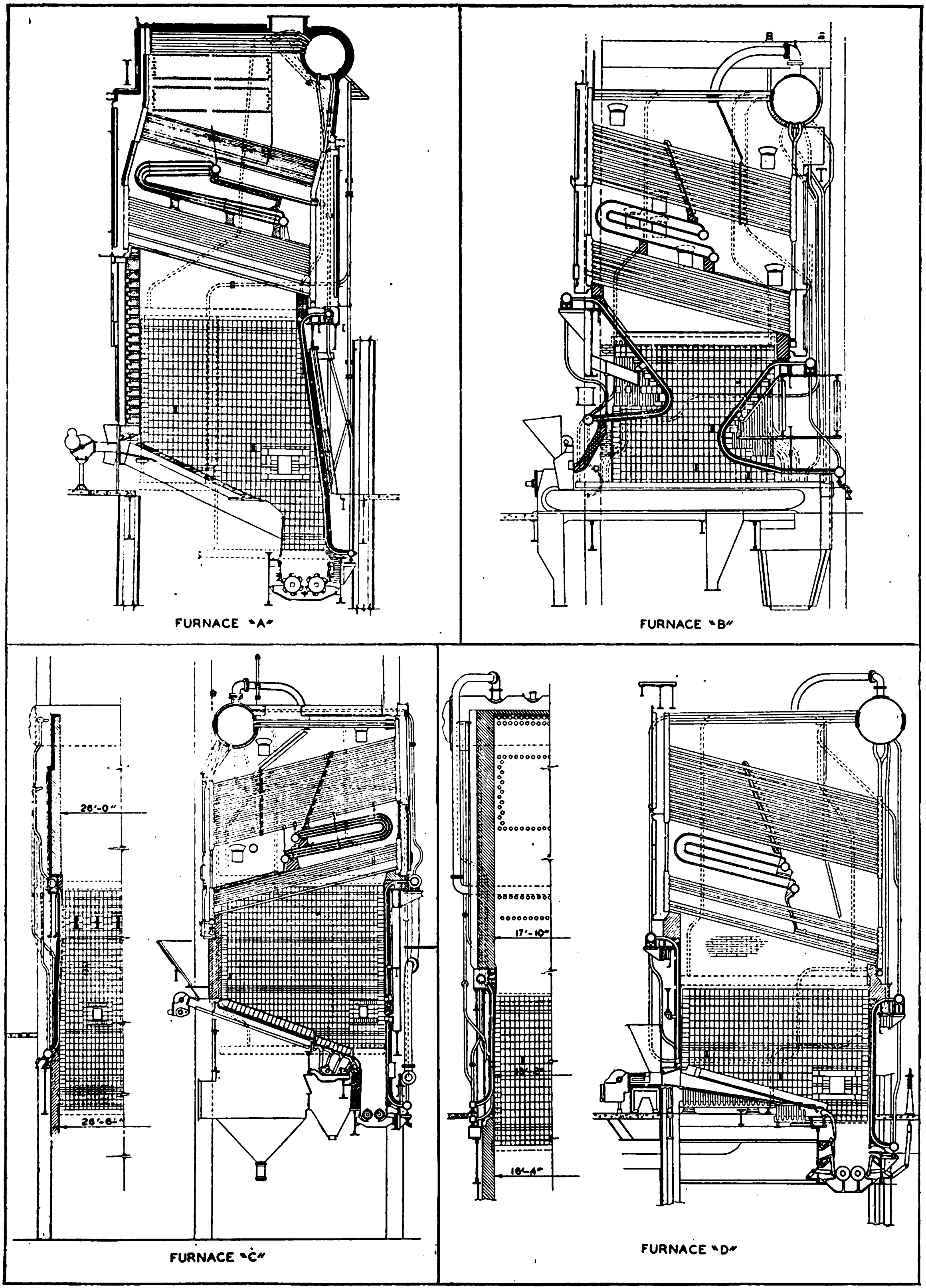
FURNACE "A"
FURNACE "B"
26'-0"
26'-6"
FURNACE "C"
17'-10"
18'-4"
FURNACE "D"

FIG. 30—EXAMPLES OF BAILEY WALL INSTALLATIONS—FULLER LEHIGH CO.

stoker, justifies carrying water-cooled surface over all walls even to the extent of eliminating refractory in the front wall. There are many smaller installations burning coal with a high ash fusing temperature and operating at moderate ratings, where only partial water cooling is justified. A protected tube type of water wall construction which will maintain its protective feature is particularly desirable in the side walls adjacent to the fuel bed and in the bridge wall from an elevation of a few feet above the stoker down into the clinker pit. Table II shows the wide variety of applications of the Bailey wall to stoker-fired boilers.

During the past year, 24 boilers equipped with Bailey walls have been placed in operation and 16 additional units are now in process of design or erection. These units represent practically all of the well known types of boilers and stokers and range in size from 6630 to 31,790 sq. ft. Ten of these furnaces represent repeat orders, placed as a result of favorable experience with previously installed Bailey walls.

In the larger sizes of boiler units the economic desirability of installing the largest possible amount of stoker grate area calls for a type of water-wall construction which is adaptable to local conditions and requirements. Fig. 30 illustrates several examples of the adaptation of Bailey furnace walls to meet unusual physical limitations of boiler and stoker design.

Furnace A is a 1400-lb. installation in which the length of the boiler tubes at the time the job was designed was limited to 18 ft. because of the extremely high operating pressure. Since the width of boiler was limited by the maximum length of drum obtainable, the capacity desired made it necessary to install a stoker of greater length than the boiler tubes in order to obtain sufficient grate surface. This difference in length was accommodated by sloping the Bailey bridgewall to the rear. Complete water cooling was installed in the side walls and the ends of the ash pit in order to insure freedom from clinker obstruction. The bridgewall at its lower end is sloped away from the stoker to provide a diverging passage for movement of refuse to the discharge crusher rolls. An access doorway was provided in each of the water-cooled side walls, by cutting out short sections of certain wall tubes and installing cross headers above and below the opening thus formed. A cast-iron frame and door with refractory lining completes the assembly, which is carried on the pressure-part structure by extended block studs. Small inspection doors are placed at strategic points in the side walls and bridgewall for convenient observation of all portions of the fire.

Furnace B was installed with complete water cooling in the side walls and arches. No difficulty was experienced in designing these arches to obtain the proper primary and secondary combustion zones in the furnace with the proper throat opening between arches. The usual problems of supporting large refractory arches were not encountered with the use of Bailey construction and no limitations were placed on the design on this account. Refractory faced blocks are used on the side walls, the bottom of the front arch, and the noses of both arches. The blocks on the under side of the front arch are a cemented-in type of refractory block which will maintain a high furnace surface temperature to aid ignition. The upper portions of the side walls and arches are of smooth bare metal block construction to reduce the temperature of the gases entering the boiler tubes and decrease tube slagging.

In furnace C it was necessary to obtain the maximum of capacity from a unit limited in size by existing building columns. In order to accommodate the widest possible stoker and to eliminate all brick work from the side walls the water-cooled walls were sloped outward from the top and at this point were made flush with the boiler setting.

Furnace D is an installation where a stoker slightly wider than the boiler at the tubes was selected. This required bending the side walls outward to match the stoker width. Previous experience with the failure of solid refractory front walls on other boilers caused this particular customer to want a water-cooled front wall. In this construction expansion is allowed for by providing clearance at the bottom of the wall which is sealed by a casting attached to the stoker feed hopper. This forms a sliding seal with the square header.

Water-cooled walls have been found to reduce stoker maintenance. This effect is marked on high capacity installations operating with highly preheated air. It has also been found that units operating under these conditions must be handled very carefully; otherwise severe heat conditions may occur at the lower end of the stoker which not only damage the stoker but may also punish any type of furnace wall construction that is installed.

The data given in Table III, which have been collected through the courtesy of operating companies, indicate the low furnace wall maintenance on a representative number of Bailey wall installations on stoker-fired boilers.

TABLE III

MAINTENANCE ON REPRESENTATIVE BAILEY FURNACE WALLS IN OPERATION OF STOKER FIRED BOILERS

Station	Avg. Cap. per Boiler Lb. Steam per Hr.	Months Service	Usage Factor	Maintenance Cost (dollar) per Ton of Coal Burned
E	85,000	31	63.7	$0.01345*
F	165,000	23	66.6	0.0
G	31,000	46	49.2	0.0
H	125,000	34	61.7	0.00146
J	100,000	28	73.0	0.00012
L	90,000	13	88.8	0.0
M	130,000	12	42.4	0.0043
N	80,000	10	72.5	0.00418
Q	85,000	25	86.5	0.0
R	50,000	11	75.8	0.0
S	90,000	12	66.5	0.0116

*Maintenance caused by tube failure due to scale formation and low water.

The protected tube type of construction is recognized as necessary in all types of water-wall construction where cooling is located in zones of intense punishment such as along the fuel bed and in the lower section of a bridgewall. The T-shaped block which fits between the cooling tubes is used in the Bailey construction. It is a wedge fit between the tubes and when it expands under the temperature conditions of operation, it tends to make a better fit and closer contact with the tubes. When expansion occurs on a block which clamps around a tube it grows away from the tube and tends to destroy any contact. With rates of heat transfer as high as 100,000 B.t.u. per sq. ft., which we have found are sometimes obtained on bare blocks installed on stoker jobs, the life of the block depends on obtaining suitable heat transfer from the block to the tubes which can be secured only by good contact and the use of proper heat conducting bond between the block and tube surfaces.

Furnace wall tubes may undoubtedly be exposed to more severe conditions than boiler and superheater tubes. Due to the location, they are at times subjected to higher rates of heat input per sq. ft. of tube surface than any other part of the boiler unit. These tubes are nearly always vertical so that the steam film, which is formed when heat is applied to water at saturation temperature, persists in following up the hot side of the tube, thereby creating a heat insulating zone of appreciable magnitude. Whenever any scale forming matter is present it is more likely to adhere to the surfaces where the higher rates of absorption are taking place. All of these factors tend toward increasing the temperature of the furnace wall tube for any given steam pressure.

For these reasons it is important to protect the furnace wall tubes against excessively high rates of heat transfer, to distribute the heat to various portions of the tube without high localized intensity, and to supplement further the strength of the tube by armoring it with a block structure which will minimize the danger from this source.

The Fuller Lehigh Company has developed a rough sur-

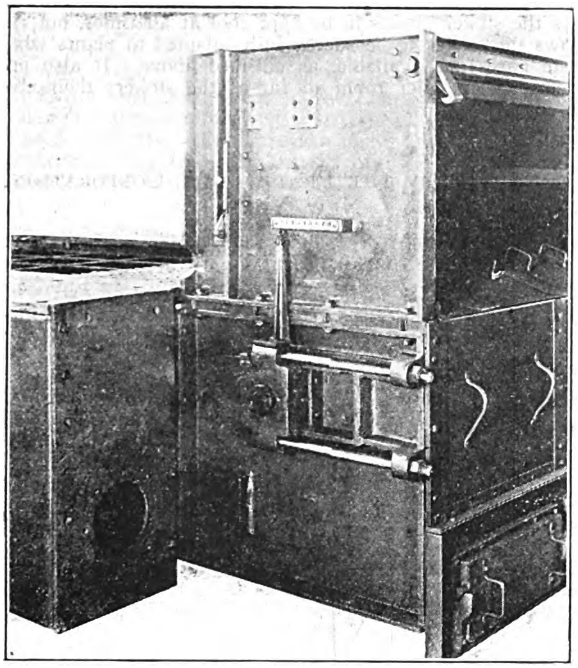

FIG. 31—TAKE UP INDICATOR—ILLINOIS STOKER CO.

faced bare metal block which has been used in place of refractory faced blocks. This block has a ribbed surface somewhat like the surface of a waffle iron to which the fly ash and slag will adhere and gradually build up a refractory coating. For certain conditions this block admirably serves the purpose of the refractory block.

Probably the first water-cooled installation on a stoker-fired boiler burning anthracite screenings was placed in service early in January, 1929, at the Nanticoke plant of the Glen Alden Coal Company. This is a 6680 sq. ft. chain grate stoker-fired Stirling boiler equipped with Bailey side walls. The results obtained from this installation will be watched with interest.

The rehabilitation of old stoker-fired boilers with modern water walls is of some interest. Experience has proved that it is not only possible by this means to reduce high furnace maintenance, but also to increase both efficiency and capacity.

The Memphis Gas & Electric Company installed Bailey bridgewalls on three of the boilers in their Fourth Street plant in April, 1927, to eliminate high furnace maintenance. Prior to the installation of Bailey walls, it was necessary to renew these bridgewalls about every six to nine months. Since that time they have had no maintenance on the Bailey wall and the refractory above the water-cooled portion is protected sufficiently by radiation from the boiler tubes to have required little maintenance.

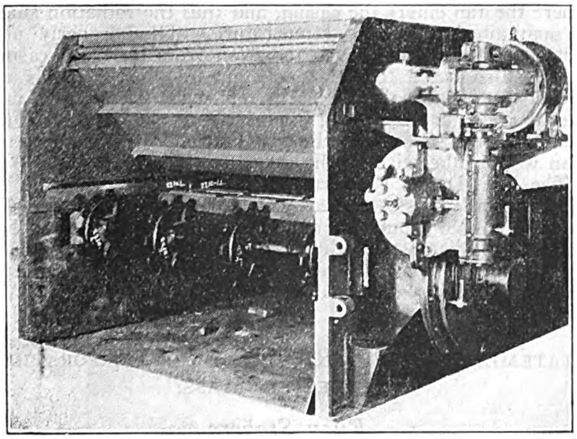

FIG. 32—NEW TYPE DRIVE FOR FORCED DRAFT CHAIN GRATE STOKER—FRONT VIEW—ILLINOIS STOKER CO.

Tests reported by The Philadelphia Electric Company, which were run on their Boiler No. 7 at Chester both before and after the installation of water walls, indicate an increased efficiency after the walls were installed. This difference was of the order of 2 per cent at normal ratings and 5 per cent at maximum ratings of about 12,000 lb. of coal per hr.

STATEMENT BY THE ILLINOIS STOKER COMPANY, ALTON, ILL.

Major Improvements on Illinois Forced Draft Chain Grate Stoker

1. Take-Up Indicator

During the past year the Illinois Stoker Company has designed and applied to its forced draft stokers a take-up indicator for the purpose of checking the alignment of the front drive shaft. Referring to Fig. 31, it will be seen that this feature consists of a cast iron pointer bolted to the front shaft bearing, this construction being applied to both sides of the stoker. A brass scale is attached to the upper part of each stoker head frame. By means of the pointers and scales the operator can at all times easily check the alignment of his front drive shaft and make sure that the two pointers indicate the same reading on the scales. Heretofore there has been no convenient method provided for checking the alignment of the front shaft, and for this reason very little attention has been paid to this point by the operator. If the front shaft is allowed to become out of line, it usually follows that the chain works to one side, or may jump the front sprockets, or various other difficulties, all of which involve the possibility of breakage and shut-down.

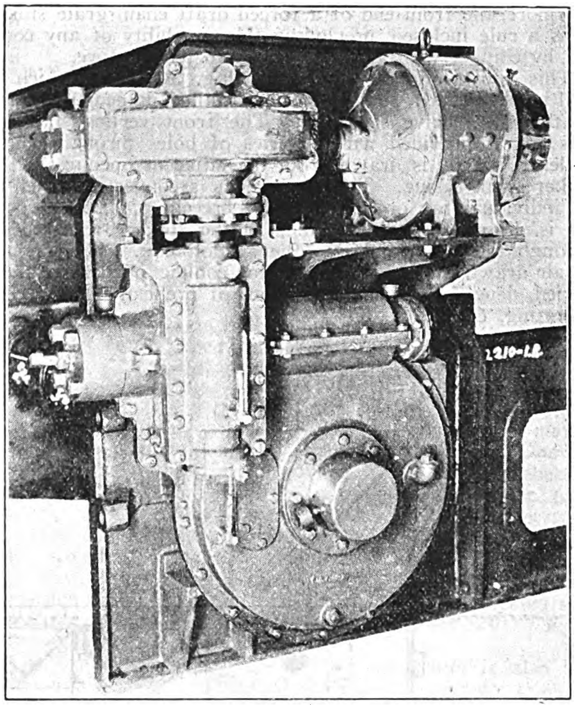

FIG. 33—NEW TYPE DRIVE FOR FORCED DRAFT CHAIN GRATE STOKER—SIDE ELEVATION—ILLINOIS STOKER CO.

With this new feature, it is very easy for the operator to make sure at all times that the front drive shaft is properly lined up.

2. New Drive

This company has developed a new type of drive for its forced draft chain grate stokers, as is shown on Fig. 32 and 33, which consists of three worm and gear reductions mounted in series and driven by a direct connected motor having a wide speed range. The entire drive is integral with the front drive shaft of the stoker, and moves forward or backward as the chain take-up bolts are adjusted. All gears and worms are equipped with cut teeth and are running in oil, and thrust bearings are provided where necessary.

The distinct advantages of this new drive are that it eliminates the necessity of using belts, belt tighteners, chain drives, etc.

3. Chain Cooling

A new system of cooling stoker chains, especially where preheated air is used, recently has been developed by this company. In this type of stoker very little heat radiation escapes from the chain before re-entering the furnace, due to the fact that the chain is subjected to a high degree of heat, not only in passing through the furnace, but also in traveling from the rear of the furnace to the front. Furthermore, the front end of a forced draft chain grate stoker is as a rule inclosed, precluding the possibility of any cooling by contact with air at boiler room temperature.

This construction is shown on Fig. 34, from which it will be seen that a suction box is installed immediately back of the front drive sprockets. The front vertical face of this box is provided with a series of holes through which boiler room air is drawn from the adjacent opening in the stoker front casing. This cross duct is connected either to an individual fan or to the boiler breeching. Boiler room air is drawn through openings in the stoker front casing through the chain and into the suction box. The amount of air drawn through the chain for cooling purposes can be varied, depending upon the amount of preheat, the per cent of rating, etc.

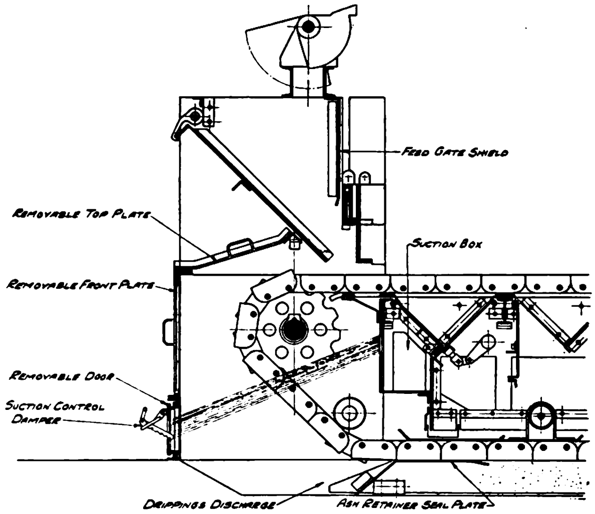

FIG. 34—ENCLOSURE OF FRONT END OF FORCED DRAFT CHAIN GRATE STOKER—ILLINOIS STOKER CO.

In some industrial plants gases having a higher or lower calorific value are made as a waste by-product. It has become common practice to convey these gases to the boiler room and use them as at least a part of the medium for burning the fuel on forced draft chain grates. Any escape into the boiler room of such gases as hydrogen-sulphide, sulphur dioxide and carbon monoxide makes operatating conditions a menace to health.

Dust also escapes from the front of a stoker, making operating conditions unsatisfactory.

It will, therefore, be seen that this feature not only allows the stoker chains to be kept cool at all times, but also allows the stoker to be successfully adapted to plants where waste gases are available, as outlined above. It also provides a clean boiler room so far as the stokers themselves are concerned.

STATEMENT BY THE PRAT-DANIEL CORPORATION, NEW YORK

The Prat-Daniel Corporation for a number of years has advocated the use of ball bearings with induced draft fans instead of water-cooled bearings. As shown in Fig. 35, a circular plate divided at the center so that it can be removed from the shaft is placed along the side of the induced draft fan portion of the Thermix Stack and located about 2 in. from the metal of the fan or stack itself. This radiation shield is approximately the same size as the fan wheel.

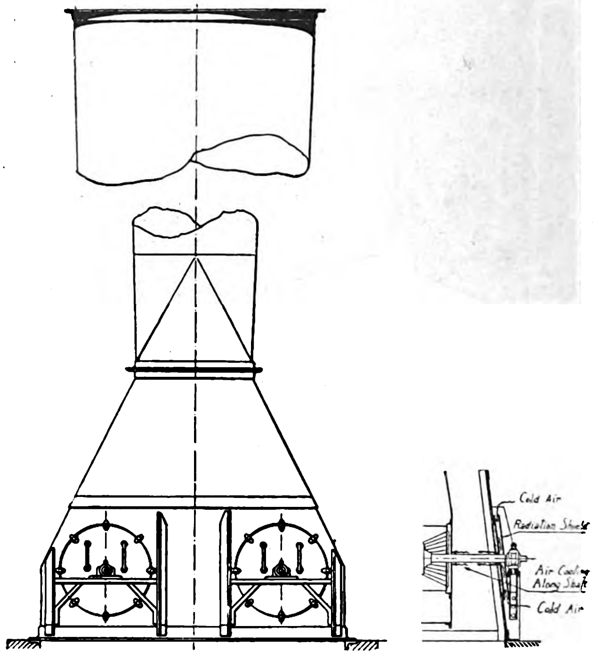

FIG. 35—THERMIX STACK AND INDUCED DRAFT FAN WITH BALL BEARINGS—PRAT DANIEL CORP.

An annular opening of about ¼ in. is made around the shaft at the point where it enters the fan casing or inlet box. Cold air is, therefore, constantly drawn to the point where the fan enters the casing, and thus the radiation shield is maintained at a low temperature. This properly protects the ball bearings from radiation from the stack casing.

It is also noted that this cold air leakage, which is not sufficient to materially affect the efficiency of the fan, carries the air directly along the shaft to the center of the fan, and thus maintains the shaft at a lower temperature than would otherwise be the case.

The Prat-Daniel Corporation has used this system in all of its installations, some of which handle gases up to 750 deg. fahr. No trouble is experienced from overheated ball bearings. This system is considered superior to water cooling due to the possibility of the water being shut off and the bearing becoming damaged in consequence.

STATEMENT BY THE RILEY STOKER CORPORATION, WORCESTER, MASS.

Riley Stokers

The demand for higher capacities and maximum efficiencies at high boiler ratings has continually increased during the past year, so that in practically every large stoker installation the stoker has been increased in length so that it takes up the entire furnace depth. This increase in the length of underfeed stokers necessitated many changes in their design. It was necessary to strengthen the main supporting members, which in the case of the Riley super-stoker are the reciprocating retort sides. This was accomplished with the Riley super-stoker by using a box construction in the side bars instead of merely extending one flange as used with the smaller Riley stokers. Fig. 36 shows this construction and gives some idea of the extreme ruggedness of the present side bars of the Riley air-zoned super-stoker and the method used to completely air-zone this stoker. A typical Riley air-zoned super-stoker is that installed at the Stamford Gas & Electric Company plant at Stamford, Conn; the length of this stoker is 19 ft., 2 in.

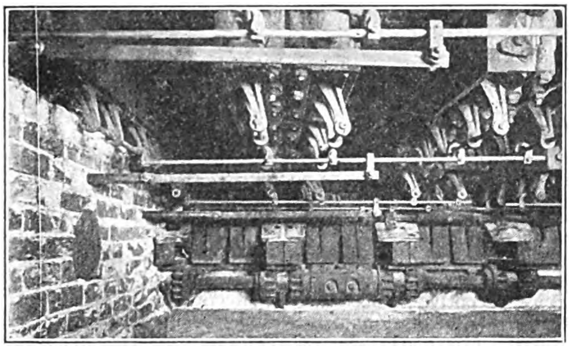

FIG. 36—STOKER CONSTRUCTION—RILEY STOKER CORP.

The high coal burning capacities of the modern underfeed stokers also demanded an increase in the size of the clinker-grinder pits. This was accomplished by the use of double roll clinker grinders and by increasing the depth of the pits to over 6 ft., as compared with previous designs having a depth of not quite 4 ft. The greater depth was obtained by increasing the size of the air admitting rocker grate. Fig. 37 shows the clinker grinder pit used on the large Riley super-stokers at the new unit of the Kearny Station of the Public Service Electric & Gas Company. A further refinement has been made to the operating mechanism of the clinker grinders. This mechanism is now so designed that each roll can be operated at a different speed, or, if desirable, one roll can remain stationary and the other roll can be operated at the speed desired. Details of this operating mechanism are shown in Fig. 38.

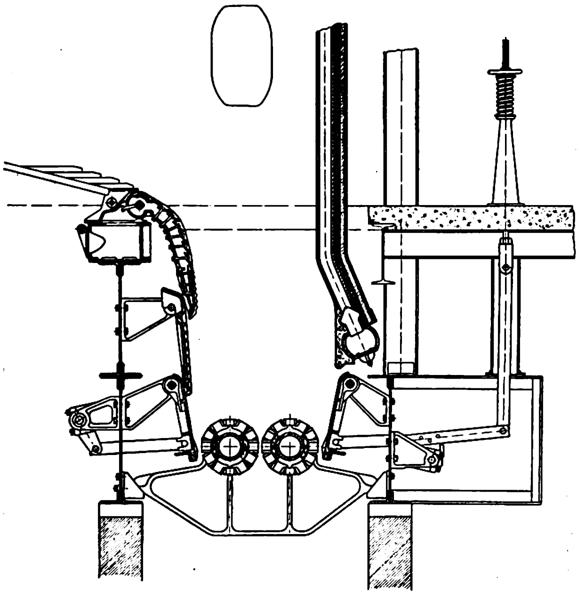

FIG. 37—CLINKER GRINDER PIT CONSTRUCTION—KEARNY STATION.

A new hydraulic drive for operating the clinker grinder of the Riley super-stoker has been developed and installed at the Kearny plant of the Public Service Electric & Gas Company. This drive consists of a hydraulic cylinder, which is operated by means of a special valve.

Because of the quantity of coal which must be fed to these large underfeed stokers, either the speed or size of the standard feeding mechanism must be increased materially. In order to retain maintenance at as low a figure as possible, the Riley Stoker Corporation has increased the size and stroke of the coal feeding mechanism, so that at the present time it has the greatest coal feeding capacity per stroke of any underfeed stoker. The use of the large plunger necessitated wider retorts, and on the face of things it would appear that this meant a decrease in the area of air admitting tuyeres. This disadvantage was overcome by increasing the size of the grate blocks immediately beyond the coal chutes, so that, with the Riley super-stoker, the ratio of air admitting grate area to retort area is very large.

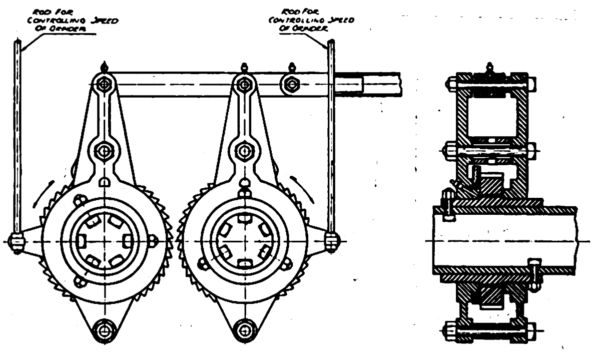
ROD FOR CONTROLLING SPEED OF GRINDER
ROD FOR CONTROLLING SPEED OF GRINDER

FIG. 38—OPERATING MECHANISM CLINKER GRINDER ROLLS—RILEY STOKER CORP.

The use of highly preheated air has become quite standard. The limiting factor is stoker maintenance. One of the situations to be overcome when using highly preheated air was the large amount of expansion of the stoker, particularly with the largest size. It was not found necessary to make any changes in the general construction of the Riley stokers to take care of this expansion, because there is a free lengthwise expansion of 8 in. and free sidewise expansion of ¾ in. per retort. In the use of preheated air, therefore, the use of reciprocating retort sides proved most advantageous.

The use of preheated air in smaller plants is also increasing. A recent installation consisting of two 2500-sq. ft. return tubular boilers with Riley stokers, preheats air up to 510 deg. fahr. without an appreciable increase in maintenance.

The increase in the length of underfeed stokers has made necessary better air distribution and control throughout the length of the stoker. With the shorter stoker of a few years ago it was sufficient to have control over the air to the overfeed section and one control for the underfeed section, but that is not true with the stokers 20 ft. long. Present Riley super-stokers are completely air-zoned, the entire air admitting surface being under damper control. Each side bar is equipped with a variable number of small dampers depending upon the length of the stoker. Very often the number is as high as seven, so that with these long stokers there are seven different air compartments for each side bar. The air pressure in each of these zones can be controlled individually to meet any desired requirement. Fig. 36 shows these small air zones with the dampers and operating mechanism.

The design of the chute of the Riley super-stoker has

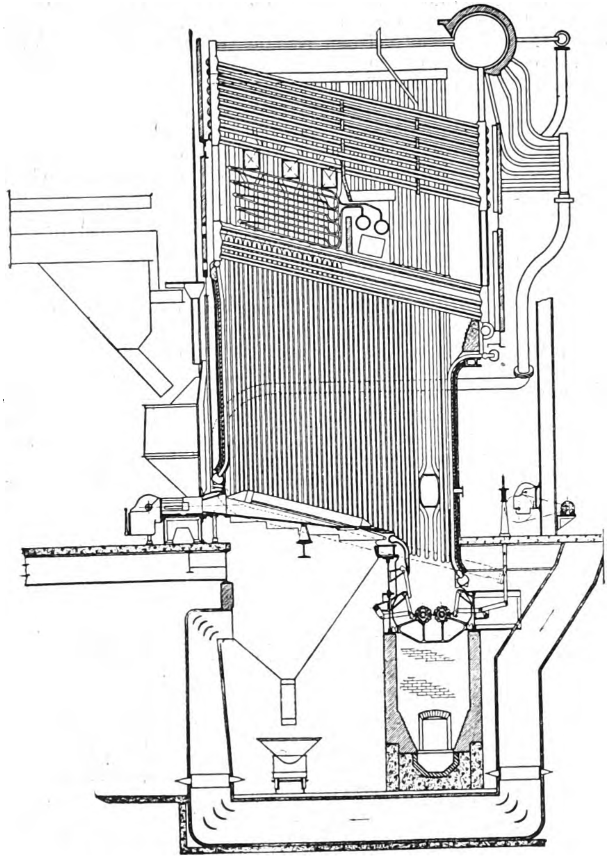

FIG. 39—BOILER UNIT—KEARNY STATION.

been changed so as to admit air at the front wall of the stoker. This air is under separate damper control, the operating handles being located at each side of the stoker at the front.

The effectiveness of the air-zoning feature of the Riley air-zoned super-stoker is indicated by the results being obtained at the Hollingsworth and Vose plant at West Groton, Mass. This is a small installation of a 5000-sq. ft. boiler without water walls, air preheaters or economizers, and in spite of this absence of auxiliaries, efficiencies of 83 per cent are being obtained.

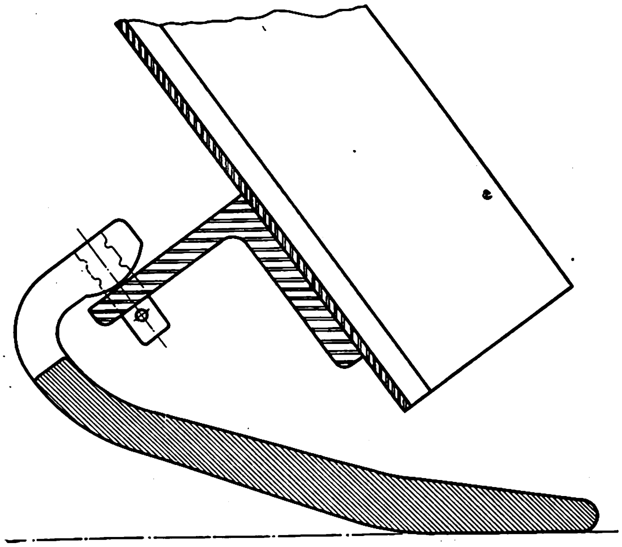

FIG. 40—CLIP LEVELING DEVICE—HARRINGTON TRAVELING GRATE STOKER.

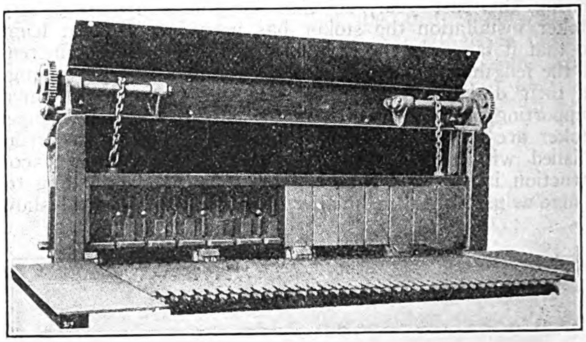

FIG. 41—GATE WITH REFRACTORY LINING—HARRINGTON STOKER.

New units of the Kearny Station of the Public Service Electric & Gas Company (Fig. 39) have been placed in service recently. This installation consists of 22,600-sq. ft. boilers with large double roll clinker-grinder stokers. High air preheat is used. An unusual feature is the water wall construction. The water walls completely cover the inside of the furnace, extending to the very top of the boiler instead of stopping at the boiler tube line. The additional heat recovery, because of this extension of the water wall tubes, more than pays for the additional expense of this construction.

Harrington Stokers

Refinements have been made to the Harrington traveling grate stoker. A clip leveling device has been developed, which forces the clips into mesh and at the same time eliminates any possibility of coal getting between the clip edges and preventing them from properly meshing. (See Fig. 40.) This improvement has materially reduced clip maintenance on many installations.

Improvement also has been made to the gate and gate lifting mechanism. The method of retaining the refractory lining in the gate is now designed so that the metal gate shoes are not subjected to the heat of the furnace. (See Fig. 41.) The gate lifting mechanism has been improved by using worms and gears, so that gates on the widest stokers can be easily raised or lowered, as shown in Fig. 42.

Unusual life has been given to the rear track of the Harrington stoker by using a renewable track of white iron, which is mounted on the base casting. When replacements are necessary they are easily made and at a low cost.

Gratifying results have been obtained with the Har-

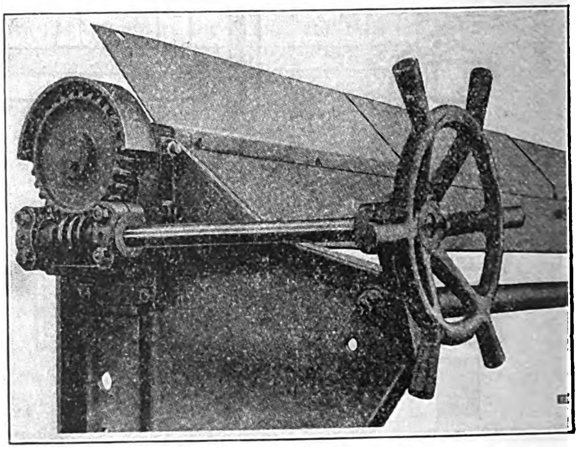

FIG. 42—GATE LIFTING MECHANISM—HARRINGTON STOKER.

rington stoker for burning the poor grade lignites of the Northwest. At the Kidder Station of the Otter Tail Power Company, Wahpeton, N. D., two 7500-sq. ft. boilers are each equipped with two 8 x 16-ft.-Harrington traveling grate stokers with a center refractory wall. Air preheaters are used. The installation has been operated at ratings as high as 300 per cent of boiler rating, and there is every indication that higher capacities could be obtained. Exceptional efficiencies are obtained with this lignite, which contains approximately 6500 B.t.u. per lb. and has a moisture content ranging as high as 40 per cent. With a good load factor the station can generate a kilowatt-hour on 3.5 lb. of this low B.t.u. high moisture coal.

A recent installation of Harrington stokers has been made for burning anthracite silt at the New York, Ontario and Western Railroad at Middletown, N. Y. This silt has a low B.t.u. content and a very high ash content. Results have been most satisfactory. Another installation for burning No. 4 buckwheat was completed at the Lehigh Wilkes-Barre Coal Co. at Wilkes-Barre, Pa. Operation with this fuel was very satisfactory.

An interesting installation of Harrington stokers is that at the Fitchburg Gas & Electric Company at Fitchburg, Mass. These stokers were installed primarily for burning an unmarketable grade of gas house coke breeze. This fuel when mixed with bituminous coal was tried on underfeed stokers but with unsatisfactory results, so that the disposal of it in this manner was abandoned. The fuel was handled very well with Harrington stokers. When this fuel was exhausted, the yard screenings from the different anthracite coal dealers in Fitchburg was used, and when this fuel supply was exhausted eastern bituminous coal was used. Mention of this installation is made because of the satisfactory use of three widely different fuels on the same stoker and with the same setting.

Jones Stokers

An unusual stoker drive has been developed for mechanically operating Jones stokers. This new drive is known as the Riflex mechanical drive because of its extreme flexibility. With this drive and the use of a constant speed motor, the coal feed to the stoker can be varied between the limits of 60 and 6000 lb. of coal per hr. Coal can be fired at practically any rate between these two limits. The drive consists of a single spur gear reduction, and the extreme flexibility is obtained by using an intermittent stroke of the plunger. The number of strokes per hour depends upon an unique timing mechanism, which is illustrated in Fig. 43.

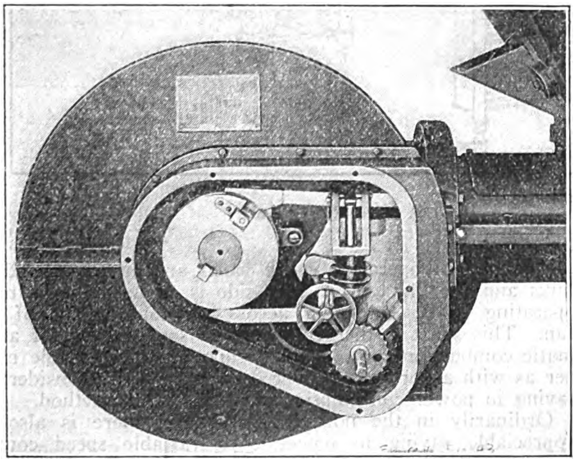

FIG. 43—TIMING MECHANISM—JONES STOKER.

Based on experience with the original Jones stoker unit, a new unit has been developed. The fan and motor have been removed from under the stoker ram case, where they were subjected to the heat of the furnace and where they operated in a great deal of dirt and grit. They are now located in front of the stoker drive, where they are accessible and away from the furnace. This still gives a compact unit without the disadvantage of the original unit. This unit, with which the Riflex drive is used, can be tied into automatic control in so far as wind box pressures and coal feed is concerned. This is accomplished by using a regulating valve which varies the rate of coal feed and controls the damper on the forced draft fan.

Riley-La Mont Water Wall

As an alternative to natural boiler circulation and large diameter tubes the Riley-La Mont water wall (Fig. 44) is available. It is based upon the use of forced circulation and constructed of long diameter flexible tubes in conjunction with relatively small headers which insure positive and proper distribution of the forced circulation.

In the Riley-La Mont water wall positive circulation is maintained in a single direction by means of a centrifugal pump of proper characteristics and by distributing orifices, which meter the proper quantity of water to each individual tube. Water enters the circulating pump by gravity from a drum of the boiler and its pressure is increased by the pump from 15 to 40 lb., depending upon the rate of heat absorption of the water walls, diameter and length of tubes, number of bends, etc. This water enters a header which is supplied with distributing orifices that meter the proper quantities of water supplied to each tube.

The capacity of these orifices is such that the quantity of water forced into each tube is several times the quantity of water which will be evaporated under the conditions of maximum heat absorption. This quantity of water, however, is insufficient to fill the tube.

As heat is absorbed in the tube, part of the water is turned into steam, which compared to the quantity of water is very great in volume. This steam produced cannot find its way out of the orifice due to the pressure drop of water across the orifice caused by the mechanical pump circulation. The orifice end being closed to steam travel gives a positive insurance against steam locking in the tube. The steam produced therefore must leave the other end of the tube, entering the header which is connected into the steam space of the boiler.

The tubes are long, compared to their cross sectional area, so that the steam produced generates exceedingly high velocities in the tubes. By selecting the proper diameter of tube relative to its length and duty, this velocity can be kept between approximately 1000 to 4000 ft. per min. or more, which is many times as fast as the velocity of water and steam in a natural circulation type of water wall. The steam from the header moving at great velocity carries with it the excess water which entered through the orifices. This amounts to approximately 80 per cent by weight, but is only about 1 or 2 per cent by volume.

It may be seen that with such positive circulation steam binding under these conditions is impossible, and the precipitates formed will be swept from the tube surface by the high velocity of water and steam provided the water has been softened by chemicals to any reasonable degree. The reverse is also true.

If through careless water treatment a scale is formed the use of an increased quantity of chemicals will soften the surface of the scale which the high velocity of water and steam will gradually wear away as each layer of softened surface scale is exposed.

Further, with forced circulation, the tubes may be installed vertically, horizontally or inclined in any direction with the flow either up or down and the tubes can also be bent at any angle to avoid structural obstacles and furnace openings. Due to high velocities in the tubes, the headers and connecting pipes to the drums can be very small in comparison with natural circulation types of water walls, to convey a given quantity of steam carrying its small amount of moisture.

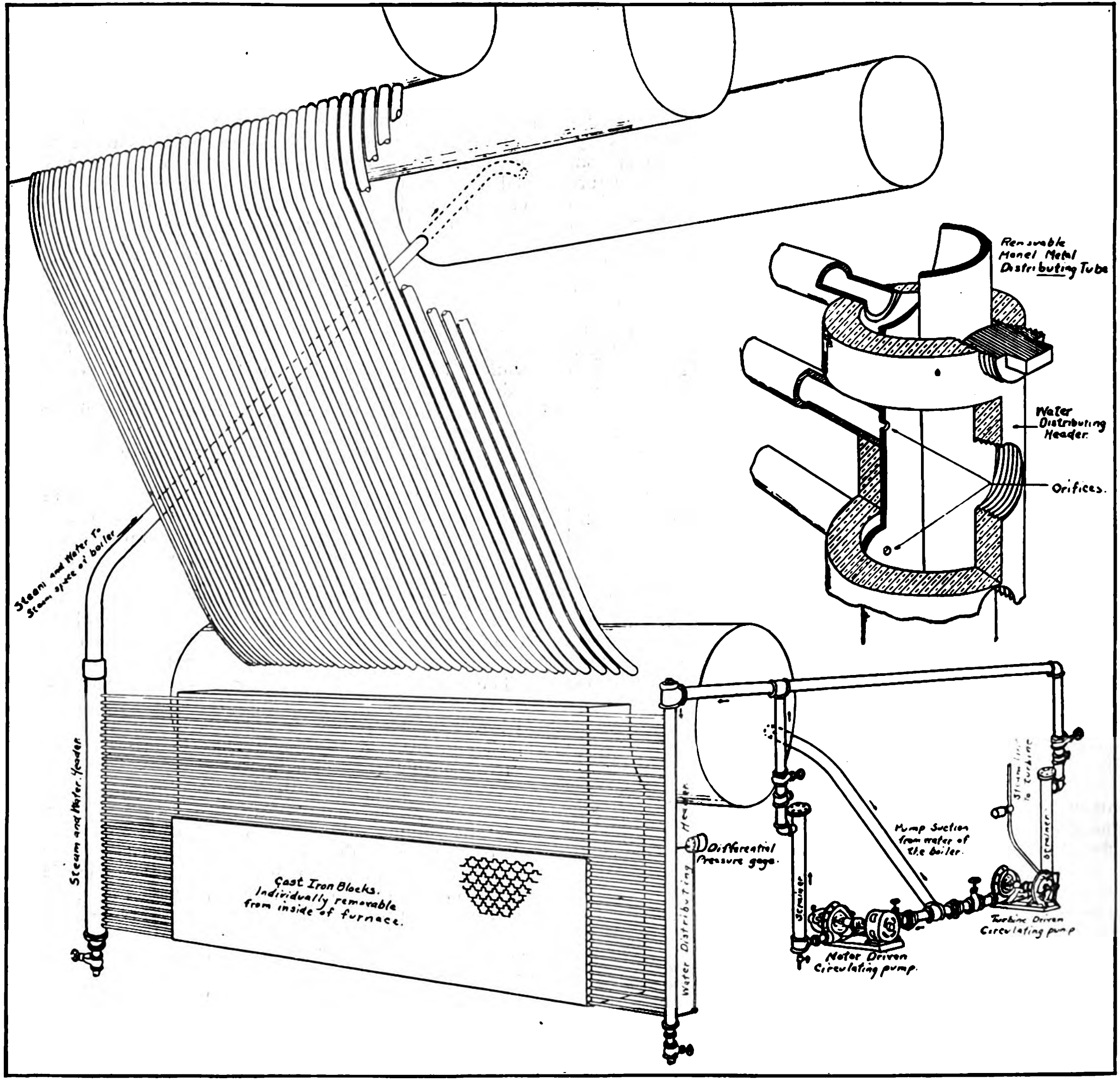
Removable Monel Metal Distributing Tube
Water Distributing Header
Orifices.
Steam and Water to Steam space of boiler
Steam and Water Header
Cast Iron Blocks. Individually removable from inside of furnace.
Water Distributing Header
Differential Pressure gage.
Strainer
Pump Suction from water of the boiler.
Steam line to Turbine
Strainer
Motor Driven Circulating pump.
Turbine Driven Circulating pump

FIG. 44—CONSTRUCTION OF RILEY-LA MONT WATER WALL SYSTEM.

STATEMENT BY THE B. F. STURTEVANT COMPANY, HYDE PARK, BOSTON, MASS.

Induced Draft

In the 1927-28 Report of the Subcommittee on Stokers and Furnaces, the Sturtevant Turbovane I.D. fan for induced draft was announced. There are two main features, not found on any other type of induced draft fan. The first is the elimination of the uncertainty of inlet box loss by supplying inlet boxes as an integral part of the fan, the fan characteristics having been determined with these boxes attached to the fan. These boxes are of spiral shape and are provided with spiral vanes which guide the gas into the wheel evenly from all sides, thus eliminating the indeterminate effect of the uneven inlet flow resulting from the older type of inlet box.

The second, and almost as important feature, is the method of volume and pressure control. The spiral shaped vanes in the inlet boxes are made to pivot on short shafts at each side of the inlet boxes, the vanes overlapping each other when entirely closed. The fan is driven by a constant speed squirrel cage motor and the pressure and volume controlled by opening or closing the vanes. Fig. 45 shows the method of operation. The vanes are interconnected by links and the linkage on each side is connected to a main operating shaft, extending across the top or side of the fan. This shaft is then connected to some system of automatic combustion control which functions in the same manner as with an ordinary boiler damper but with considerable saving in power consumption over this latter method.

Ordinarily in the normal load range, there is also an appreciable saving in power over variable speed control in addition to the saving in motor investment.

Forced Draft

For forced draft, the volume is controlled by V-shaped vanes placed radially in the cone inlet. These vanes are operated by bevel gears and a linkage similar to that used on the induced draft fan. This is shown in Fig. 46.

STATEMENT BY THE WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY

Probably the most outstanding development in coal burning equipment in recent years is the application of an undulating link-grate overfeed section to long multiple retort underfeed stokers. Fig. 47 illustrates this arrangement. In combination with the usual underfeed retorts, it produces a stoker which has the simple and effective combustion principles of the underfeed stoker and the positive fuel and refuse conveying ability of an undulating link-grate system.

Fig. 48 shows the application of a 15-retort stoker of this type under a 23,800 sq. ft. B. & W. boiler at the Hudson Avenue Station of the Brooklyn Edison Company. Four of these units are in service. Fig. 49 is a preliminary layout for the three 31,800 sq. ft. boilers for the new Reed Station of the Duquesne Light Company on Brunots Island, Pittsburgh.

The principle of this design is that a flat undulating grate surface of large area extending across the entire width of the furnace moves as a unit at the rear of the stoker. It receives fuel and refuse discharged from the lower ends of the retorts of the underfeed stoker and effectively completes the combustion of this fuel and discharges the refuse into the clinker-grinder pit. This overfeed grate surface is made of a sufficient size so that large quantities of coal may be burned on it, thereby permitting a large amount of coal to be discharged from the retorts. In fact, so much coal is discharged that the ash, which normally collects on the lower tuyeres of the underfeed stoker, is almost completely wiped away by the moving coal. The fire on the underfeed section is, at all times, free from undesirable ash and clinker accumulations.

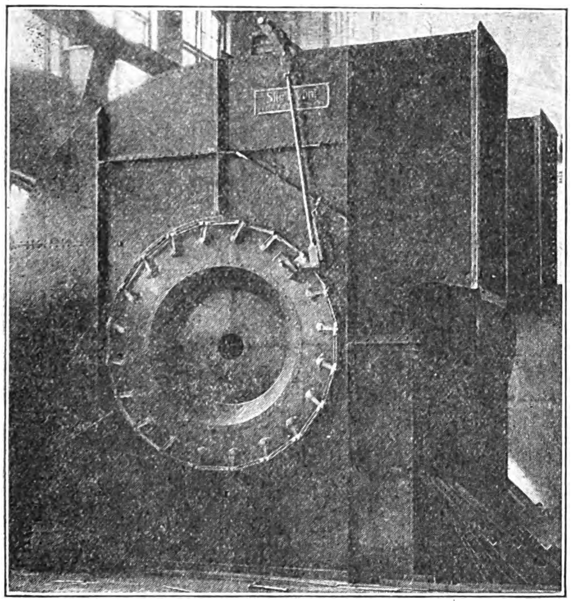

FIG. 45—VANE CONTROL INDUCED DRAFT FAN—B. F. STURTEVANT CO.

This flat and continuously moving grate surface carries the fuel and refuse away from the underfeed section uniformly, regardless of the character of the fuel or its clinkering tendencies. Therefore, a constant minimum resistance is present at the lower end of the retorts and the retorts are enabled to maintain proper fuel distribution with very little attention or adjustment by the operator.

The fuel is burned on the overfeed section in approximately the same combustion cycle as on the underfeed section. The streams of fresh fuel pass from the retorts onto the grate, while streams of ash and actively burning coke pass from the tuyere rows on to the grate. The motion of the grate is such that as the fresh fuel from the retorts moves along, it is spread into the burning lanes from the tuyeres until a homogeneous body of ignited fuel results. The lower end of the overfeed grate completes the combustion of the mixture of coal and ash and discharges the refuse positively and uniformly into the clinker-grinder pit.

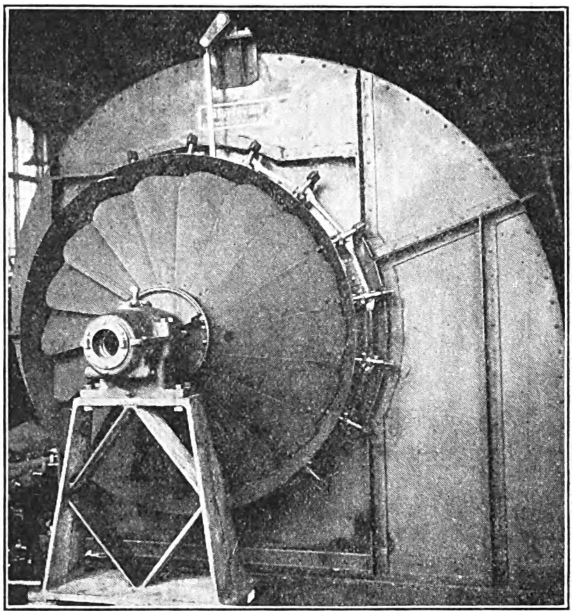

FIG. 46—VANE CONTROL FORCED DRAFT FAN—B. F. STURTEVANT CO.

The motion imparted to the overfeed grate surface combining positive conveying action and breaking motion, prevents the formation of large clinkers. The refuse is well broken and uniformly sized and is ground very easily and uniformly by the clinker grinder.

The motion of the undulating link-grate overfeed element is controlled separately from that of the stoker feeding rams. Therefore, the regulation of the ash discharge from the stoker is accomplished without disturbing the distribution of fuel in the retorts and over the tuyeres. Separation of the two control functions makes the stoker adaptable to handling all grades of fuel with a minimum of attention and adjustment. Adjustments to compensate for changes in the ash content or other characteristics of the fuel can be made whenever their necessity becomes apparent, without interfering in any way with the rate of feeding of the fuel.

A brief description of the link grate will illustrate its action.

Referring to Fig. 47, it will be seen that the grate consists of a series of grate supporting frames hinged together to form a chain-like series as shown by A-B-C-D-E. The upper frame A as pivoted to the lower end of the underfeed section, or retort, at P.

The grate surface proper consists of grate bars fastened in the frames, and the grate bars assemble into a flat, smooth grate surface. The frames are each 21 in. wide,

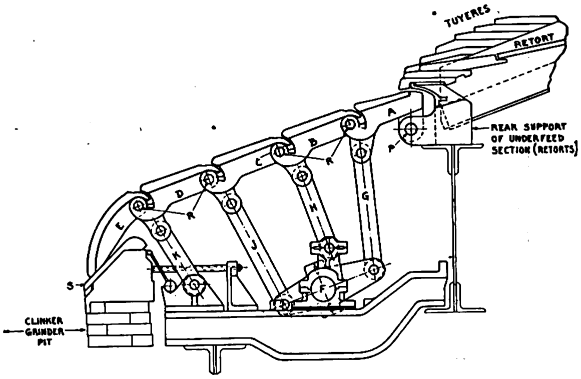

FIG. 47—UNDULATING LINK GRATE OVERFEED SECTION—WESTINGHOUSE UNDERFEED STOKER.

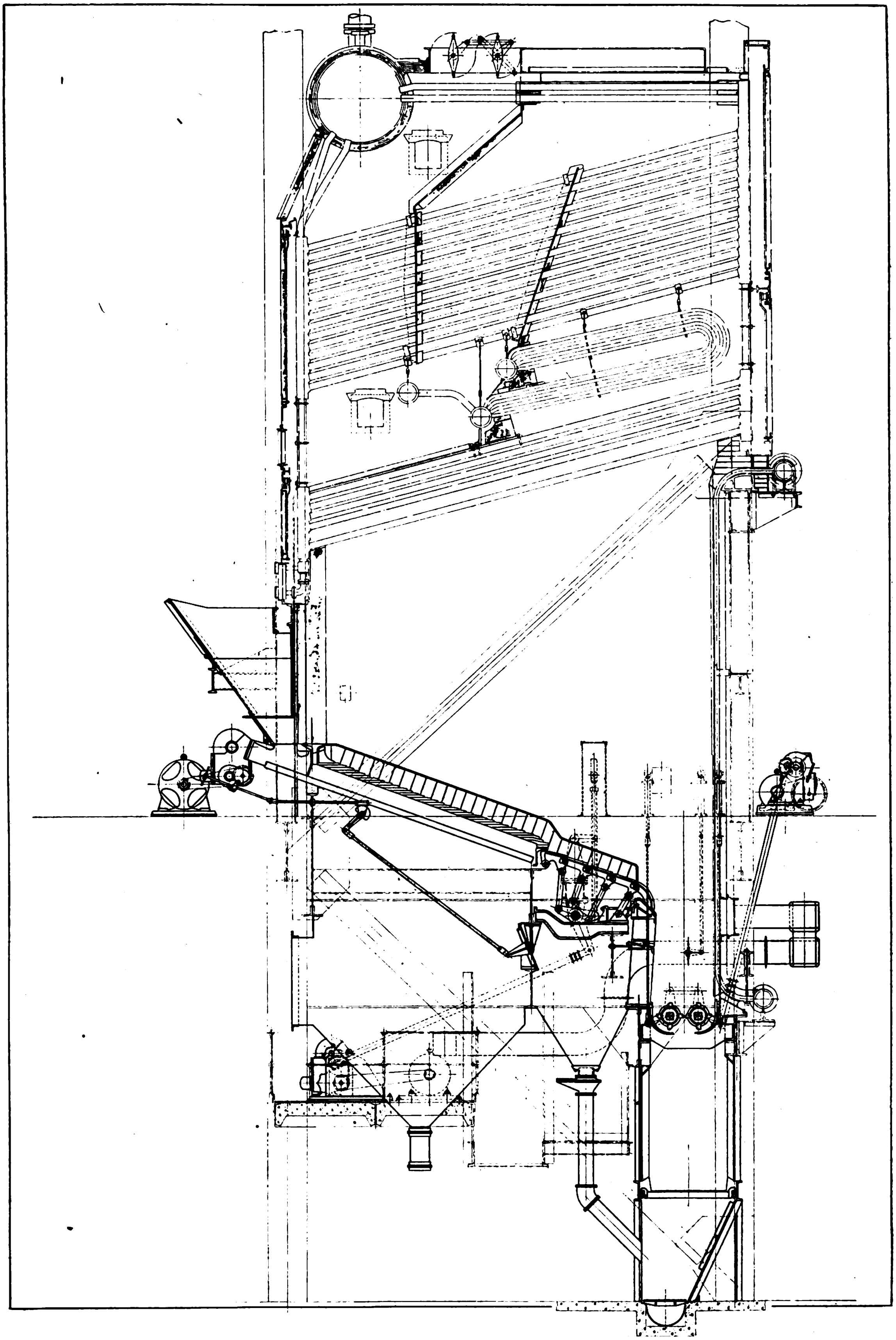

FIG. 48—WESTINGHOUSE UNDERFEED STOKER WITH UNDULATING LINK GRATES.

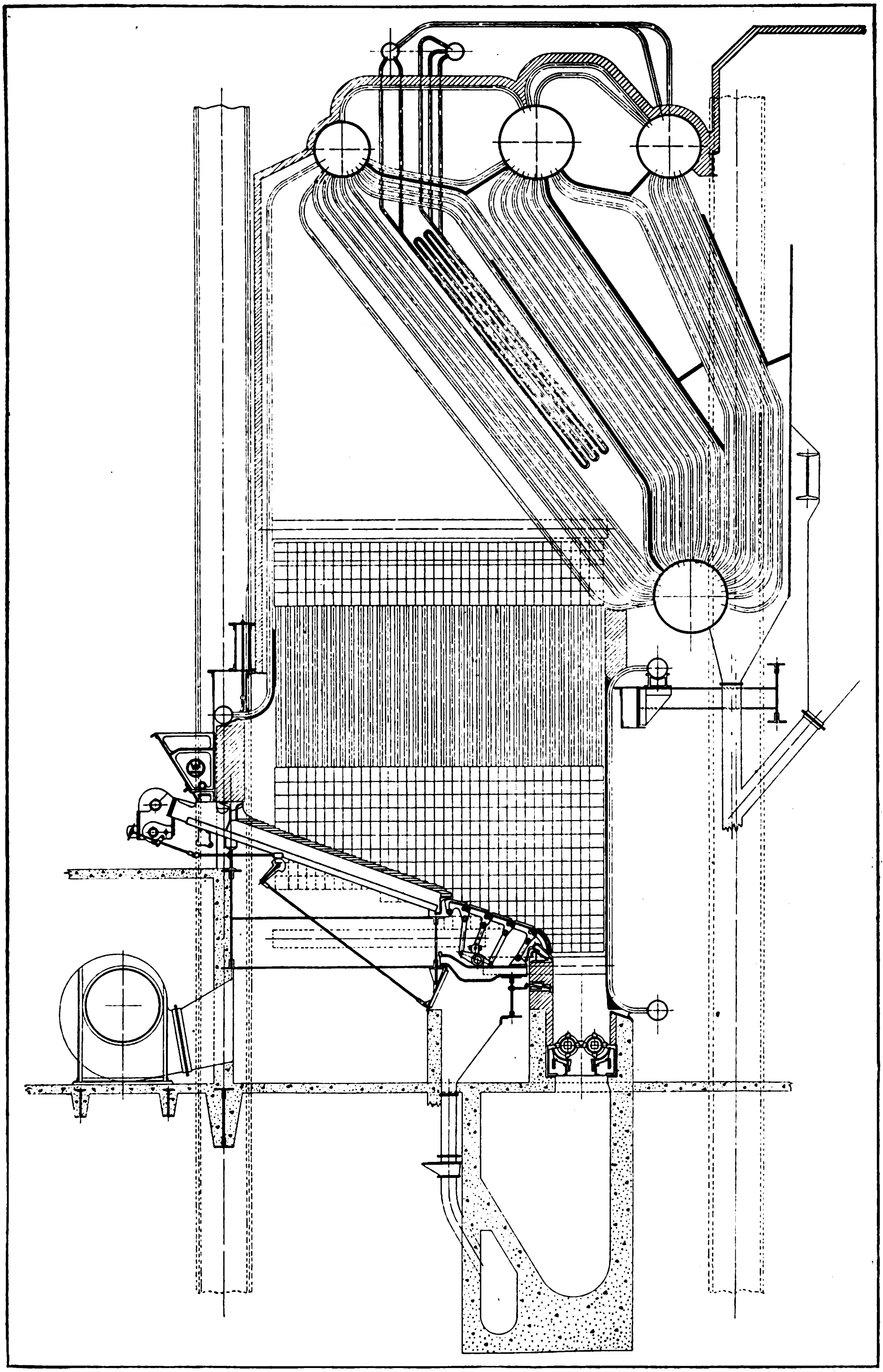

FIG. 49—PRELIMINARY LAYOUT FOR THREE NEW BOILERS—REED STATION—DUQUESNE LIGHT CO.

corresponding to the width between centerlines of tuyere rows. Hence, the grate surface is composed of 21-in. sections. In each frame there is a key grate which is retained by a removable pin. Removing the pin and the key grate allow the remaining grates in the same frame to be lifted out when necessary for renewals.

A drive shaft, F, imparts motion to a rocker bar which, through arms G and J, impart rocking motion to the ends of frames A and C. This sets the entire grate system in undulating motion.

Links H and K merely act as free-moving supports for the other joints of the system. A stationary grate, S, supports the sliding lower end of frame E.

The rest or zero position is shown in Fig. 47. The solid lines, Fig. 50, indicate the positions of the frames when frame A is in its highest position. The dotted lines indicate positions when frame A is in its lowest position.

It will be noted that, due to pivot P being below the line of centers of the hinge pins, oscillation of frame A causes this frame to have a reciprocatory motion, which in turn gives the entire grate system a similar motion. This reciprocatory motion gives the link grate its conveying or fuel propelling effect.

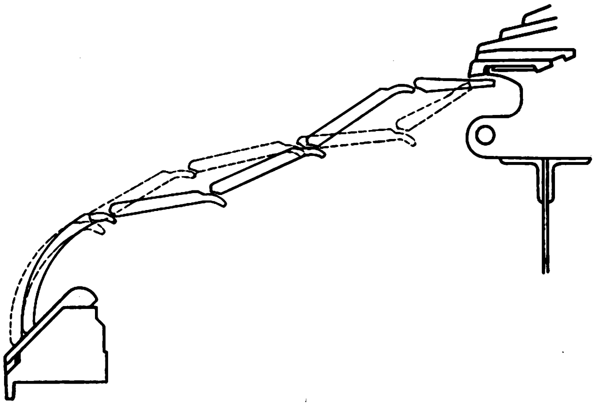

FIG. 50—DIAGRAM OF UNDULATING GRATE SECTION—WESTINGHOUSE UNDERFEED STOKER.

The rocker shaft F is operated by a gear box and crank mechanism. The application of the gear box and operating mechanism is made to conform to the requirements of the individual installation. The shaft F may be either extended through the boiler side wall and operated by a mechanism placed in the boiler aisles, or it may terminate at the side walls and be operated at or near its middle by a driving rod extended through the front of the stoker and connected to a gear box located below the stoker gear boxes.

The gear box is usually driven by a silent chain from the stoker speedshaft, or from a jackshaft driven by the stoker driving motor. In some cases a separate motor may drive the link-grate, the controller of this motor being mechanically connected with the controller of the stoker driving motor, to synchronize the speed control of the two drives.

The connection between the gear box and driving shaft F contains a lost motion device to enable the operator to vary the motion of the grates as desired. By means of a simple device, the motion of the grates is controlled in six increments from zero to maximum. A shearing pin is provided to protect the mechanism from overloads, such as would be caused by an excessive accumulation of refuse in the clinker-grinder pit due to operating negligence.

This structure produces the following results:

1. A flat grate surface that exposes a minimum of surface to the fire and is thoroughly cooled by air passing between and around narrow grate bars.
2. A grate surface which positively conveys the fuel and refuse toward the rear of the stoker.
3. A grate motion which agitates the fuel sufficiently to always keep the fuel supporting surface uniformly covered.

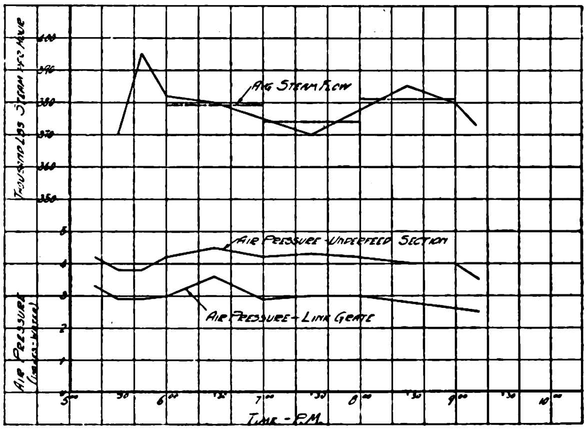

FIG. 51—CURVES FOR WESTINGHOUSE STOKER—HUDSON AVE. STATION.

4. A grate motion which, in combination with the positive ash conveying properties of the grate, prevents the formation of large clinkers, and discharges into the clinker-grinder pit the refuse which is thoroughly burned out and is of a size easily and uniformly handled by the clinker grinder.
5. An ash ejecting mechanism, attached to the lower end of the underfeed section, which is positive in action, and which is regulated without disturbance of the fuel feeding and distributing mechanism. Fig. 51 shows the relatively low air pressures required at high capacities on the boilers at Hudson Avenue. These curves were made from data obtained during regular operation. The load recorded was the highest available during a peak period and does not represent the ultimate capacity of the units, as was clearly indicated by the ease with which the fuel bed was handled and its condition. No official tests have yet been run, but observations indicate an average overall efficiency of 85 per cent or more. There are economizers, but no preheated air. Maintenance is amazingly low.

Clinker-Grinder Pit

The Hudson Avenue stoker is equipped with a clinker-grinder pit embodying radically new features of design. This type of grinder pit has also been applied to later installations, of both conventional underfeed stokers and combined underfeed and link-grate stokers.

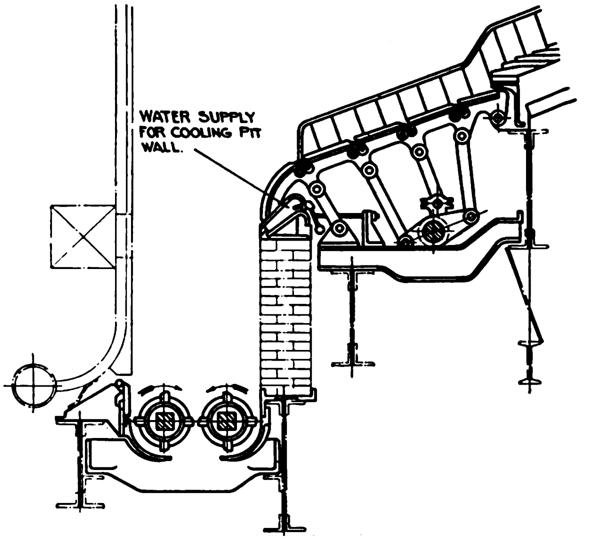

FIG. 52—FRONT PIT WALL—HUDSON AVE. STATION.

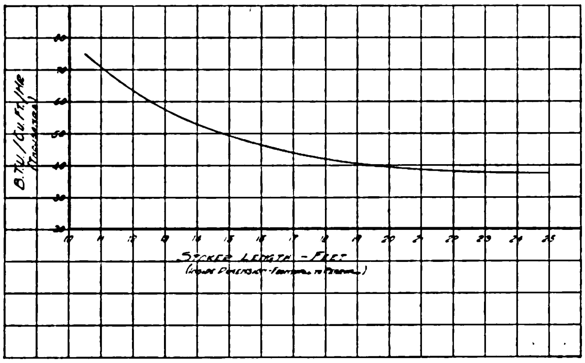

FIG. 53—HEAT LIBERATION CURVE—WESTINGHOUSE ELECTRIC & MFG. CO.

The design employs a front pit wall of hard-burned firebrick, Fig. 52. The base of the wall is supported by the casting to which the front clinker-grinder shield is attached. The upper edge of the wall is capped by a casting which supports the lower end of the link grate, or the agitator of the usual type underfeed stoker. Water is discharged from the bottom of this casting and trickles downward over the face of the wall between the brickwork and the refuse. The effect is to create a film of water over the face of the wall, which will not allow slag to stick to the refractory material. Water is not sprayed into the refuse.

When it is desirable, air can be discharged through the wall. To do this, hollow castings are built into the wall to form air passages. These castings expose a minimum of surface to the heat of the refuse.

It is preferable that the rear wall of the grinder pit be some form of water wall. If the economics of the installation do not permit the use of a water wall, the rear wall of the pit may be built similar to the front wall.

This construction eliminates, as far as possible, the use of cast iron parts in the clinker-grinder pit, and by thus reducing the number of parts subject to the destructive action of heat insures reliability and continuity of service.

Setting Heights and Furnace Volumes

There is a tendency toward setting boilers unnecessarily high when used with short stokers, and too low when used with long stokers. The setting height of a boiler and consequently the furnace volume are influenced by the character of the fuel to be burned, and the length of the stokers. Fig. 53 shows what this company has determined as a general basis upon which to figure the maximum heat liberation per cubic foot of furnace volume for maximum combustion efficiencies. This being a general basis, it must be modified for the particular characteristics of fuel under consideration. Having determined the total coal to be burned and the heat release per cubic foot, the effective furnace volume is established. In determining the setting height, due consideration must be given to the shape of the furnace and the relation of the natural flow of gas from the fuel bed to the heating surface of the boiler as affecting the effective furnace volume.

Water Walls

Experience teaches that water walls have several advantages. They do prevent clinker adhesions at and just above the line of the stoker. They do have some effect upon reducing exit gas temperature, which is synonymous to increasing efficiencies, but to exactly what extent this is accomplished is problematical. The first place to consider the placing of water walls on a multiple retort stoker is at the rear above the dump grate or in the rear wall of the grinder pit. Next would come the side walls. We have seen no advantage in front water walls. Water walls considerably affect furnace conditions. The right amount of water wall is highly desirable, but if the amount of bare iron surface becomes too great with respect to the furnace volume, the furnace temperature may be too low, ignition will be slow, particularly on single retort stokers, and combustion reactions may be slowed down enough to lower the efficiency.

Preheated Air

Preheated air does not increase capacity. The same capacity may be obtained with less coal. Preheated air within the range used for boilers has no detrimental effect upon the stoker proper, but temperatures much above 350 deg. create conditions in the fuel bed which may make it difficult to handle. Many of the earlier difficulties have been overcome by changes in design.

Most installations suffer more difficulties with corrosion, warping and fouling of the preheaters, and with expansion troubles and leakage in the air ducts than are encountered with the stoker proper. All of these factors can be overcome by proper layout and design. The experience gained in the existing preheated air installations is now a valuable guide for future layouts.

Single Retort Stokers

Experience with single retort stokers demonstrates that satisfactory coal distribution becomes more difficult to obtain as the length of the retort increases. Fuel distribution throughout the length of the stoker is the combined func-

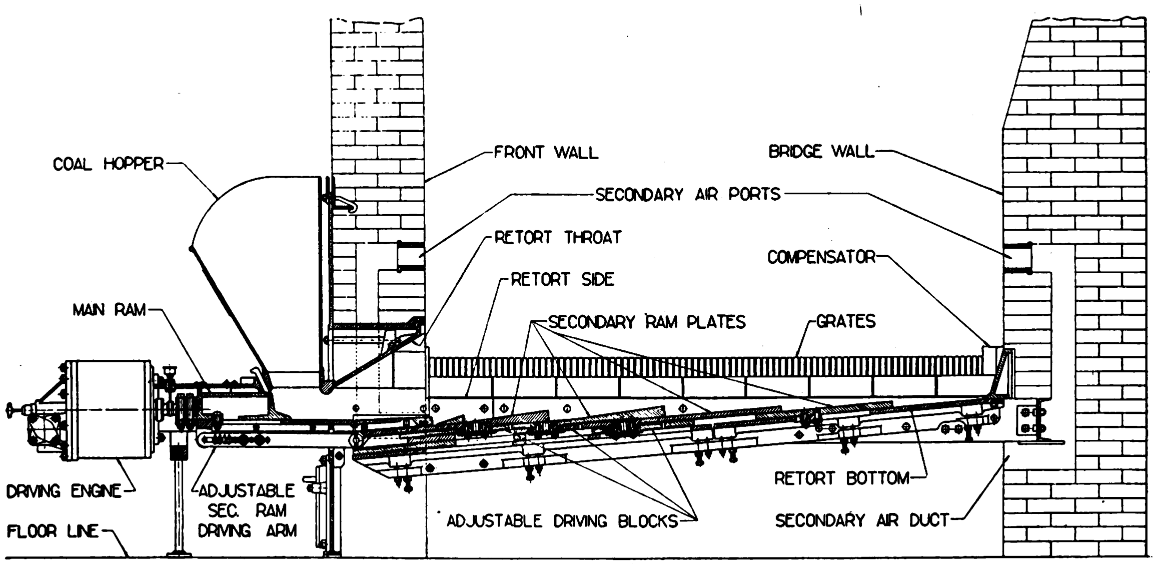

FIG. 54—DESIGN OF SINGLE RETORT STOKER—WESTINGHOUSE ELECTRIC & MFG CO.

tion of the retort and the secondary ram. Experiments were conducted to produce a design of these elements that is sufficiently flexible to give satisfactory distribution for different grades of coal and varying furnace conditions. The design as finally adopted is shown in Fig. 54. The retort is relatively deep at the throat, with a sharp upward slope to the bridgewall. This shape of retort enables the secondary ram to push the coal upward and over the grates at a uniform rate. The retort being shallow at the rear end, the secondary ram is rendered most effective in ejecting from the retort any clinkers or hard coke formations which may accumulate during a long banked period.

Adjustments to obtain correct fuel distribution for the available coal are made by varying the lost motion in the elements of the secondary ram. This adjustment is made from the windbox and is of a more or less permanent character.

The secondary ram having a fuel moving capacity in excess of that of the main coal feeding ram, permits the use of a lost-motion device between the main and secondary rams to make these desired adjustments.

The pushing faces of the secondary ram plates are self-cleaning to prevent fouling with wet coal dust which would result in loss of effectiveness.

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CONDENSING EQUIPMENT

Summary

Owing to the lack of sufficient data and to variations in conditions under which condensers operate, it is very difficult to make an accurate comparison of the performance of the several types of surface condensers.

A study of the data received by this committee. after being corrected to a common basis of water velocity and inlet water temperature, indicates that the performance of single-pass condensers is somewhat better than that of the two-pass type. Performance of vertical condensers is appreciably better than horizontal condensers with the same number of passes.

Tables included give design and performance data for fifteen two-pass and eleven single-pass condensers. The variation of average heat transfer rates with inlet water temperatures is also shown.

Excessive condenser leakage resulting from tube vibration has been experienced in some cases. This has been most effectively remedied by the installation of additional tube support sheets and by the use of thicker tubes.

Two companies report satisfactory operation with condensers having the tubes rolled into the tube sheet at both ends.

STUDY OF PERFORMANCE RECORDS OF SINGLE-PASS AND TWO-PASS CONDENSERS

The work of the Subcommittee during the past year has been almost entirely confined to a study of the relative performance of single and two-pass condensers. It has been based upon data supplied by members of the Prime Movers Committee, approximately complete data having been obtained for 15 two-pass and 11 single-pass installations. The data for these installations have been tabulated and are shown in Tables I and II.

Statements received from companies supplying data are included in the latter part of this report, together with curves showing the performance of each condenser.

It is very difficult to appraise the value of any given type from the performance of such a limited number of condensers which is affected not only by the amount of air leakage, but to a very great extent by the fouling characteristics of the circulating water and the frequency with which the tubes are cleaned.

The following comparisons are based entirely upon the data given in Tables I and II and have general application only to the extent that the installations reported are representative of the single and two-pass designs. The limitations of this study should be borne in mind when considering these comparisons.

Relation of the Actual to the Expected Coefficient of Heat Transfer

The average ratio of the actual to the expected heat transfer coefficient was found to be 0.835 for all two-pass and 0.808 for single-pass installations. The minimum and maximum ratios for individual single-pass condensers were 0.66 and 0.86 respectively. For individual two-pass condensers, the minimum ratio was 0.63 and the maximum 1.28. Two two-pass condensers gave an average ratio of actual to expected heat transfer in excess of unity. In some cases the expected values were based upon manufacturers' guarantees and in others upon test data obtained when the tubes were clean. Since in nearly all cases the air leakage was reasonably low, the performance with clean tubes corresponded closely with the manufacturers' guarantees. The difference between actual and expected heat transfer results mainly from fouling of the condenser tubes.

Comparison of Heat Transfer in Single-Pass and Two-Pass Condensers

Tables III and IV show performance results obtained with inlet circulating water temperature of 35, 55 and 70 deg. fahr. These values were taken from the curves plotted for individual condensers. It will be noted that data for the 35 deg. circulating water temperature were not available in all cases. In addition to the actual heat transfer coefficient and water velocity, the heat transfer coefficient corrected to a water velocity of 6 ft. per sec. is shown. The average water velocity was 6.3 ft. per sec. for two-pass condensers and 6.25 ft. per sec. for single-pass condensers.

The correction for circulating water velocity was based upon test data obtained by G. A. Orrok (A. S. M. E. Trans., 1910, Vol. 32, p. 1773). The results obtained in Mr. Orrok's tests were corrected by E. E. Wilson (A. S. M. E. Trans., 1915, Vol. 37, p. 47) to an arbitrary mean water temperature of 60 deg. fahr. and the reciprocal of the corrected coefficients of heat transfer were plotted by him against the reciprocal of the water velocity in the tubes. The test points plotted in this manner fell very close to a straight line, indicating that there was an approximate straight line relationship between the resistance to heat transfer and the reciprocal of the water velocity. The corrections made in this report for variation in water velocity were determined from the slope of this line. A line plotted from the reciprocal values of heat transfer coefficients and water velocities for mean water temperatures of other than 60 deg. fahr. will have a different slope than the 60-deg. line. The relation

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TABLE I

SINGLE PASS CONDENSERS
DESIGN CHARACTERISTICS & PERFORMANCE DATA

STATION	TWIN BRANCH	MIDDLETOWN	PARR	PARR	BINGHAMTON	EAST RIVER	AVON	AVON	TRENTON CHANNEL	TRENTON CHANNEL	LAKE SIDE
NUMBER OF UNIT	2	2	1	2	6	1	1	2	4	5	6
MANUFACTURER	WHEELER C. & ENGR. CO.	WHEELER C. & ENGR CO.	INGERSOLL RAND	INGERSOLL RAND	C H WHEELER	FOSTER - WHEELER CORP	WORTHINGTON	WORTHINGTON	WORTHINGTON	WORTHINGTON	FOSTER - WHEELER
SURFACE AREA	25,710	38,000	9,000	25,000	22,000	47,500	42,000	42,000	51,475	51,375	25,000
NUMBER OF TUBES	5,046	9,225	2,300	5,800	4,630	8,540	8,360	8,360	8,286	8,270	5,013
SIZE & GAUGE OF TUBES	1639 - 1" 1733 - 7/8" 2034 - 3/4" ALL 18 BWG	3/4" - 18 BWG	3/4" - 17 BWG	3/4" - 17 BWG	7/8" - 17 BWG	7/8 - 18 BWG	7/8" - 18 BWG	7/8" - 18 BWG.	1" - 18 BWG	1" - 18 BWG	1612 - 1" 1448 - 7/8" 1953 - 3/4" ALL 18 BWG
LENGTH OF TUBES	21 FT 2½"	21 FT. 2½"	20 FT. 0"	22 FT. 0"	21 FT 0"	23 FT 3"	22 FT. 0"	22 FT. 0"	24 FT. 0	24 FT 0"	22 FT. 0"
NUMBER OF TUBE SUPPORT SHEETS	2	3	3	3	3	2	2	2	2	2	2
VOLUME OF STEAM SPACE OF CONDENSER BELOW FACE OF STEAM INLET	3,210	3,039	1,103	2,058	1,918	5,740	—	—	—	—	—
MANNER OF TUBE SPACING	RADIAL	VARIABLE	VARIABLE	VARIABLE	VARIABLE	VARIABLE	EQUAL	EQUAL	EQUAL WITH WEDGE SHAPED STEAM LANES		RADIAL
MANNER OF TUBE FASTENING *	B	B	B	B	B	A	B	B	A	A	B
TYPE OF PACKING	FIBRE	CORSET LACE	CORSET LACE	CORSET LACE	CORSET LACE	CORSET LACE WITH FIBRE RINGS	METALLIC	METALLIC	ALLEN	CANVASS & FIBRE	
CIRCULATING PUMP DRIVE	NONE	1 DUAL DR. 1 MOTOR DR.	1 DUAL DR.	1 DUAL DR. 1 MOTOR DR.	1 DUAL DR. 1 MOTOR DR.	TURBINES	1 DUAL DR. 1 MOTOR DR.	1 DUAL DR. 1 MOTOR DR.	D.C. MOTORS	D.C. MOTORS	C.S. MOTOR
SOURCE OF CIRCULATING WATER	ST. JOSEPH RIVER	SUSQUEHANNA RIVER	BROAD RIVER	BROAD RIVER	SUSQUEHANNA RIVER	EAST RIVER	LAKE ERIE	LAKE ERIE	DETROIT RIVER	DETROIT RIVER	LAKE MICHIGAN

AVERAGE PERFORMANCE FOR PERIOD REPORTED

STATION	TWIN BRANCH	MIDDLETOWN	PARR	PARR	BINGHAMTON	EAST RIVER	AVON	AVON	TRENTON CHANNEL	TRENTON CHANNEL	LAKE SIDE
MONTHS COVERED BY REPORT	12	12	11	7	12	12	12	12	11	11	12
HEAT TRANSF RATE (B.T.U./SQ. FT./HR)	11,400	7,200	12,750	10,100	6,700	7,100	4,770	4,750	6,000	6,050	9,100
LBS. CIRC WATER/1000 B.T.U. TRANSFERRED	140	92.5	90	87	110	123	126	130	121	119	110
LBS CIRC WATER/HR/SQ FT. SURFACE	1,600	666	1,150	880	735	870	602	617	723	720	996
AVERAGE VELOCITY OF WATER IN TUBES	11.4	5.6	8.45	7.8	4.95	6.5	4.1	4.2	4.5	4.5	6.8
INLET CIRCULATING WATER TEMPERATURE	53.3	56.8	62.3	56.5	49.9	53.8	51.6	51.2	52.1	52.0	49.6
COEFFICIENT OF HEAT TRANSFER	407	271	605	440	296	302	247	250	278	270	462
RATIO OF ACTUAL TO EXPECTED HEAT TRANSFER	.835	.66	.84	.81	.85	.68	.83	.83	.86	.83	.86
BASIS OF EXPECTED HEAT TRANSFER	B	—	—	—	—	B	B	B	T	T	B
AIR LEAKAGE - CU. FT. PER MINUTE	3.5	NEGLIGIBLE	NEGLIGIBLE	7.0	NEGLIGIBLE	4.7	3.0	2.1	3.9	4.0	8.8
DEPRESSION OF CONDENSATE - DEG. FAHR.	0	.3	.8	11.0	.2	6.4	1.8	19.0	.4	.8	4.4
PERCENT LEAKAGE OF CIRCULATING WATER	0	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE	.2	.2	.2	—	NEGLIGIBLE	.2
NUMBER OF TUBE CLEANINGS †	7 R	38 R 1 C	1 R	0	1 R	2 S (a)	1 R	0	13 R	12 R	18 R
KWH. CIRC. PUMP POWER CONSUMPTION PER MILLION BTU TRANSFERRED	—	.98	.88	.86	1.03	1.06	1.18	1.18	.70	.68	.88

* (A) INDICATES TUBES PACKED AT BOTH ENDS (B) INDICATES TUBES ROLLED AT ONE END & PACKED AT THE OTHER. ⊗ (T) TESTS MADE WITH CLEAN TUBES (B) MANUFACTURERS DATA

† (a) EVERY OTHER NIGHT ¼ TO ½ OF THE TUBES ARE CLEANED WITH WATER & AIR.
(R) RUBBER PLUGS (M) METALLIC CLEANERS (C) CHEMICALS (S) SAND BLAST

STATION	TWIN BRANCH	MIDDLETOWN	PARR	PARR	BINGHAMTON	EAST RIVER	AVON	AVON	TRENTON CHANNEL	TRENTON CHANNEL	LAKE SIDE
TOTAL RATED H.P. OF CIRC. WATER PUMP DRIVE		600	300	450	250	600	500	500	700	700	300
ACTUAL FULL CAP. OF CIRC. PUMPS G.P.M.		65,000	22,000	45,000	34,000	91,000	89,000	89,000	100,000	100,000	D 50,000
ACTUAL HEAD ACROSS CIRC PUMPS WITH FULL CAP. FT. WATER		29.0	19.0	18.8	19.2	15.1	14.	14.	19.7	19.7	D 17.0
LBS. OF CIRC. WATER PER 1000 B.T.U. OF HEAT TRANSFERRED OBTAINED WITH FULL PUMP CAP. & AVG. RATE OF HEAT TRANSFER		119	96	89	115	135.	222	222	162	162	165

TABLE II

TWO PASS CONDENSERS
DESIGN CHARACTERISTICS & PERFORMANCE DATA

STATION	RICHMOND	RICHMOND	EDGAR	COLUMBIA	SPR'DALE	ACME	HELL GATE	HELL GATE	COLFAX	HIGH BRIDGE	PINE GROVE	VALMONT	VALMONT	CRAWFORD AVE.	CRAWFORD AVE.
NUMBER OF UNIT	10	11	1	1	3	3	6	7	3-B	1	3	1	2	4	5
MANUFACTURER	C.H. WHEELER	WHSE.	WORTH.	WORTH.	WHSE.	WHEELER C&E CO.	WHSE	WHSE.	WHSE.	WORTH.	WORTH.	WHSE.	WHEELER C&E CO.	WORTHINGTON	WORTHINGTON
SURFACE AREA	70,000	70000	45,232	48,000	55,000	45,000	63,000	65,000	55,000	40,380	50,000	30,000	30,000	2-35,260	2-35000
NO OF TUBES	12,720	12,734	8,595	10,400	10,504	8,069	12,688	14,934	10,500	8,337	8,680	6,085	6,085	7186 EACH	7130 EACH
SIZE & GAUGE OF TUBES	1"-18 BWG	1"-18 BWG	1"-18 BWG	1"-16 BWG	1"-18 BWG	1"-18 BWG	1"-18 BWG	7/8"-16 BWG	1"-16 BWG	1"-18 BWG	1"-18 BWG	1"-18 BWG	1"-18 BWG	1"-18 BWG	1"-18 BWG
LENGTH OF TUBES	21 FT 3"	21 FT 7"	20 FT 0"	18 FT 2¼"	20 FT 3"	21 FT 0"	19 FT 3"	19 FT 3"	20 FT 3"	18 FT 9"	22 FT 3¼"	18 FT 10"	18 FT 10"	19 FT 0"	19 FT 0"
NO OF TUBE SUPPORT SHEETS	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2
VOL OF STEAM SPACE OF CONDENSER BELOW FACE OF STEAM INLET CU. FT.	6,300	7,400	6,800	—	4,370	4,077	—	—	—	2,675	—	—	—	—	—
MANNER OF TUBE SPACING	DIFFER.	DIA. PITCH	EQUAL	EQUAL	EQUAL	MULTI-PITCH PLAN	VARIABLE	VARIABLE	EQUAL	EQUAL	STAGGER'D	EQUAL	EQUAL		
MANNER OF TUBE FASTENING *	B	B	A	B	B	A	A	B	B	A	B	A	B	B	B
TYPE OF PACKING	METALLIC	METALLIC	CORSET LACE	WICKING & FIBRE	FIBER	FIBRE AT INLET CORSET LACE AT OUTLET	CORSET LACE	CORSET LACE	FIBRE	METALLIC	FIBRE & WICKING	METALLIC	METALLIC	FIBRE	FIBRE
CIRCULATING PUMP DRIVE	C.S. IND. MOTOR	C.S IND. MOTOR	V.S. IND MOTOR	C.S. IND. MOTORS	V.S. IND. MOTOR	SYN. MOT. & TURBINE	C.S IND MOTOR	C.S. IND. MOTOR	C.S. IND. MOTOR	C.S. IND. MOT. & TURBINE	2 SPEED IND. MOT.	1 DUAL DR. 1 MOT. DR.	1 DUAL DR. 1 MOT. DR.	V.S. IND. MOTOR	V.S. IND. MOTOR
SOURCE OF CIRCULATING WATER	DELAWARE RIVER	DELAWARE RIVER	FORE RIVER	OHIO RIVER	ALLEGHENY RIVER	MAUMEE RIVER	EAST RIVER	EAST RIVER	ALLEGHENY RIVER	MISSISSIPPI RIVER	SWATARA CREEK	ARTIFICIAL LAKE	ARTIFICIAL LAKE	CHICAGO DRAINAGE CANAL	CHICAGO DRAINAGE CANAL
AVERAGE PERFORMANCE FOR PERIOD REPORTED															
MONTHS COVERED BY REPORT	10	12	12	12	12	12	12	12	12	12	12	12	12	12	12
HEAT TRANSF. RATE (B.T.U./SQ.FT./HR.)	5,846	5,860	3,240	6,550	5,450	5,800	7,900	6,800	5,100	5,300	4,620	5,644	6,762	5,120	6,150
LBS. CIRC. WATER/HR./SQ.FT. SURFACE	569	511	473	—	578	600	800	618	520	530	540	632	709	565	813
LBS. CIRC. WATER/1000 B.T.U. TRANSFERRED	97.5	87.	146.	—	106.	103.	101.	91.	102.	100.	117.	112.	105.	110	132
AVG VELOCITY OF WATER IN TUBES	6.3	5.6	4.9	—	6.0	6.7	7.8	7.0	5.55	5.2	6.25	6.2	7.1	5.6	7.9
INLET CIRCULATING WATER TEMPERATURE	59.6	55.5	51.0	—	52.5	60.8	54.6	54.5	53.2	51.3	74.0	63.6	57.5	50.1	52.5
COEFFICIENT OF HEAT TRANSFER	264	274	174	—	267	292	321	293	213	258	290	369	373	262	369
RATIO OF ACTUAL TO EXPECTED HEAT TRANSFER	.65	.69	.85	.86	.83	.83	.72	.63	.82	.75	.74	.85	.90	1.16	1.28
BASIS OF EXPECTED HEAT TRANSFER ⊗	B	B	B	T	B	—	—	—	B	T	—	B	B	—	—
AIR LEAKAGE - CU. FT. PER MINUTE	5.0	5.0	—	2.0	4.0	15.0	3.5	3.3	13.5	2.3	—	3.8	2.1	—	—
DEPRESSIONS OF CONDENSATE - DEG. F.	4.4	1.3	1.4	1.8	0	3.0	.7	.1	0	6.4	1.0	0	4.2	0	0
PERCENT LEAKAGE OF CIRCULATING WATER	.1	.0	—	.0	.25	.3	NEGLIBLE	NEGLIGIBLE	NEGLIGIBLE	—	—	0	0	.9	1.0
FREQUENCY & METHODS OF TUBE CLEANING	20 R	24 R	1 R	1 R	14 M 1 R	7 R 1 S	6 M	6 M 1 R	66 R 6 M	83	3	1 C	1 C	84 W 28 C	42 W 35 C
KWH CIRC. PUMP POWER CONSUMPTION PER MILLION B.T.U. OF HEAT TRANSFERRED	1.20	.93	—	—	1.53	1.19	—	—	—	1.21	—	1.44	1.21	—	—
*(A) INDICATES TUBES PACKED AT BOTH ENDS (B) INDICATES TUBES ROLLED AT ONE END & PACKED AT THE OTHER ⊗(T) TEST DATA WITH CLEAN TUBES (B) MANUFACTURERS DATA															
(R) RUBBER PLUGS (M) METALLIC CLEANERS (C) CHEMICALS (S) SAND BLAST (W) WASHED WITH WATER															
TOTAL RATED H.P. OF CIRC. WATER PUMP DRIVE	1000	1000	580	700	600	500	800	640	900	300		175	150	700	1300
ACTUAL FULL CAP. OF CIRC. PUMPS G.P.M.	80,000	78,000	60,000	72,000	68,200	50,000	90,000	76,000	80,000	43,000		24,600	27,700	80,000	120,000
ACTUAL HEAD ACROSS CIRC. PUMP WITH FULL CAP. FT. OF WATER	20.7	15.8	26.6	—	22.	22.	21.	19	26.0	15.5		7.8	9.9		34.1
LBS. OF CIRC. WATER PER 1000 B.T.U. OF HEAT TRANSFERRED OBTAINED WITH FULL PUMP CAP. & AVG. RATE OF HEAT TRANSF	97	95	205	115	112	95	90	85	145	100	—	72	68	111	140

TABLE III

COMPARISON OF PERFORMANCE OF SINGLE PASS CONDENSERS

Station	Twin Branch	Middle-town	Parr	Parr	Bing-hamton	East River	Avon	Avon	Trenton Chan-nel*	Trenton Chan-nel*	Lake-side
Number of Unit	2	2	1	2	6	1	1	2	4	5	6
COMPARISON WITH 35° F. INLET WATER TEMPERATURE											
Heat transferred per sq. ft. per hr.	11,200	...	...	...	6,500	6,800	4,700	4,700	6,000	6,000	9,300
Water velocity in tubes, ft. per sec.	10.3	...	...	...	4.4	5.2	4.0	4.2	4.0	4.2	6.8
Actual heat transfer coefficient, arith. "U"	315	...	...	...	245	170	195	190	200	185	380
"U" corrected to 6 ft. per sec. water velocity	281	...	...	...	266	174	213	205	219	199	365
COMPARISON WITH 55° F. INLET WATER TEMPERATURE											
Heat transferred per sq. ft. per hr.	11,500	7,200	13,700	9,800	6,800	7,200	4,800	4,800	6,100	6,000	9,000
Water velocity in tubes, ft. per sec.	10.7	4.9	8.5	8.2	5.2	7.4	4.2	4.0	4.5	4.7	6.8
Actual heat transfer coefficient, arith. "U"	435	270	600	440	300	330	255	260	280	290	495
"U" corrected to 6 ft. per sec. water velocity	387	280	537	408	310	316	275	284	298	306	476
COMPARISON WITH 70° F. INLET WATER TEMPERATURE											
Heat transferred per sq. ft. per hr.	11,700	7,300	12,200	10,400	6,700	7,400	4,800	4,800	6,200	6,000	8,900
Water velocity in tubes, ft. per sec.	11.3	7.4	8.4	8.3	5.0	7.7	4.3	4.0	5.0	4.8	6.8
Actual heat transfer coefficient, arith. "U"	480	320	645	490	355	400	295	310	345	375	585
'U" corrected to 6 ft. per sec. water velocity	427	310	584	456	368	382	314	339	357	394	561

*Log. coef. used.

TABLE IV

COMPARISON OF PERFORMANCE OF TWO PASS CONDENSERS

Station	Rich-mond	Rich-mond	Edgar	Colum-bia	Spring-dale	Acme	Hell Gate	Hell Gate	Col-fax	High Bridge	Pine Grove	Val-mont	Val-mont	Craw-ford Ave.	Craw-ford Ave.
Number of Unit	10	10	1	1	3	3	6	7	3-B	1	3	1	2	4	5
COMPARISON OF PERFORMANCE WITH 35° F. INLET WATER TEMPERATURE															
Heat transferred per sq. ft. per hr.	...	5,600	3,700	6,600	5,700	...	7,100	6,000	4,900	5,200	...	...	...	4,900	5,900
Water velocity in tubes, ft. per sec.	...	5.7	5.2	4.4	5.5	...	6.3	6.1	4.5	5.2	...	...	...	5.6	7.9
Actual heat transfer coefficient, arith. "U"	...	185	150	265	190	...	220	195	150	180	...	...	...	205	230
"U" corrected to 6 ft. per sec. water velocity	...	187	153	289	193	...	217	194	159	184	...	...	...	208	219
COMPARISON OF PERFORMANCE WITH 55° F. INLET WATER TEMPERATURE															
Heat transferred per sq. ft. per hr.	5,800	5,800	3,000	6,600	5,500	5,800	8,000	6,900	5,200	5,300	...	5,700	7,000	5,100	6,000
Water velocity in tubes, ft. per sec.	6.3	5.7	5.0	4.5	6.5	6.7	7.7	7.3	5.2	5.2	...	6.3	7.0	5.6	8.0
Actual heat transfer coefficient, arith. "U"	245	270	180	310	280	245	325	295	220	270	...	355	360	280	330
"U" corrected to 6 ft. per sec. water velocity	242	272	184	333	275	241	311	285	225	278	...	350	347	283	313
COMPARISON OF PERFORMANCE WITH 70° F. INLET WATER TEMPERATURE															
Heat transferred per sq. ft. per hr.	6,000	6,000	3,000	6,600	5,200	5,800	8,600	7,400	5,400	5,400	4,600	5,200	6,100	5,300	7,300
Water velocity in tubes, ft. per sec.	6.3	5.7	4.8	7.4	6.7	6.7	8.8	8.0	6.4	5.2	6.3	5.9	7.8	5.5	8.0
Actual heat transfer coefficient, arith. "U"	310	335	200	450	350	340	390	370	270	340	270	385	450	360	580
"U" corrected to 6 ft. per sec. water velocity	308	340	205	431	343	333	365	352	268	349	268	384	425	366	537

between the reciprocal values referred to above were therefore determined for other mean water temperatures by varying the 60-deg. value in accordance with Poisenelles' value for the ratio of viscosity to density of water, with temperature. From the preceding, corrections were made as follows to the reciprocal of the coefficient of heat transfer per unit of difference between the actual and arbitrary value of the reciprocal of the water velocity which is 0.1667.

35 deg. inlet temperature........	0.0053
55 deg. inlet temperature........	0.00385
70 deg. inlet temperature........	0.00320

The average heat transfer coefficients corrected to 6 ft. per second water velocity for condensers reported in Tables III and IV were as follows:

For 8 Single-Pass and 10 Two-Pass Condensers

Inlet circulating water temperature	35 deg.	55 deg.	70 deg.
Average corrected heat transfer for single - pass condensers (B.t.u. per sq. ft. per hr. per deg.)	240	331	393
Average corrected heat transfer for two-pass condensers (B.t.u. per sq. ft. per hr. per deg.).....	200	276	356

For 11 Single-Pass and 15 Two-Pass Condensers

Inlet circulating water temperature	35 deg.	55 deg.	70 deg.
Average corrected heat transfer for single - pass condensers (B.t.u. per sq. ft. per hr. per deg.)	240	352	409
Average corrected heat transfer for two-pass condensers (B.t.u. per sq. ft. per hr. per deg.).....	200	281	351

These average values of heat transfer coefficient are higher for the single-pass condensers than for two-pass condensers as shown below:

Inlet water temperature deg. fahr.	Per cent greater heat transfer—single over two pass
35	20
55	25
70	17

This difference may be partly due to the use of smaller tube sizes in the single-pass designs. Of the eleven single-pass condensers reported, three were equipped with ¾-in. tubes, four with ⅞-in. tubes, two with 1-in. tubes and two with tubes of three different sizes (¾, ⅞ and 1 in.). The two single-pass condensers having tubes 1 in. in diameter gave a heat transfer coefficient approximately 12 per cent lower than the average of all of the single-pass installations.

Only one two-pass condenser was equipped with tubes smaller than 1 in. in diameter. Although this unit gave a performance slightly better than the average of all two-pass installations, the performance was 8 per cent lower than that of a condenser of the same size and manufacture installed in the same station but equipped with 1-in. tubes.

Fig. 1 shows the arithmetical mean temperature difference obtained with 70 deg. inlet water temperature corrected to 6 ft. per sec. water velocity, plotted against the rate of heat transfer. It will be noted that if the four single-pass condensers which were operated at the highest rates of heat transfer were excluded, the average performance of the single-pass condensers would be approximately the same as that of the two-pass installations.

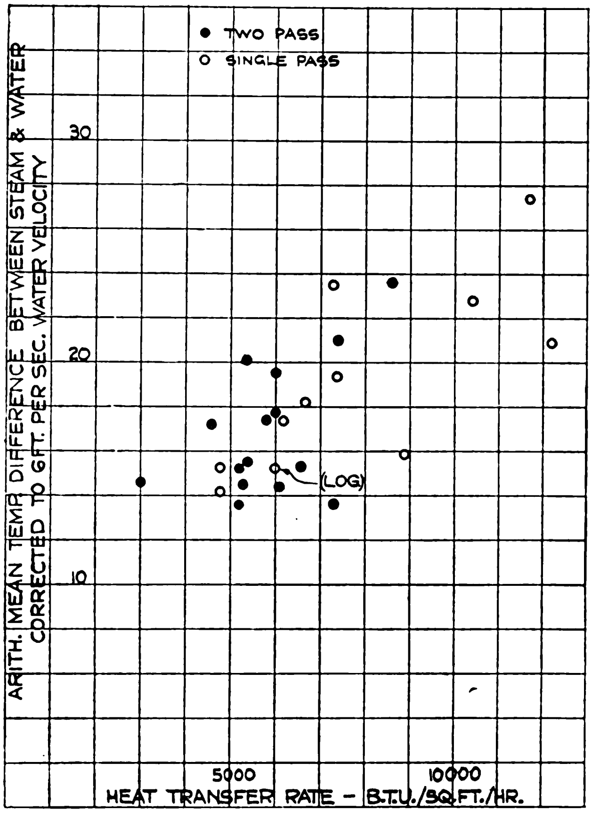

FIG. 1—Values of Arithmetic Mean Temperature Difference Obtained with 70 Deg. Fahr. Inlet Water Temperature.

Vertical Condensers

Three of the condensers for which data have been received are of the vertical two-pass type and were made by the same manufacturer. Two are installed in the same station. The average ratio of actual to expected heat transfer for these condensers is 1.10 compared to the average of 0.835 for all two-pass condensers. Comparison of the average heat transfer coefficients corrected to 6 ft. velocity of the circulating water of the three vertical condensers at three inlet water temperatures of 35, 55 and 70 deg. fahr. with the coefficients for all two-pass condensers at the same inlet water temperatures shows better heat transfer of the vertical type as follows:

Inlet water temp.	Per cent greater heat transfer
35 deg. fahr.	19
55 deg. fahr.	10
70 deg. fahr.	26

The heat transfer coefficients of these three vertical condensers plotted against the inlet water temperature gives a curve that is concave upward whereas the other condensers give curves that are either straight or are concave downward.

Circulating Water Quantities

As is to be expected, a greater quantity of circulating water is used with single-pass condensers than with two-pass. The quantity of water per thousand B.t.u. of average heat transfer obtained with the circulating water pumps operating at full capacity is 109 lb. for two-pass and 149 lb. for single-pass condensers. The average head across the circulating water pumps when operating at full capacity is 20.5 ft. for two-pass condensers and 18.5 ft. for single-pass.

The efficiency of the circulating water pumps has been determined from power consumption and water quantity data obtained with the pumps operating at full capacity. The average efficiency of the pumps used with two-pass condensers is 64 per cent as compared with 71 per cent obtained for the pumps operated with single-pass units. Owing to the difficulty of member companies accurately determining the values upon which the efficiency calculations are based, the pump efficiencies above are no doubt considerably in error.

Effect of Circulating Water Velocity on Heat Transfer

The correction made for the effect of water velocity on the heat transfer coefficient as shown in Tables III and IV was based upon tests made with clean tubes and hence no allowance is made for any possible effect of water velocity on the cleanliness of the tube. In order to determine whether the water velocity has an appreciable influence on the fouling of the condenser tubes, the values of heat transfer coefficient corrected to 6 ft. per sec. water velocity have been plotted against actual water velocity. This relation is shown for 55 deg. inlet water in Fig. 2 and for 70 deg. inlet water temperature in Fig. 3. It will be seen that while the very highest values of heat transfer were obtained with the higher water velocities, there is no definite relation between the water velocity and the heat transfer.

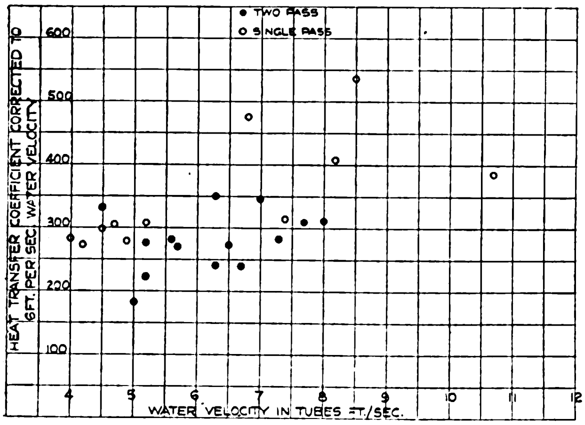

FIG. 2—RELATION OF WATER VELOCITY AND CORRECTED HEAT TRANSFER COEFFICENTS WITH 55 DEG. FAHR. INLET WATER TEMPERATURE.

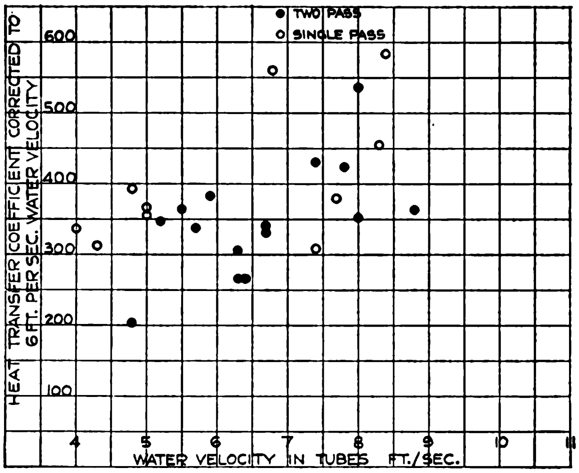

FIG. 3—RELATION OF WATER VELOCITY AND CORRECTED HEAT TRANSFER COEFFICIENTS WITH 70 DEG. FAHR. INLET WATER TEMPERATURE.

The relation between the average water velocity and the ratio of actual to expected heat transfer is shown in Fig. 4. The ratio of actual to expected performance is apparently no greater for condensers operated with high water velocities than for those operated at the lower velocities.

The average circulating water quantity and velocity were as follows for all condensers for which these data were reported:

	Two-pass Condensers	Single-pass Condensers
Lb. of circulating water per hr. per sq. ft. of surface..............	605	869
Lb. of circulating water per thousand B.t.u. transferred..........	101	113
Velocity of water in tubes, ft. per sec.	6.3	6.25

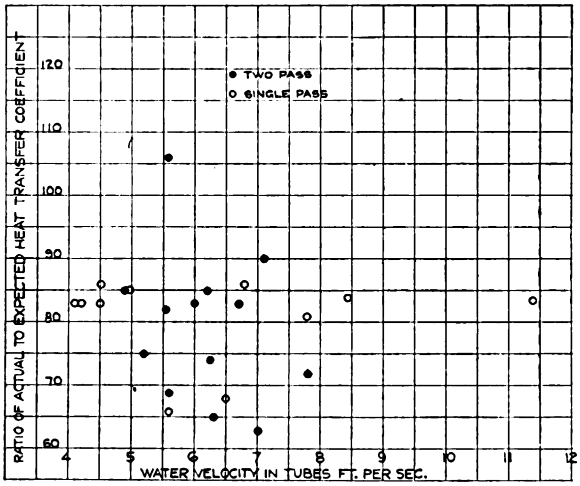

FIG. 4—RELATION OF WATER VELOCITY TO THE RATIO OF ACTUAL TO EXPECTED HEAT TRANSFER COEFFICIENT.

Power Consumption of Circulating Pumps

Circulating pump power consumption data were not available for all condensers. For the seven two-pass and nine single-pass condensers for which data were reported, the average consumption and water quantities were as follows:

	Two-pass Condensers	Single-pass Condensers
Circulating pump power consumption, kw. per 100 sq. ft..........	7.2	6.9
Circulating pump energy consumption in kw-hr. per million B.t.u. of heat transferred............	1.24	.94

	Two-pass Condensers	Single-pass Condensers
Lb. of circulating water per hr. per sq. ft. of surface................	590	796
Lb. of circulating water per 1000 B.t.u. of heat transferred.......	102	111
Velocity of water in tubes, ft. per sec.	6.2	5.7

Although a smaller quantity of water is used in two-pass condensers, the power consumption is greater probably on account of the higher friction drop through the condenser.

Effect of Circulating Water Temperature on Heat Transfer

The effect of the inlet circulating water temperature on performance is shown by comparing the values of heat transfer coefficient corrected to 6 ft. per sec. water velocity. For the cases where data are available over the range of temperature from 35 to 70 deg. fahr. the heat transfer coefficient varies as follows:

Average Heat Transfer Coefficient in Per Cent of Value with 35 deg. fahr. Inlet Circulating Water Temperature

Inlet circulating water temperature, deg. fahr.	55	70
Single-pass condensers	138	164
Two-pass condensers	138	178
Two-pass vertical condensers................	130	186

Cleaning of Condenser Tubes

Considerable variation in the frequency of tube cleaning is noted: For two of the installations no cleanings are reported, whereas five of the twenty-six condensers were cleaned more than fifty times during the year. Investigations show there is no definite relation between frequency of cleaning and the ratio of actual to expected heat transfer. Several of the installations showing the poorest performance were cleaned most frequently; both of the installations for which no cleanings were reported showed a comparatively high ratio of actual to expected heat transfer; and of the five which were cleaned more than fifty times during the year, one gave a low performance as compared with the expected, one an average performance, one a relatively good performance, and the remaining two gave performance appreciably better than the expected.

The average frequency of cleaning of two-pass installations was approximately 29 times per year as compared to approximately 15 times for single-pass condensers. The high average for the two-pass condensers is due to some of these units being cleaned a great deal more frequently than the other condensers of this type.

Rubber plugs were used either alone or in addition to other methods of cleaning in eighteen out of the twenty-four condensers for which cleaning data were reported.

Metallic cleaners were used in cleaning four condensers. In the case of three of these four condensers the metallic condensers were used almost exclusively, while in the fourth condenser the metallic cleaners were used six times and the rubber plugs sixty-six times. Four of the condensers were cleaned once and two others were cleaned several times during the year with chemical solutions to remove deposits on the water side of the tubes. In two cases the chemical solution was the only cleaning given and in the others this method of cleaning was used in addition to shooting with rubber plugs or cleaning by washing with water.

Sand blasting was performed on two installations which, in addition, used other methods of cleaning. One company reports that the tubes are cleaned regularly with water and air. Another company, taking water from the Chicago Drainage Canal, cleans the tubes by washing with water. Both cold and hot water have been used. Hot water has been found more effective.

Circulating Water Leakage

In all but two cases where circulating water leakage is reported, it is either negligibly small or less than 0.3 per cent of the condensate. The accuracy of the leakage data is not such as to make possible a comparison of the effectiveness of the various types of packing. It appears, however, that satisfactory results can be obtained with any one of the types of packing reported when it is properly used and when tube vibration does not occur.

Air Leakage

The values of air leakage reported range from 2 to 15 cu. ft. per min., the average being approximately 5 cu. ft. per min. Only four installations, however, report leakage in excess of 5 cu. ft. per min. The air leakage reported was in nearly all cases between 2 and 6 cu. ft. per min. It is impossible to show the relation between air leakage and condenser performance since the effect of air leakage is small in comparison with the effects of other variables.

Depression of the Condensate Temperature

Depression of the condensate temperature reported ranges from 0 to 19 deg. fahr. The average for single-pass condensers is 4.1 deg. fahr. and for two-pass condensers 1.6 deg. fahr. The higher average depression of the single-pass condensers results from the inclusion of two condensers, with a depression appreciably higher than the average of the other nine single pass installations. Eleven of the fifteen two-pass condensers and seven of the eleven single-pass condensers show an average depression of less than 2 deg. fahr. However, in many cases the depression is reduced as a result of the discharge of hot drains from heaters and air ejector condensers into the main condenser hotwell. No definite relation shows between the depression and the air leakage.

OPERATING COMPANY STATEMENTS

STATEMENT BY THE W. S. BARSTOW & COMPANY, READING, PA.

The performance of condensers No. 1 and 2 at Parr Station are shown in Fig. 5 and 6, and Table V and VI; of condensers No. 1 and 2 at the Middletown Station in Fig. 7-8, and Tables VII and VIII; and of No. 6 condenser at the Binghamton Station in Fig. 9 and Table IX.

The circulating water piping for No. 6 condenser at Binghamton is arranged for reversing the flow of the circulating water while the unit is in operation, consequently this condenser shows a better ratio of actual to expected heat transfer and less frequent cleaning of the tubes.

STATEMENT BY THE CLEVELAND ELECTRIC ILLUMINATING COMPANY, CLEVELAND, OHIO

Table I includes design data for condensers No. 1 and 2 at the Avon Station of the Cleveland Electric Illuminating Company which were installed in August, 1926. Condensers No. 1 and 2 are identical in design; No. 3 differs from these in tube sheet lay-out, although it is quite similar to No. 1 and 2 in surface, water quantity and number and length of tubes.

Performance data are given in Tables X, XI, and Fig. 10-11 for condensers No. 1 and 2 and on Table XII for No..3. Expected performance is from manufacturers' data and is the same for all units. Actual performance is based on half hourly readings taken from the oiler's log sheet. The actual heat transfer rate is determined from the average monthly values of vacuum, water temperatures, load and other pertinent data.

Capillary depression of the mercury column is recognized as an error in these calculations, although the magnitude is kept small by the use of special large bore tubes. No correction has been made in the data for test and experimental operation at arbitrarily high back pressures obtained by air bleeding. A third source of error lies in the use of average values of load, vacuum and water temperatures to calculate the average transfer rates, rather than to use an average of the rates as calculated for each of the half hourly periods. All errors introduced are of such a nature as to make the reported per cent of expected performance actually realized too low.

The operation of the condensers is quite satisfactory. Water leakage is easily kept to the values shown, air leakage is uniformly low and no cleaning has been found necessary. No tube failures have occurred. No. 4 condenser to be installed in 1929 will be identical with No. 3.

> NOTE—As the temperature rise of the circulating water at this station is low, the difference between "Log. Mean" as given in the tables and the "Arith. Mean" is within the accuracy of the data. Therefore "Arith. Coef. heat transfer" has been compared directly with "Expected coef. heat transfer (Log)."

STATEMENT BY THE COLUMBIA POWER COMPANY, CINCINNATI, OHIO

Description of Installation

Condenser No. 1 at the Columbia Power Station is a Worthington inclined vertical condenser with 48,000 sq. ft. of surface; it was installed during 1925 and was put into operation during December, 1925. Table II gives design characteristics of this condenser.

The condenser shell and tube bank are set on an angle of 35 deg. from vertical. Condensate is drained from the two tube support sheets directly to the hot well. Air removal apparatus consists of Worthington hydraulic vacuum pumps. Two circulating pumps are provided for the condenser, each driven by a constant speed squirrel cage motor.

TABLE V

AVERAGE OPERATING PERFORMANCE OF NO. 1 CONDENSER
PARR STEAM STATION OF THE BROAD RIVER POWER COMPANY
YEAR 1928

1. Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
2. Heat transferred per hr. per sq. ft. of surface, B.t.u.	12,800	12,030	13,330	13,510	......	12,130	14,570	10,460	11,360	12,440	13,760	13,880
3. Lb. of circ. water per hr. per sq. ft. of surface	1,066	1,352	1,120	1,145	......	1,156	1,079	1,125	1,160	1,141	1,146	1,128
4. Av. velocity of circ. water in tubes, ft. per sec.	7.9	9.9	8.3	8.4	......	8.5	8.0	8.3	8.6	8.3	8.5	8.3
5. Inlet circ. water temp., °F	41.0	45.5	52.7	60.0	......	80.0	87.5	77.3	71.2	68.3	52.8	47.6
6. Temp. rise of circ. water, °F	12.0	8.9	11.9	11.8	......	10.5	13.5	9.3	9.8	10.9	12.0	12.3
7. Arithmetic mean temp. difference between circ. water and steam, °F	26.5	24.1	22.5	21.7	......	17.7	21.8	15.7	18.0	19.6	22.6	24.3
8. Arithmetic coefficient of heat transfer	483	499	592	622	......	685	668	666	631	635	609	571
9. Expected heat transfer coefficient with clean tubes	688	715	719	692	......	761	734	722	733	708	740	712
10. Ratio of actual to expected heat transfer, %	70.2	69.7	82.3	89.8	......	90.0	91.0	92.3	86.1	89.7	82.3	80.2
11. Air leakage, cu. ft. per min.				No rea	dings t	aken, l	eakage	neglig	ible			
12. Depression of condensate temp., °F	5.0	2.0	0.3	1.2	......	0.0	0.0	0.0	0.1	0.1	0.4	0.7
13. Leakage of circ. water, %					Minim	um l	eakage					
14. Frequency of and methods used in cleaning tubes*	0	0	0	0	......	0	0	0	0	1R	0	0
15. Hours in service	28	61	225½	224½	258	200½	164	248½	301	276	247	223½
16. Power requirement of circ. water pumps, kw. per 1,000 sq. ft.	11.3	11.4	11.3	11.3	......	11.3	11.2	11.3	11.3	11.3	11.3	11.3

*R—Cleaning with rubber plugs.

TABLE VI

AVERAGE OPERATING PERFORMANCE OF NO. 2 CONDENSER
PARR STEAM STATION OF THE BROAD RIVER POWER COMPANY
YEAR 1928

		Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1.	Month												
2.	Heat transferred per hr. per sq. ft. of surface, B.t.u.	9,270	9,160	9,560	......	......	12,200	......	11,260	......	......	9,145	10,150
3.	Lb. of circ. water per hr. per sq. ft. of surface	800	893	911	......	......	940	......	873	......	......	907	812
4.	Av. velocity of circ. water in tubes, ft. per sec	7.09	7.95	8.07	......	......	8.35	......	7.77	......	......	8.0	7.2
5.	Inlet circ. water temp., °F	43.3	40.8	49.0	......	......	77.0	......	83.0	......	......	62.2	40.5
6.	Temp. rise of circ. water, °F	11.6	10.25	10.5	......	......	13.0	......	12.83	......	......	10.08	12.5
7.	Arithmetic mean temp. difference between circ. water and steam, °F	23.9	27.82	16.75	......	......	17.5	......	18.78	......	......	18.59	25.8
8.	Arithmetic coefficient of heat transfer	335	321	544	......	......	537	......	465	......	......	488	393
9.	Expected heat transfer coefficient with clean tubes	420	414	503	......	......	750	......	714	......	......	602	420
10.	Ratio of actual to expected heat transfer, %	79.8	77.6	100.8	......	......	71.6	......	65.2	......	......	81.2	93.6
11.	Air leakage, cu. ft. per min	7.4	7.0	7.8	......	......	7.0	......	6.4	......	......	6.4	5.6
12.	Depression of condensate temp., °F	14.8	22.3	11.0	......	......	3.0	......	3.5	......	......	8.5	15.0
13.	Leakage of circ. water, %					Minimum leakage							
14.	Frequency of and methods used in cleaning tubes	0	0	0	......	......	0	......	0	......	......	0	0
15.	Hours in service	391½	263½	30½	......	......	24	......	205	36	54	139½	87
16.	Power requirement of circ. water pumps, kw. per 1,000 sq. ft	8.7	8.8	8.8	......	......	8.5	......	8.7	......	......	8.8	8.7

TABLE VII

AVERAGE OPERATING PERFORMANCE OF NO. 1 CONDENSER
MIDDLETOWN STATION OF THE METROPOLITAN EDISON COMPANY
YEAR 1928

		Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1.	Month												
2.	Heat transferred per hr. per sq. ft. of surface, B.t.u.	5,870	5,835	5,845	5,440	5,510	5,765	6,200	6,690	6,605	6,275	6,435	6,250
3.	Lb. of circ. water per hr. per sq. ft. of surface	470	467	475	446	612	790	838	816	560	475	463	467
4.	Av. velocity of circ. water in tubes, ft. per sec	3.7	3.7	3.7	3.5	4.8	6.2	6.6	6.4	4.4	3.7	3.6	3.6
5.	Inlet circ. water temp., °F	39.1	36.4	40.2	48.3	62.0	69.5	76.5	79.5	67.8	59.3	48.2	38.8
6.	Temp. rise of circ. water, °F	12.5	12.5	12.3	12.2	9.0	7.3	7.4	8.2	11.8	13.2	13.9	13.4
7.	Arithmetic mean temp. difference between circ. water and steam, °F	28.5	29.9	28.8	23.0	19.6	17.8	20.3	22.9	26.6	27.8	32.6	31.2
8.	Arithmetic coefficient of heat transfer	206	195	203	237	281	324	305	292	248	226	198	200
9.	Expected heat transfer coefficient with clean tubes	219	197	227	303	307	464	465	471	0	365	348	311
10.	Ratio of actual to expected heat transfer, %	94.0	99.0	89.4	78.2	91.5	69.9	65.6	62.0	61.7	61.9	56.9	64.3
11.	Air leakage cu. ft. per min				No readings taken, leakage negligible								
12.	Depression of condensate temp., °F	4.2	4.9	3.1	1.4	1.1	0.7	0.0	0.2	0.1	0.0	0.0	3.7
13.	Leakage of circ. water, %					Minimum leakage							
14.	Frequency of and methods used in cleaning tubes*	2R	2R	1R	3R	1R	4R	3R	0	2R	1R	1C 6R	1C 9R
15.	Hours in service	537½	566	326	425½	463	468	506	667	606½	727	658	683½
16.	Power requirement of circ. water pumps, kw. per 1,000 sq. ft	5.0	5.0	5.0	4.9	5.8	10.3	10.5	10.4	5.6	5.0	4.9	4.9

*R—Cleaning with rubber plugs.
C—Cleaning with chemicals.

TABLE VIII

AVERAGE OPERATING PERFORMANCE OF NO. 2 CONDENSER
MIDDLETOWN STATION OF THE METROPOLITAN EDISON COMPANY
YEAR 1928

1. Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
2. Heat transferred per hr. per sq. ft. of surface, B.t.u.	6,925	7,095	7,115	6,860	6,960	6,980	7,265	7,790	7,380	7,340	7,260	7,490
3. Lb. of circ. water per hr. per sq. ft. of surface	554	518	556	623	839	872	931	856	600	556	571	513
4. Av. velocity of circ. water in tubes, ft. per sec.	4.7	4.4	4.7	5.3	7.1	7.4	7.9	7.2	5.1	4.7	4.8	4.3
5. Inlet circ. water temp., °F	40.9	39.1	41.5	48.6	62.0	69.5	76.4	79.5	67.5	59.3	48.7	39.0
6. Temp. rise of circ. water, °F	12.5	13.7	12.8	11.0	8.3	8.0	7.8	9.1	12.3	13.2	12.7	14.6
7. Arithmetic mean temp. difference between circ. water and steam, °F	26.4	32.9	32.5	27.8	21.5	19.5	18.7	22.9	29.1	29.3	34.3	40.0
8. Arithmetic coefficient of heat transfer	262	216	219	247	324	358	389	340	254	251	212	187
9. Expected heat transfer coefficient with clean tubes	333	293	354	410	481	506	550	541	441	394	380	272
10. Ratio of actual to expected heat transfer, %	78.7	73.7	61.8	60.2	67.3	70.8	70.7	62.9	57.6	63.7	55.8	68.8
11. Air leakage, cu. ft. per min.				No readings taken, leakage negligible								
12. Depression of condensate temp., °F	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.5	2.1
13. Leakage of circ. water, %					Minimum leakage							
14. Frequency of and methods used in cleaning tubes*	2R	3R	1C 1R	5R	2R	4R	3R	0	1R	2R	6R	9R
15. Hours in service	563½	582½	664	558½	572	546½	529	619	625	687	703½	663½
16. Power requirement of circ. water pumps, kw. per 1,000 sq. ft.	4.9	5.3	4.9	5.5	11.2	11.3	11.0	11.2	5.2	4.9	4.8	5.3

*R—Cleaning with rubber plugs.
C—Cleaning with chemicals.

TABLE IX

AVERAGE OPERATING PERFORMANCE OF NO. 6 CONDENSER
BINGHAMTON STATION OF THE BINGHAMTON LIGHT, HEAT & POWER CO.
YEAR 1928

1. Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
2. Heat transferred per hr. per sq. ft. of surface, B.t.u.	6,270	6,750	6,060	6,215	6,085	6,220	6,940	6,895	7,150	7,120	7,110	7,570
3. Lb. of circ. water per hr. per sq. ft. of surface	667	637	600	915	780	798	789	775	737	678	726	707
4. Av. velocity of circ. water in tubes, ft. per sec.	4.5	4.3	4.0	6.1	5.3	5.4	5.3	5.2	5.0	4.6	4.9	4.8
5. Inlet circ. water temp., °F	33.6	33.4	35.7	41.6	54.3	63.2	72.0	72.7	61.5	54.2	41.1	34.4
6. Temp. rise of circ. water, °F	9.4	10.6	10.1	6.8	7.8	7.8	8.8	8.9	9.7	10.5	9.8	10.7
7. Arithmetic mean temp. difference between circ. water and steam, °F	25.1	24.1	24.0	21.2	17.9	16.2	19.0	20.1	22.5	26.9	27.8	36.8
8. Arithmetic coefficient of heat transfer	250	280	253	293	340	384	365	343	318	265	256	206
9. Expected heat transfer coefficient with clean tubes	261	272	283	307	377	429	516	510	425	365	280	253
10. Ratio of actual to expected heat transfer, %	95.8	103.0	89.4	95.5	90.3	89.5	70.7	67.2	74.8	72.6	91.4	81.4
11. Air leakage, cu. ft. per min.				No readings taken, leakage negligible								
12. Depression of condensate temp., °F	0.3	0.5	0.7	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13. Leakage of circ. water, %					Minimum leakage							
14. Frequency of and methods used in cleaning tubes*	0	0	0	0	1R	0	0	0	0	0	0	0
15. Hours in service	728	665	744	720	689½	704	728	676	468½	737½	702	695
16. Power requirement of circ. water pumps, kw. per 1,000 sq. ft.	6.8	6.8	6.7	6.9	6.9	7.0	7.0	7.0	6.9	6.8	6.9	6.9

*R—Cleaning with rubber plugs.

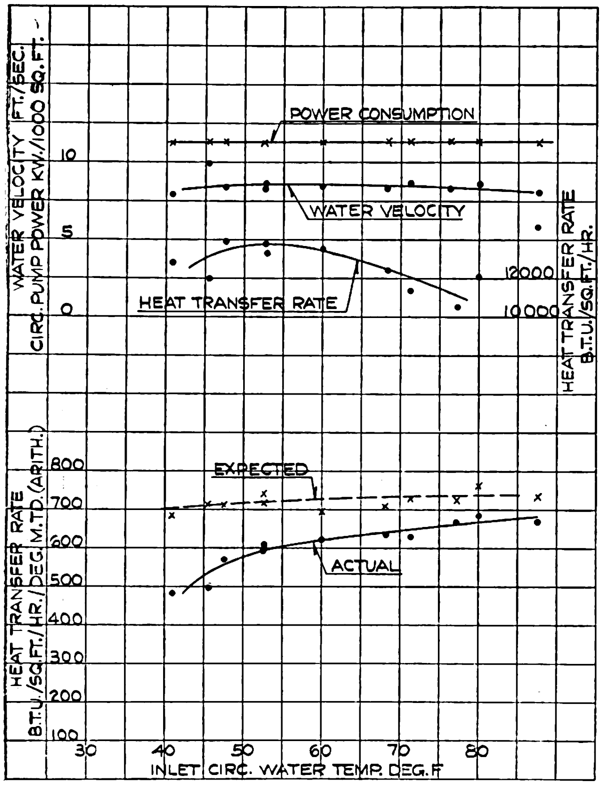

FIG. 5—PERFORMANCE OF NO. 1 CONDENSER, PARR STEAM STATION.

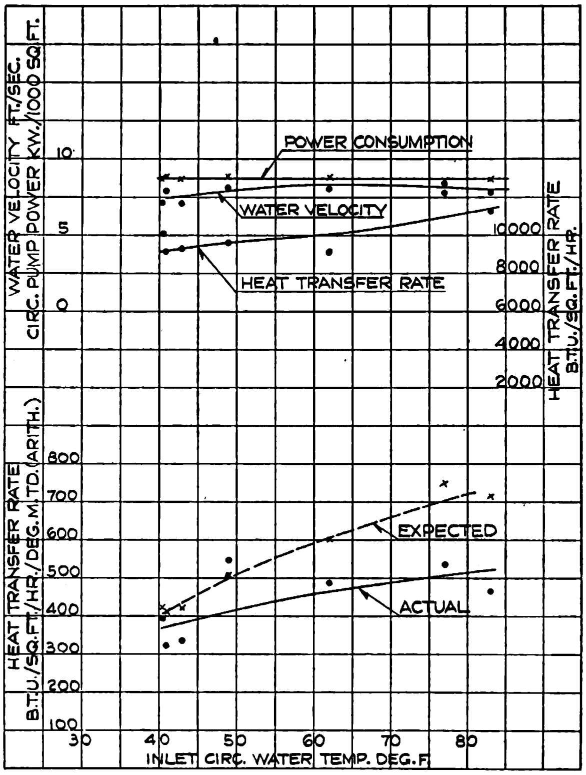

FIG. 6—PERFORMANCE OF NO. 2 CONDENSER, PARR STEAM STATION.

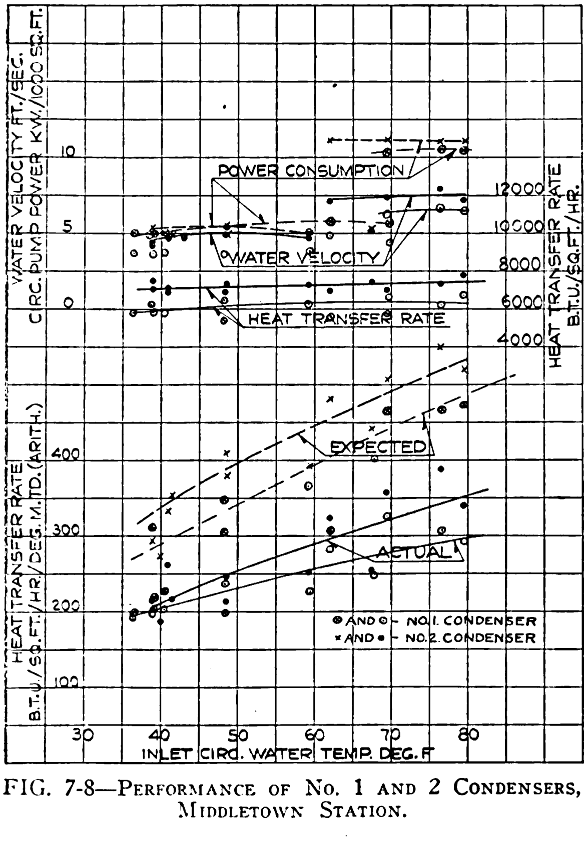

FIG. 7-8—PERFORMANCE OF NO. 1 AND 2 CONDENSERS, MIDDLETOWN STATION.

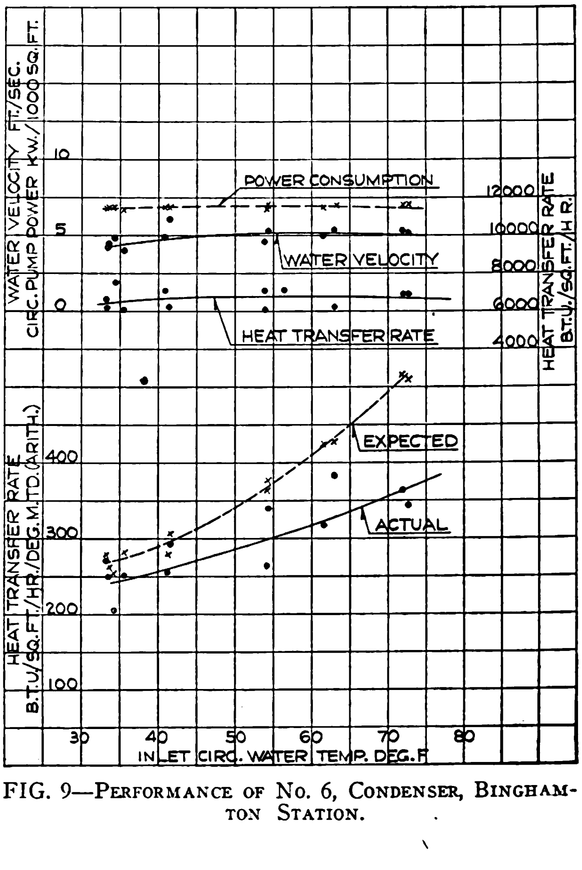

FIG. 9—PERFORMANCE OF NO. 6, CONDENSER, BINGHAMTON STATION.

TABLE X

AVERAGE OPERATING PERFORMANCE OF NO. 1 CONDENSER
AVON STATION OF THE CLEVELAND ELECTRIC ILLUMINATING CO.

YEAR 1928

1. Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
2. Heat transferred per hr. per sq. ft. of surface, B.t.u.	4,670	4,620	4,630	4,740	4,660	4,680	4,910	4,930	4,775	4,675	4,985	5,070
3. Lb. circ. water per hr. per sq. ft. of surface	599	592	579	593	590	592	578	725	612	584	587	590
4. Av. velocity of circ. water in tubes, ft. per sec.	4.07	4.03	3.94	4.03	4.02	4.03	3.93	4.94	4.17	3.97	3.98	4.00
5. Inlet circ. water temp., °F.	34.4	33.8	35.4	43.9	54.9	63.1	73.8	75.4	66.2	56.4	46.1	37.1
6. Temp. rise circ. water, °F.	7.8	7.8	8.0	8.0	7.9	7.9	8.5	6.8	7.8	8.0	8.5	8.6
7. Arithmetic mean temp. difference between circ. water and steam, °F.	25.7	24.3	23.1	20.4	18.9	17.1	16.1	14.2	16.6	18.6	22.0	22.9
8. Arithmetic coefficient of heat transfer	182	190	200	232	247	274	305	347	288	250	226	221
9. Expected heat trans. coefficient (clean, based on log mean)	231	231	237	281	311	328	345	390	340	313	287	252
10. Ratio of actual to expected heat transfer, %	79.0	82.3	84.3	82.5	79.5	83.5	88.5	89.0	84.8	80.0	78.8	87.6
11. Air leakage, cu. ft. per min.	3.0	2.6	2.8	3.2	3.7	3.5	3.1	2.4	2.7	2.1	3.5	2.9
12. Depression of condensate temp., °F.	3.2	2.7	2.2	2.0	1.5	1.3	0.9	1.0	1.6	1.5	2.7	1.5
13. Leakage of circ. water, %	0.0	0.1	0.2	0.4	0.3	0.2	0.1	0.1	0.1	0.1	0.3	0.2
14. Frequency of and methods used in cleaning tubes	......	......	......	......	......	......	*	......	......	......	......	......
15. Hours in service	507	532	540	612	594	594	513	594	364	288	532	462
16. Power requirement of circ. water pumps, kw. per 1,000 sq. ft.	5.33	5.33	5.33	5.35	5.60	5.59	5.40	8.32	5.64	5.33	5.34	5.33

* Approximately 7,000 tubes cleaned with plugs.

TABLE XI

AVERAGE OPERATING PERFORMANCE OF NO. 2 CONDENSER
AVON STATION OF THE CLEVELAND ELECTRIC ILLUMINATING CO.

YEAR 1928

1. Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
2. Heat transferred per hr. per sq. ft. of surface, B.t.u.	4,582	4,570	4,580	4,540	4,645	4,560	5,020	4,970	5,060	4,825	4,980	4,900
3. Lb. circ. water per hr. per sq. ft. of surface	611	617	611	590	603	608	605	742	595	589	607	628
4. Av. velocity of circ. water in tubes, ft. per sec.	4.08	4.20	4.14	4.02	4.10	4.13	4.12	5.05	4.05	4.01	4.12	4.26
5. Inlet circ. water temp., °F.	34.5	33.8	35.4	44.3	54.9	63.1	73.7	75.3	58.8	58.5	45.6	36.8
6. Temp. rise of circ. water, °F.	7.5	7.4	7.5	7.7	7.7	7.5	8.3	6.7	8.5	8.2	8.2	7.8
7. Arithmetic mean temp. difference between circ. water and steam, °F.	25.7	24.5	23.3	20.6	17.4	15.9	15.9	14.9	16.4	17.6	21.5	25.0
8. Arithmetic coefficient heat transfer	178	186	197	220	267	287	316	334	309	274	232	196
9. Expected heat transfer coefficient (clean, based on log mean)	237	236	243	279	314	332	356	394	328	322	293	259
10. Ratio of actual to expected heat transfer, %	75.0	78.8	81.0	78.9	85.0	86.5	88.8	84.8	94.1	85.1	79.2	75.7
11. Air leakage, cu. ft. per min.	2.4	2.5	2.2	2.8	2.6	2.3	2.3	1.8	1.1	0.8	2.5	2.0
12. Depression of condensate temp., °F.	3.3	3.4	2.7	1.9	1.5	1.7	0.8	0.8	0.3	1.0	2.1	2.9
13. Leakage circ. water, %	0.0	0.1	0.2	0.4	0.3	0.2	0.1	0.1	0.1	0.1	0.3	0.3
14. Frequency of and methods used in cleaning tubes					Tubes	not cl	eaned					
15. Hours in service	586	538	600	486	547	510	614	428	181	557	550	552
16. Power requirement of circ. water pumps, kw. per 1,000 sq. ft.	5.33	5.33	5.33	5.35	5.44	5.43	5.49	8.24	5.33	5.33	5.34	5.34

TABLE XII

AVERAGE OPERATING PERFORMANCE OF NO. 3 CONDENSER, AVON STATION OF THE CLEVELAND ELECTRIC ILLUMINATING CO. 1928

	Started in Oper.	Aug.	Sept.	Oct.	Nov.	Dec.
1. Heat transferred per hr. per sq. ft. of surface, B.t.u.	....	4,600	5,020	4,860	5,070	5,070
2. Lb. circ. water per hr. per sq. ft. of surface	....	730	627	640	604	604
3. Av. velocity of circ. water in tubes, ft. per sec	....	4.97	4.27	4.35	4.10	4.10
4. Inlet circ. water temp., °F.	....	76.6	66.9	58.8	46.4	37.3
5. Temp. rise of circ. water, °F.	....	6.3	8.0	7.6	8.4	8.4
6. Arithmetic mean temp. difference between circ. water and steam, °F.	....	9.7	13.5	13.9	17.7	20.8
7. Arithmetic coefficient heat transfer	....	474	372	350	286	244
8. Expected heat trans. coefficient (clean, based on log mean)	....	384	349	335	294	256
9. Ratio of actual to expected heat transfer, %	....	123.4	106.5	104.5	97.3	95.4
10. Air leakage, cu. ft. per min.	....	0.8	0.7	0.8	0.9	0.8
11. Depression of condensate temp., °F.	....	1.4	2.3	2.9	4.5	6.1
12. Leakage of circ. water, %	....	0.2	0.1	0.1	0.1	0.0
13. Frequency of and methods used in cleaning tubes	....	Tubes not	cleaned			
14. Service hours	....	196	607	517	468	544
15. Power requirement circ. water pumps, kw. per 1,000 sq. ft.	....	6.56	5.46	5.33	5.46	5.33

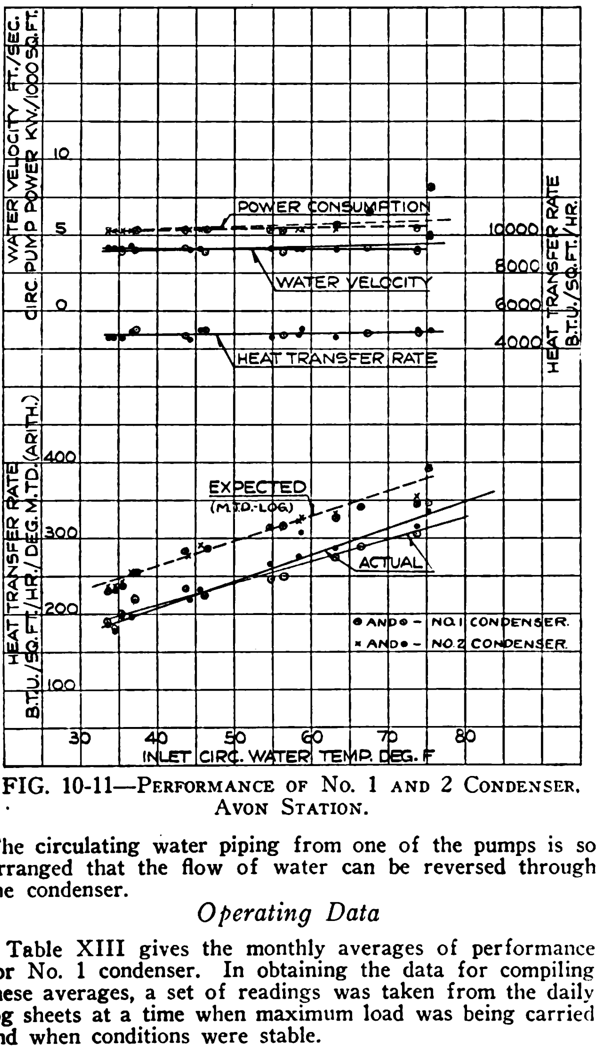

FIG. 10-11—PERFORMANCE OF NO. 1 AND 2 CONDENSER, AVON STATION.

The circulating water piping from one of the pumps is so arranged that the flow of water can be reversed through the condenser.

Operating Data

Table XIII gives the monthly averages of performance for No. 1 condenser. In obtaining the data for compiling these averages, a set of readings was taken from the daily log sheets at a time when maximum load was being carried and when conditions were stable.

During the months of October and November the maximum load that was carried gradually decreased, which is indicated by the heat transferred per hr. per sq. ft. of surface.

The amount of steam condensed was obtained from condensate flow meter data. The flow meter is installed in the condensate discharge line. The readings were checked against turbine steam flow data obtained from steam flow meter charts.

The river water leakage is determined by the electrical method. Readings of the condensate are the same as readings obtained from steam condensed in the 18th stage heater. The similarity of the readings indicates zero river water leakage into the condenser.

The data for air leakage were not taken during the year. A test of this leakage in December, 1928, gave a value of 2.14 cu. ft. per min. The monthly average of 2.25 as given in the table is based entirely upon the test value obtained.

During the months when both one and two circulating

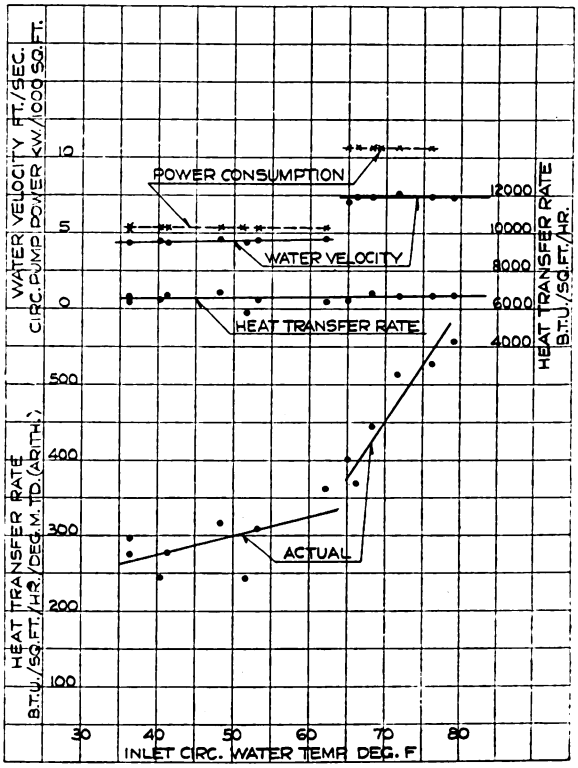

FIG. 13*—PERFORMANCE OF NO. 1 CONDENSER, COLUMBIA STATION.

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* As Table XII covers only 5 months of initial operation, Fig. 12 has been omitted.

TABLE XIII

AVERAGE OPERATING PERFORMANCE OF NO. 1 CONDENSER, COLUMBIA POWER STATION OF COLUMBIA POWER CO., YEAR 1928

	Pumps Operating	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1. Heat transferred per hr. per sq. ft. of surface, B.t.u.	......	6,770	6,370	6,730	6,880	6,480	6,850	6,730	6,730	6,670	6,360	5,820	6,530
2. Lb. circ. water per hr. per sq. ft. of surface	1	449	448	448	469	456	......	......	......	......	476	448	453
	2	......	......	......	......	728	745	748	748	766	747	......	......
3. Av. velocity circ. water in tubes, ft. per sec.	1	4.43	4.42	4.42	4.62	4.51	......	......	......	......	4.69	4.42	4.47
	2	......	......	......	......	7.19	7.36	7.38	7.38	7.55	7.37	......	......
4. Inlet circ. water temp., °F.	1	36.1	36.2	41.1	48.2	53.1	......	......	......	......	62.1	51.5	40.1
	2	......	......	......	......	64.9	68.2	76.3	79.2	71.6	66.1	......	......
5. Temp. rise of circ. water, °F.	1	15.1	14.2	15.0	14.7	14.4	......	......	......	......	13.6	13.0	14.4
	2	......	......	......	......	9.2	9.2	9.0	9.0	8.7	8.2	......	......
6. Arithmetic mean temp. difference between circ. water and steam, °F.	1	22.75	23.10	24.20	21.65	21.20	......	......	......	......	18.00	24.10	22.10
	2	......	......	......	......	16.70	15.40	12.70	12.10	12.95	16.60	......	......
7. Arithmetic coefficient of heat transfer (Actual)	1	298	276	278	318	310	......	......	......	......	361	242	245
	2	......	......	......	......	401	445	529	556	515	370	......	......
7A. Arithmetic coefficient heat transfer corrected constant load 313,000 lb. steam per hr. to condenser	1	298	296	278	310	316 } 366	......	......	......	......	371 } 383	297	302
	2	......	......	......	......	401 }	433	524	556	515	402 }	......	......
8. Expected heat transfer coefficient with clean tubes	1	300	300	325	365	440	545	650	......	585	500	380	320
9. Ratio of actual to expected heat transfer	......	0.99	0.985	0.85	0.85	0.83	0.795	0.805	......	0.88	0.77	0.78	0.94
10. Air leakage, cu. ft. per min.	......	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25
11. Depression condensate temp., °F.	1	2.4	2.4	1.6	2.2	1.8	......	......	......	......	2.0	2.5	1.6
	2	......	......	......	......	......	0.8	1.1	2.1	2.0	2.0	......	......
12. Leakage of circ. water, %			Test o	f water	indica	ted Zero	Leaka	ge					
13. Frequency of and methods used in cleaning tubes	......	None	None	None	None	None	None	None	None	None	None	⅔R.	None
14. Hours in service	......	641	657	676	623	676	678	660	666	595	740	579	......
15. Power requirement circ. water pumps, kw. per 1,000 sq. ft.	1	5.36	5.36	5.36	5.36	5.36	......	......	......	......	5.36	5.36	5.36
	2	......	......	......	......	10.72	10.72	10.72	10.72	10.72	10.72	......	......

R—Condenser cleaned with rubber plugs.

pumps were operated, the data were averaged not as a whole, but were separated into one and two pump operation averages. The data are given in Table XIII as separate averages.

Fig. 13 shows the actual monthly average heat transfer rate plotted against river water temperature. The expected heat transfer rate with clean tubes is also given. In the case of the actual data, the heat transfer rates were corrected to the condition when 313,000 lb. of steam per hr. are condensed. The corrected heat transfer rates are given in column 8A of Table XIII.

Since the condenser tubes have been cleaned only twice since installing the condenser, heat transfer data on condensers with clean tubes are rather limited. Above the river water temperature of 58 deg. fahr. no data with clean tubes are available. The curve showing heat transfer values with clean tubes above this temperature is drawn parallel to the actual operation data and may vary somewhat from the real values.

STATEMENT OF THE COMMONWEALTH EDISON COMPANY, CHICAGO, ILL.

Table II includes design characteristics of condensers Nos. 4 and 5 at the Crawford Avenue Station. These are Worthington units of 70,520 sq. ft. and 70,000 sq. ft. respectively, condenser No. 4 having been installed in 1926 and No. 5 in 1927.

The performance values given in Fig. 14 and 15, and Tables XIV and XV are based on monthly averages of hourly condenser readings. The quantity of circulating water was determined from the temperature rise, and the amount of steam condensed based on the steam distribution at the given average load of turbine. It will be noted that this circulating water quantity is practically constant, which is due to the fact that the pumps are normally running at full speed, thus maintaining a high and constant water quantity and velocity. This keeps the condensers clean for a longer period. Each of the two circulating water pumps on condenser No. 4 are driven with variable speed motors, while those on condenser No. 5 are driven with two, two-speed motors. However, the pump speed is reduced to about 75 per cent of its full value only in case the loads of No. 4 and 5 drop below 40,000 kw. and 50,000 kw. respectively. It was found that the saving in pump power consumption due to speed reduction does not outweigh the loss due to lower vacuum.

The expected heat transfer values shown are based on the manufacturers' guarantees. Corrections were made for the variation in load, inlet water temperature and quantity of circulating water from the guaranteed values. It will be noted that with the exception of a few months on No. 4 and one month on No. 5 the average actual heat transfer is higher than the expected value. This is largely due to the fact that the actual obtained vacua are better than the guaranteed values at the corresponding loads. The guaranteed vacua throughout the given range of load are not less than 1 in. Hg.

In addition to the above expected values, Tables XIV and XV show heat transfer values which were based on computed maximum possible vacua of clean condensers, condensing air free steam, taking into account the variation in load, velocity and mean temperature of circulating water.

The condensers cannot be cleaned while in service except by back-washing and lancing which was normally done with cold water alone or cold water and a chemical compound. The cold water was recently replaced by hot water since this speeds up the cleaning process considerably.

TABLE XIV

AVERAGE OPERATING PERFORMANCE OF UNIT NO. 4 CONDENSER, CRAWFORD AVENUE STATION OF THE COMMONWEALTH EDISON CO., YEAR 1928

1.	Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
2.	Heat transferred per hr. per sq. ft. of surface, B.t.u.	4,660	4,520	5,375	5,150	5,025	4,900	5,180	......	6,340	5,110	5,320	4,730
3.	Lb. of circ. water per hr. per sq. ft. of surface	568	564	566	566	564	570	569	......	566	568	566	570
4.	Av. velocity of circ. water in tubes, ft. per sec	5.6	5.56	5.58	5.58	5.56	5.61	5.6	......	5.58	5.6	5.58	5.61
5.	Inlet circ. water temp., °F	37	37	39	46	56	61	67	......	64	59	47	38.0
6.	Temp. rise of circ. water, °F	8.2	8.0	9.5	9.1	8.9	8.6	9.1	......	11.2	9	9.4	8.3
7.	Arithmetic mean temp. difference between circ. water and steam, °F	17.1	17.8	19.7	22.5	15.0	19.1	11.7	......	22.8	24.5	29.4	31.6
8.	Arithmetic coefficient of heat transfer	272	254	273	229	335	257	443	......	278	209	181	150
9.	Expected heat transfer coefficient with clean tubes*	159	154.5	182	205	248	293	362	......	338	270	212	166
10.	Ratio of actual to expected heat transfer	1.71	1.64	1.50	' 11	1.35	.88	1.22	......	0.82	0.77	0.85	0.90
11.	Heat transfer coefficient, based on ideal vacuum	450	452	465	492	632	696	695	......	655	625	538	492
12.	Ratio of actual to ideal heat transfer	0.60	0.56	0.59	0.47	0.53	0.37	0.64	......	0.43	0.34	0.34	0.31
13.	Air leakage, cu. ft. per min	......	......	......	......	......	......	......	......	......	......	......	......
14.	Depression of condensate temp., °F**	0	0	0	0	0	0	0	......	0	0	0	0
15.	Leakage of circ. water, %	1.26	0.71	1.23	0.54	0.76	0.83	0.68	......	0.80	0.81	1.00	1.15
16.	Frequency of and methods used in cleaning tubes***	11-CW 2CW-CL	11-CW 2CW-CL	11-CW 2CW-CL	12-CW 3CW-CL	2-C W 4CW-CL	10-CW 4CW-CL	2-CW 3CW-CL	......	4-CW 2CW-CL	6-CW 3CW-CL	1-CW 2CW-CL 5HW	1-CW 1CW-CL 8HW
17.	Hours in service	516	541	560	573	665	625	224	......	515	645	641	649
18.	Power requirement of circ. water pumps, kw. per 1,000 sq. ft.	......	......	......	......	......	......	......	......	......	......	......	......

*Based on manufacturer's guarantee.
**No depression due to hot drains.
***CW—Cleaning with cold water.
CW-CL—Cleaning with cold water and cleaner (Dearborn chemical compound No. 5).
HW—Cleaning with hot water (Temp. about 160° F.).

TABLE XV

AVERAGE OPERATING PERFORMANCE OF UNIT NO. 5 CONDENSER, CRAWFORD AVENUE STATION OF THE COMMONWEALTH EDISON CO., YEAR 1928

1.	Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
2.	Heat transferred per hr. per sq. ft. of surface, B.t.u.	6,300	5,670	5,640	5,590	5,690	6,170	6,890	7,580	7,240	5,490	6,120	5,660
3.	Lb. of circ. water per hr. per sq. ft. of surface	818	810	817	810	812	812	811	815	813	819	815	810
4.	Av. velocity of circ. water in tubes, ft. per sec	8.0	7.92	7.98	7.92	7.95	7.94	7.93	7.97	7.96	8.0	7.98	7.90
5.	Inlet circ. water temp., °F	38	37	35	47	58	61	69	74	65	60	48	39.0
6.	Temp. rise of circ. water, °F	7.7	7.0	6.9	6.9	7.0	7.6	8.5	9.3	8.9	6.7	7.5	7.0
7.	Arithmetic mean temp. difference between circ. water and steam, °F	25.6	23.0	31.1	17.5	11.6	17.7	10.8	10.4	15.7	21.5	25.4	21.0
8.	Arithmetic coefficient of heat transfer	246	246.5	181.0	319	491	348.5	638	729	461	255	241	269
9.	Expected heat transfer coefficient with clean tubes*	193	168	163	203	289	333.0	456	580	409	296.5	229.5	175
10.	Ratio of actual to expected heat transfer	1.28	1.47	1.11	1.57	1.70	1.05	1.40	1.26	1.13	0.86	1.05	1.54
11.	Heat transfer coefficient based on ideal vacuum	503	537	425	600	702	751	795	785	706	677	642	560
12.	Ratio of actual to ideal heat transfer	0.49	0.46	0.43	0.53	.0.70	0.46	0.80	0.93	0.65	0.38	0.375	0.48
13.	Air leakage, cu. ft. per min	......	......	......	......	......	......	......	......	......	......	......	......
14.	Depression of condensate temp., °F.**	0	0	0	0	0	0	0	0	0	0	0	0
15.	Leakage of circ. water, %	1.60	0.93	1.28	1.05	0.89	0.95	0.72	0.84	0.81	0.75	0.90	1.10
16.	Frequency of and methods used in cleaning tubes***	4CW 2CW-CL	4CW 1CW-CL	4CW 2CW-CL	7CW 2CW-CL	1CW 1CW-CL	5CW 3CW-CL	4CW 5CW-CL	3CW 4CW-CL	2CW 5CW-CL	3CW 4CW-CL	2CW 4CW-CL	2CW 2CW-CL 4-HW
17.	Hours in service	621	600	666	616	150	605	647	680	631	679	652	656
18.	Power requirement of circ. water pumps, kw. per 1,000 sq. ft.	......	......	......	......	......	......	......	......	......	......	......	......

Condenser was overhauled in May.
*Based on manufacturer's guarantee.
**No depression due to hot drains.
***CW—Cleaning with cold water.
CW-CL—Cleaning with cold water and cleaner (Dearborn chemical compound No. 5).
HW—Cleaning with hot water.

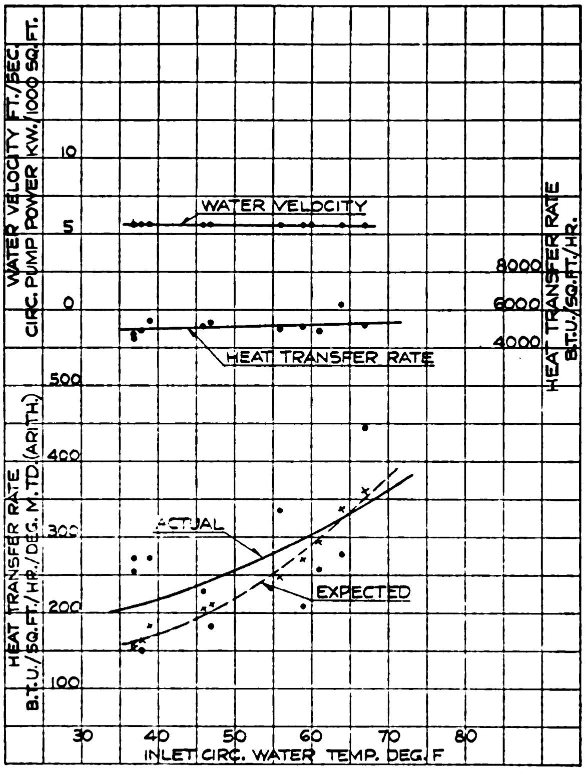

FIG. 14—PERFORMANCE OF NO. 4 CONDENSER, CRAWFORD AVENUE STATION.

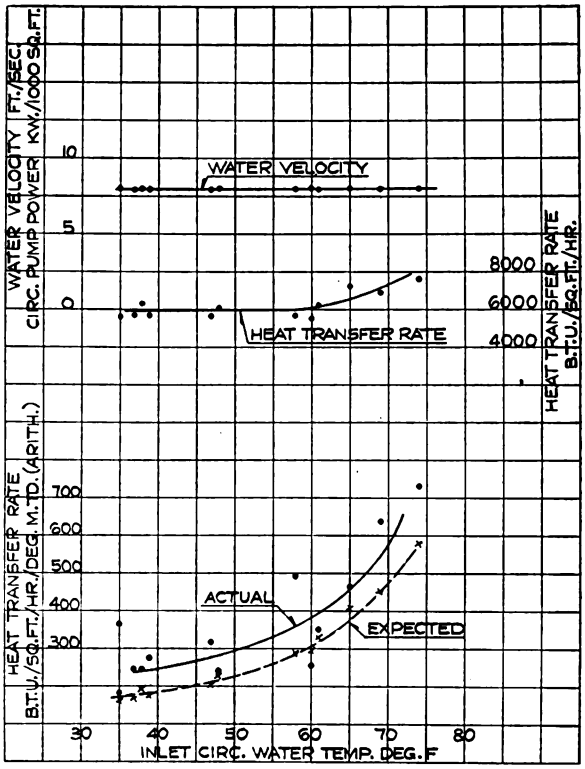

FIG. 15—PERFORMANCE OF NO. 5 CONDENSER, CRAWFORD AVENUE STATION.

The hot water cleaning is usually done over the week-end as load conditions at the station make cleaning impossible at other times.

STATEMENT BY THE DETROIT EDISON COMPANY, DETROIT, MICH.

Design

Condensers No. 4 and 5 at the Trenton Channel Plant were installed during the years 1926 and 1927 respectively. They are identical 51,500 sq. ft., single-pass, Worthington units.

The condenser tube sheets are set concentric with the shell and the tubes are spaced equally, with large wedge-shaped sections of tubes omitted to provide steam lanes.

Approximately one-quarter of the condenser surface is set apart as an air cooler, separated from the steam condensing section by suitable baffles. The air is removed through a header which runs longitudinally through the center of the condenser.

Each condenser is served by two 60,000 g.p.m. circulating water pumps, each pump being driven by a 240-volt, d-c., 325-h.p. motor having a speed range of 175 to 255 r.p.m.

Operating Data

Fig. 16 and 17, and Tables XVI and XVII gives the monthly averages of daily observations of performance of

TABLE XVI

AVERAGE OPERATING PERFORMANCE OF NO. 4 CONDENSER, TRENTON CHANNEL STATION OF THE DETROIT EDISON CO. YEAR 1928

1. Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.
2. Heat transferred per hr. per sq. ft. of surface, B.t.u.	5,880	5,870	5,900	5,870	5,870	5,890	5,860	5,780	6,170	6,490	6,110
3. Lb. circ. water per hr. per sq. ft. of surface	650	650	647	664	782	799	790	775	744	755	690
4. Av. velocity circ. water in tubes, ft. per sec	4.04	4.04	4.02	4.12	4.86	4.96	4.90	4.81	4.61	4.69	4.29
5. Inlet circ. water temp., °F	34.1	33.2	35.0	41.5	54.4	61.2	71.5	74.8	65.5	57.5	44.8
6. Temp. rise of circ. water, °F	9.0	9.0	9.1	8.8	7.5	7.4	7.4	7.5	8.3	8.6	8.9
7. Logarithmic mean temp. difference circ. water and steam, °F	30.2	31.1	30.2	27.8	23.6	18.9	16.5	12.0	18.0	24.0	24.5
8. Coefficient of heat transfer, B.t.u. per sq. ft. per hr. per °F	195	189	195	211	249	311	355	481	343	270	250
9. Expected heat transfer coefficient with clean tubes	220	215	225	264	354	383	406	408	386	369	291
10. Ratio of actual to expected heat transfer	0.89	0.88	0.87	0.80	0.70	0.81	0.87	1.18	0.89	0.73	0.86
11. Air leakage, cu. ft. per min	......	......	......	4.53	......	......	......	2.76	4.24	4.04	......
12. Depression of condensate temp., °F	2	2	0	0	0	0	0	0	0	0	0
13. Leakage of circ. water, %	......	......	......	......	......	......	......	......	......	......	......
14. Frequency of cleaning tubes (rubber plugs)	1	1	1	1	0	2	2	0	1	2	2
15. Hours of service	602	531	572	546	592	579	308	71	657	689	593
16. Power requirement circ. water pumps, kw. per 1,000 sq. ft.	3.36	3.36	3.34	3.48	4.92	5.15	5.02	4.82	4.39	4.54	3.72

TABLE XVII

AVERAGE OPERATING PERFORMANCE OF NO. 5 CONDENSER, TRENTON CHANNEL STATION OF THE DETROIT EDISON CO. YEAR 1928

1. Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.
2. Heat transferred per hr. per. sq. ft. of surface, B.t.u.	5,960	5,920	6,000	6,030	5,930	5,980	6,030	6,090	6,150	6,260	6,140
3. Lb. circ. water per. hr. per sq. ft. of surface	667	651	657	675	780	795	782	762	734	734	693
4. Av. velocity circ. water in tubes, ft. per sec.	4.15	4.05	4.08	4.20	4.85	4.94	4.85	4.74	4.55	4.55	4.30
5. Inlet circ. water temp., °F.	34.6	33.4	35.0	41.3	54.0	61.4	71.4	74.5	65.6	56.2	44.9
6. Temp. rise of circ. water, °F.	8.9	9.1	9.1	8.9	7.6	7.5	7.7	8.0	8.4	8.5	8.9
7. Logarithmic mean temp. difference circ. water and steam, °F.	31.8	32.8	31.2	27.0	22.0	18.6	15.4	15.1	20.9	21.3	28.4
8. Coefficient of heat transfer, B.t.u. per sq. ft. per °F.	187	181	192	223	270	322	392	402	294	294	216
9. Expected heat transfer coefficient with clean tubes	228	217	228	267	353	382	408	411	384	355	293
10. Ratio of actual to expected heat transfer	0.82	0.83	0.84	0.84	0.76	0.84	0.96	0.98	0.77	0.83	0.74
11. Air leakage, cu. ft. per min.	......	4.01	......	......	3.64	......	......	......	......	4.14	4.58
12. Depression of condensate temp., °F.	2	2	3	2	0	0	0	0	0	0	0
13. Leakage of circ. water, %	......	......	......	......	......	......	......	......	......	......	......
14. Frequency of cleaning tubes (rubber plugs)	1	1	0	1	1	2	2	1	0	1	2
15. Hours of service	491	573	650	603	574	593	580	666	226	415	676
16. Power requirement circ. water pumps, kw. per 1,000 sq. ft.	3.50	3.36	3.42	3.56	4.87	5.08	4.89	4.64	4.26	4.26	3.76

No. 4 and 5 units for the period of January to November, inclusive, 1928.

Hourly observations made by the operating force are recorded on logs. The tables are based on these observations. In order to minimize the effect of variations of load, only those observations have been considered which were made when the machine load was relatively constant, and between 40,000 and 45,000 kw.

The quantity of water condensed per hour was computed from the kilowatt load carrier by the turbine. In computing the quantity of heat transferred per hour, account was taken of the fact that the total water condensed enters the condenser partially as exhaust steam from the turbine, and partially as drip from the extraction heaters.

There are two methods available for computing the quantity of circulating water: (1) From the quantity of water condensed and the temperature rise of the circulating water, and (2) from the power consumption of the circulating pump motors. At the present time, No. 4 and 5 condensers are equipped with gas-filled thermometers indicating, on one dial, both the inlet and the outlet circulating water temperature. However, for the greater part of the year, the water temperatures were indicated by mercury thermometers of the industrial type. Inasmuch as the relation between power consumption and quantity of water pumped is known rather accurately as a result of extensive pump tests, it was felt that this method, (2), was preferable to the temperature rise method and has accordingly been used.

The temperature rise of the circulating water as recorded in Tables XVI and XVII is that which would result from

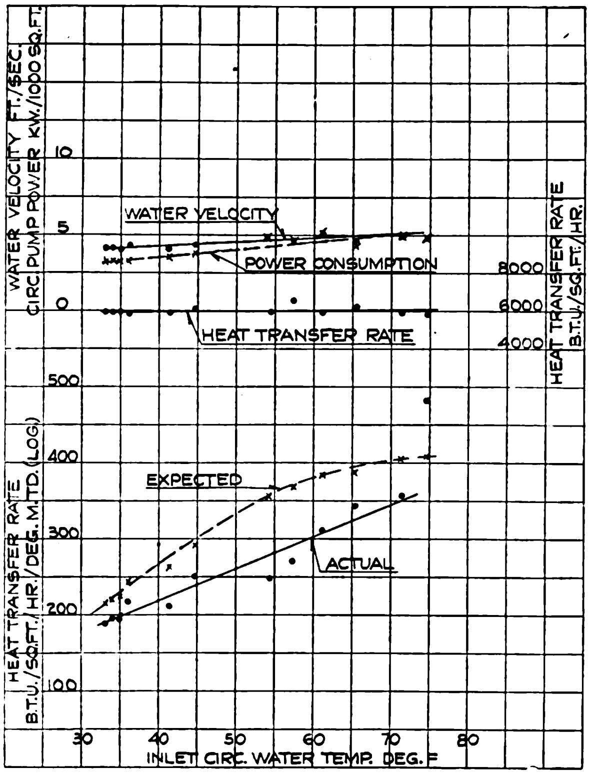

FIG. 16—PERFORMANCE OF NO. 4 CONDENSER, TRENTON CHANNEL STATION.

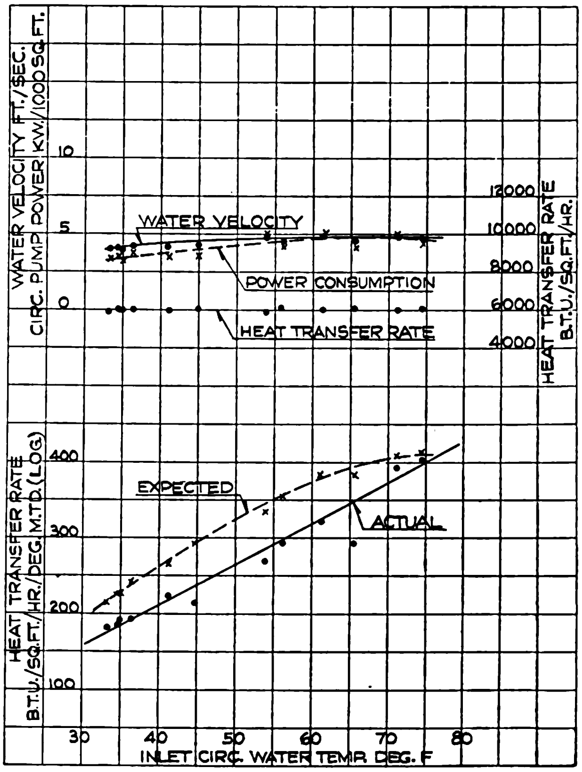

FIG. 17—PERFORMANCE OF NO. 5 CONDENSER, TRENTON CHANNEL STATION.

the circulation of the recorded amount of circulating water as determined from the power consumption of the pump motors.

The expected heat transfer coefficients with clean tubes, as recorded in the tables, take account of the quantity of steam condensed, the inlet circulating water temperature and the quantity of circulating water. Actual heat transfer coefficients are, of course, lower than the coefficients expected with clean tubes. An exception to this statement will be noted in the case of No. 4 unit for the month of August, when the ratio of actual to expected heat transfer was 1.18. However, the unit was in service for only 71 hr. during the month, after being taken out of service during July for annual overhauling. The tubes were washed on July 31, while the overhauling was in progress. The data for No. 4 unit in August are not representative of operating conditions and have not been considered in plotting the heat transfer coefficient curves for No. 4 unit.

Air and Water Leakage

While results of air leakage tests are not available for all months, the results given are representative of year-around operation. No difficulty has been experienced in keeping air leakage below 5 cu. ft. per min.

No figures for percentage of leakage of circulating water into the condenser appear in the table, although samples of condensate from each unit are tested every other day. The ratings on the Dionic water tester when testing condensate from units No. 4 and 5 average 2.0, with individual samples showing from 1.5 to 2.5 units. Inasmuch as samples of steam main drips show approximately 2.0 units on the Dionic water tester, it can be concluded that there was practically no in-leakage of circulating water into these condensers. Experience has shown that a few loose condenser tube glands will cause the condensate to increase to about 4 to 5 units on the Dionic water tester, whereas a split tube may increase the conductivity to 10 units.

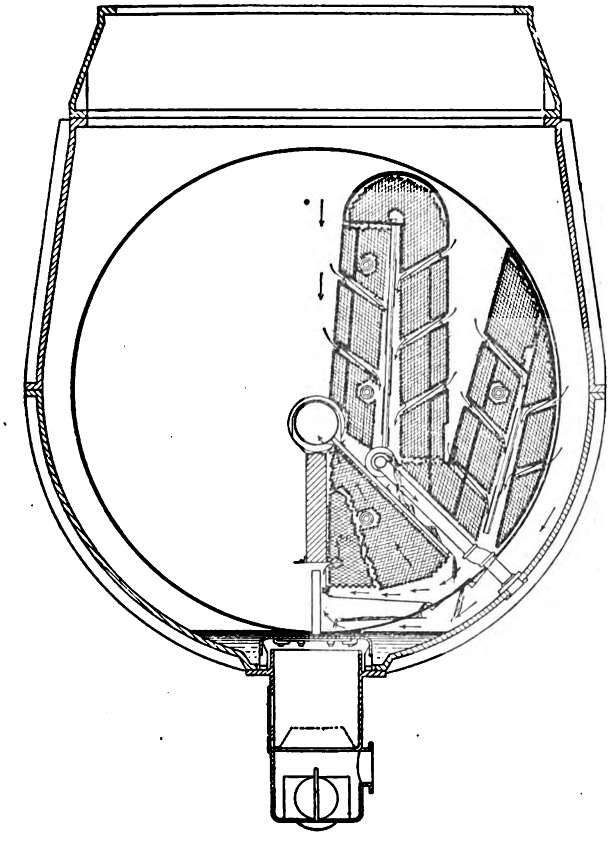

FIG. 17-A—ADDITIONAL TUBE SUPPORTS OF NO. 4 AND 5 CONDENSERS, TRENTON CHANNEL STATION.

Originally some trouble was experienced with tubes in these two condensers leaking due to holes having been worn in them by vibration of the tubes. This was first detected by an excessive number of leaks around the packing glands of the tubes on the outside of the tube banks. The first three units in this plant had condensers with three tube support plates, but those of units No. 4 and 5 had only two tube support plates. No trouble was experienced due to vibration of the tubes in the first units, but on these two units the tubes were worn so thin in the tube support plates that in some cases holes were worn through, and in the tube packing that the thin wall of the tubes crumpled within the packing when it was tightened. Three sets of sector tube support plates were installed between the original tube support plates and tube heads, giving the tubes within the areas, heavily outlined in Fig. 17A, five points of support between the tube heads. During the three months of operation since these additional support plates were added, no trouble has been experienced due to vibration.

STATEMENT BY THE DUQUESNE LIGHT COMPANY, PITTSBURGH, PA.

No. 3-A and 3-B units at Colfax were installed during the year 1924. Each unit is served by a Westinghouse 55,000-sq. ft. radial flow condenser having a divided water box so as to permit cleaning while in service (see Table II).

Each condenser is equipped with two 47,000-g.p.m. circulating pumps driven by constant speed induction motors. The amount of circulating water delivered to the condensers cannot be varied, except by changing the number of pumps in service.

Fig. 18-19 and Tables XVIII and XIX give the monthly performance of the condensers during the year 1928. These results are based upon the hourly readings taken from the regular operating instruments by the operators. The expected heat transfer is taken from the manufacturer's guarantee.

The leakage of circulating water into the condensate is

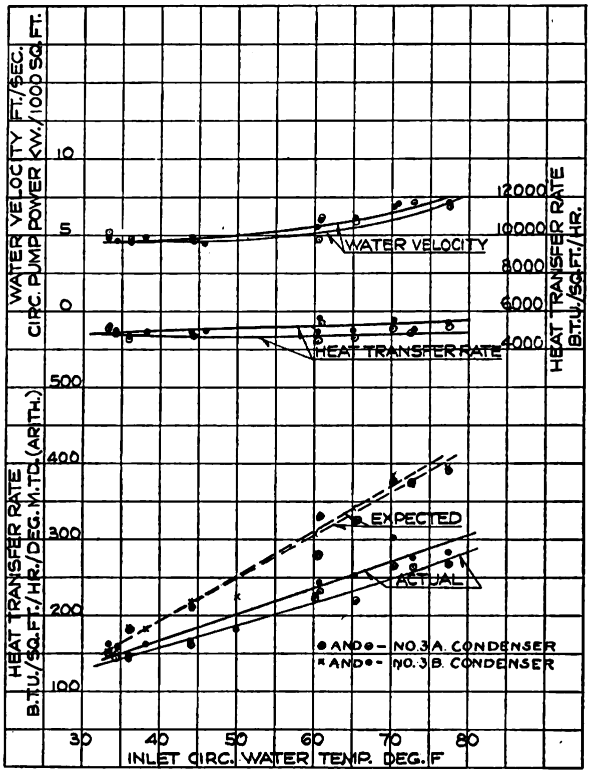

FIG. 18-19—PERFORMANCE OF NO. 3-A AND 3-B CONDENSERS, COLFAX STATION.

TABLE XVIII

AVERAGE OPERATING PERFORMANCE OF NO. 3-A UNIT CONDENSER COLFAX POWER STATION OF THE DUQUESNE LIGHT CO.

YEAR 1928

		Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1.	Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
2.	Heat transferred per hr. per sq. ft. of surface, B.t.u.	4,910	5,130	......	......	4,400	4,600	4,860	5,180	5,080	5,320	4,720	4,520
3.	Lb. circ. water per hr. per sq. foot of surface	437	473	......	......	429	542	647	630	633	557	433	442
4.	Av. velocity circ. water in tubes, ft. per sec	4.83	5.13	......	......	4.63	5.87	7.01	6.82	6.87	6.04	4.70	4.79
5.	Inlet circ. water temp., °F	34.4	33.5	......	......	60.4	65.3	72.8	77.4	70.3	60.8	44.2	36.1
6.	Temp. rise of circ. water, °F	11.6	13.8	......	......	10.6	8.7	7.7	8.4	8.2	9.8	11.2	10.2
7.	Arithmetic mean temp. difference between circ. water and steam, °F	33.6	34.0	......	......	19.5	21.1	18.5	19.4	19.3	23.0	29.2	29.6
8.	Arithmetic coefficient heat transfer	146	151	......	......	226	218	263	267	263	231	162	147
9.	Expected heat transfer coefficient with clean tubes	154	150	......	......	279	324	375	390	377	330	210	183
10.	Ratio of actual to expected heat transfer	0.95	1.00	......	......	0.81	0.67	0.70	0.69	0.70	0.70	0.77	0.80
11.	Air leakage, cu. ft. per min	7.9	11.2	......	......	8.8	14.1	10.9	11.7	9.1	7.4	7.9	7.4
12.	Depression of condensate temp., °F†	......	......	......	......	......	......	......	......	......	......	......	......
13.	Leakage of circ. water, %	......	......	......	......	......	......	......	......	......	......	......	......
14.	Frequency of and methods used in cleaning tubes*	5R	4R		1½R ½M	5R	5R	10R	10R	7R	5R 1M	4R 2M	5R
15.	Hours in service	743.2	615.6	23.9	0	513.9	720	714.1	666.4	691.9	670.1	708.0	744.0
16.	Power requirement circ. water pumps, kw. per 1,000 sq. ft.	......	......	......	......	......	......	......	......	......	......	......	......

†No depression of condensate due to hot drains entering hotwell.
*R = Cleaning with rubber plugs.
M = Cleaning with metal plugs.

TABLE XIX

AVERAGE OPERATING PERFORMANCE OF NO. 3-B UNIT CONDENSER, COLFAX POWER STATION OF THE DUQUESNE LIGHT CO.

YEAR 1928

		Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1.	Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
2.	Heat transferred per hr. per sq. ft. of surface, B.t.u.	5,120	5,330	4,930	4,970	4,860	4,990	5,050	5,430	5,530	5,630	4,930	4,710
3.	Lb. circ. water per hr. per sq. foot surface	431	449	454	414	500	562	647	655	638	556	442	413
4.	Av. velocity circ. water in tubes, ft. per sec	4.66	4.85	4.91	4.48	5.51	6.08	7.01	7.10	6.90	6.02	4.78	4.47
5.	Inlet circ. water temp., °F	34.4	33.5	38.2	45.9	60.4	65.3	72.8	77.4	70.3	60.8	44.2	36.1
6.	Temp. rise of circ. water, °F	12.3	14.2	11.2	12.4	10.0	9.1	7.3	8.5	8.9	10.4	11.5	11.4
7.	Arithmetic mean temp. difference between circ. water and steam, °F	31.9	32.6	30.2	27.3	21.2	19.8	18.3	19.3	18.3	23.1	29.4	31.9
8.	Arithmetic coefficient of heat transfer	160	163	163	182	229	252	276	282	302	243	168	143
9.	Expected heat transfer coefficient with clean tubes	156	152	183	223	309	342	375	394	385	337	220	185
10.	Ratio of actual to expected heat transfer	1.03	1.07	0.89	0.82	0.74	0.74	0.74	0.72	0.78	0.73	0.76	0.77
11.	Air leakage, cu. ft. per min	12.2	12.3	12.5	16.5	15.5	17.6	16.4	10.0	12.0	12.9	13.0	11.1
12.	Depression of condensate temperature, °F†	......	......	......	......	......	......	......	......	......	......	......	......
13.	Leakage circ. water, %	......	......	......	......	......	......	......	......	......	......	......	......
14.	Frequency of and methods used in cleaning tubes*	5-R	4-R	1-R 1-M	5-R 1-M	7-R	6-R	6-R	10-R	8-R	5-R 1-M	5-R 2-M	4-R 1-M
15.	Hours in service	660.5	666.6	642.7	683.4	689.3	655.0	343.6	700.9	659.5	692.8	675.9	742.3
16.	Power requirement circ. water pumps, kw. per 1,000 sq. ft.	......	......	......	......	......	......	......	......	......	......	......	......

†No depression of condensate due to hot drains entering hotwell.
*R—Cleaning with rubber plugs.
M—Cleaning with metal plugs.

determined by a conductivity meter, the cells being located in the hotwells of the condensers. No trouble has been experienced with excessive leakage.

The air leakage is determined by the orifice method, a recording gage giving a continuous record of the leakage. The leakage as reported also includes the leakage and noncondensible gases of the bleeder heaters, as these heaters are vented to various parts of the turbines.

The schedule of cleaning tubes is dependent upon the cost of cleaning and the resulting increase in economy. Both rubber and metal tube cleaners are used. During the summer time the rubber cleaners are used, due to the rapidity with which the tubes can be cleaned. During the winter time, when the fouling of the tubes is less rapid, the metal cleaners are used periodically, as this type removes practically all dirt and scale down to the metal, and results in a better heat transfer.

STATEMENT BY THE EDISON ELECTRIC ILLUMINATING COMPANY, BOSTON, MASS.

Condensers No. 1 and No. 2 at the Edgar Station went into service early in 1925. These are identical 45,232-sq. ft. Worthington condensers for two 32,000-kw. General Electric. 350-lb., 700-deg. fahr. turbines. Table II includes a number of the condenser design characteristics.

Hourly readings, which are averaged daily, weekly and monthly, are taken by the operating crews of the important condenser temperatures in the stations. Venturi meters are installed to measure the condensate flow, but as these meters are recording, no hourly readings are available. The water condensed has, therefore, been taken as a function of the turbine load from data previously prepared. The quantity of circulating water is determined by a condenser heat balance.

Fig. 20 and Table XX give the monthly averages of the hourly readings. The expected heat transfer values are based upon data supplied by the manufacturer for the preparation of an operating "bogey."

Various methods of cleaning condensers with different designs of plugs and by blowing with air and water have been tried at the L Street Station. Finally a plug has been developed which promises to give results. Heretofore there has been no appreciable gain in heat transfer through the use of ordinary solid rubber plugs, but they have been found effective in removing mussel shells and mud from the tubes. At Edgar Station, where the attached data were collected, the conditions do not warrant frequent cleaning with solid rubber plugs.

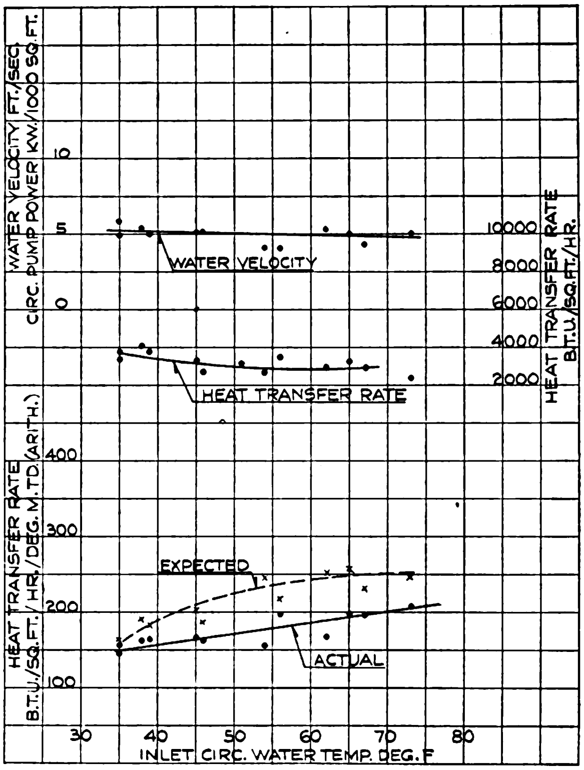

FIG. 20—PERFORMANCE OF NO. 1 CONDENSER, EDGAR STATION.

TABLE XX

AVERAGE OPERATING PERFORMANCE OF NO. 1 CONDENSER
EDGAR STATION OF THE EDISON ELECTRIC ILLUMINATING COMPANY

YEAR 1928

1. Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
2. Hours in service	501	299	457	335	433	456	172	8	429	287	388	386
3. Heat transferred per hr. per sq. ft. of surface, B.t.u.	3,760	3,350	4,070	2,710	2,720	3,040	2,850	2,400	3,290	3,460	3,420	3,800
4. Lb. circ. water per hr. per sq. foot of surface	470	558	509	542	389	507	407	480	470	385	489	475
5. Av. velocity circ. water in tubes, ft. per sec	4.95	5.88	5.36	5.22	4.10	5.34	4.29	5.06	4.95	4.06	5.16	5.01
6. Inlet circ. water temp., °F	35	35	38	46	54	62	67	73	65	56	45	39
7. Temp. rise of circ. water, °F	8	6	8	5	7	6	7	5	7	9	7	8
8. Arithmetic mean temp. difference between circ. water and steam, °F	24.0	23.0	25.0	16.5	17.5	18.0	14.5	11.5	16.5	17.5	20.5	23.0
9. Arithmetic coefficient of heat transfer	157	146	163	164	156	169	197	209	199	198	169	165
10. Expected heat transfer coefficient with clean tubes	164	164	191	189	196	253	232	246	257	218	202	185
11. Ratio of actual to expected heat transfer	0.96	0.89	0.85	0.87	0.80	0.67	0.85	0.85	0.78	0.91	0.84	0.89
12. Depression of condensate temp., °F	3	3	1	0	0	0	0	1	1	2	2	4
13. Frequency of cleaning tubes with rubber plugs	0	0	0	0	0	1	0	0	0	0	0	0
14. Frequency of cleaning tube sheets	3	8	12	24	20	26	7	2	7	5	3	5

STATEMENT BY THE INDIANA & MICHIGAN ELECTRIC COMPANY, CHICAGO, ILL.

Condensers No. 1 and 2 at the Twin Branch Station were installed during the year 1925. These are identical Wheeler condensers of the horizontal, single-pass type. They each have 25,720 sq. ft. of cooling surface with provision for 30,000 sq. ft. No circulating water pumps are installed at this station, due to utilizing the 24-ft. head of water created by the dam at the existing hydro electric plant on the St. Joseph River at this point. Table I includes a number of the design characteristics.

TABLE XXI

AVERAGE OPERATING PERFORMANCE OF NO. 2 CONDENSER, TWIN BRANCH STATION OF THE INDIANA & MICHIGAN ELECTRIC CO.

	Nov. 1927	Dec. 1927	Jan. 1928	Feb. 1928	March 1928	April 1928	May 1928	June 1928	July 1928	Aug. 1928	Sept. 1928	Oct. 1928
1. Heat transferred per. hr. per sq. ft. of surface	11,190	11,170	11,230	11,140	11,310	11,300	11,550	11,680	11,200	11,900	11,780	11,600
2. Lb. circ. water per hr. per sq. ft. of surface	1,830	1,625	1,420	1,420	1,440	1,440	1,935	1,670	1,205	1,980	1,655	1,635
3. Av. velocity circ. water in tubes, ft. per sec.	13.10	11.00	9.8	9.8	9.98	10.0	13.4	11.56	11.92	13.7	11.45	11.31
4. Circ. water inlet temp., °F	47	34	33	33	40	49	63	66	76	76	66	58
5. Temp. rise of circ. water through condenser, °F	6	7	8	8	8	8	6	7	7	6	7	7
6. Arithmetic mean temp. difference between circ. water and steam, °F	29	31.5	36	38	34	26	25	24.5	25.5	23	28.5	27.5
7 Arithmetic coefficient heat transfer	386	365	313	297	334	435	464	477	470	518	413	423
8 Expected heat transfer coefficient with clean tubes	445	370	365	365	410	465	545	570	650	650	570	525
9. Ratio of actual to expected heat transfer coefficient	0.87	0.99	0.86	0.81	0.81	0.94	0.85	0.84	0.72	0.80	0.73	0.81
10. Air leakage, cu. ft. per min.	4	4	3	3	4	3	3	4	4	3	3	3
11. Depression of condensate*	0	0	0	0	0	0	0	0	0	0	0	0
12. Leakage of circ. water, %	0	0.1	0	0	0	0	0	0.05	0	0	0.3	0
13. Frequency and method of cleaning tubes**	1-R	......	1-R	......	1-R	......	1-R	1-R	1-R	......	......	1-R
14. Hours in service	524	623	563	453	434	457	543	496	572	618	426	515

NOTE:—*No depression due to hot drains emptying into hotwell.
**R denotes cleaning with rubber plugs.

Operating Results

Daily observations are made of the performance of all the condensing equipment at the Twin Branch Station. These observations are made by a member of the test organization at a time when the turbines are heavily loaded. Steam condensed is measured by Bailey flow meters. The quantity of circulating water is determined from the quantity of steam condensed and the temperature rise of the circulating water.

Fig. 21 and Table XXI give the monthly averages of daily observations of performance. The expected heat transfer values are based on the manufacturer's guarantee. From the daily observations of performance, the difference between the actual and expected vacua are determined. This value is of use in determining when it is economic to clean the condenser tubes.

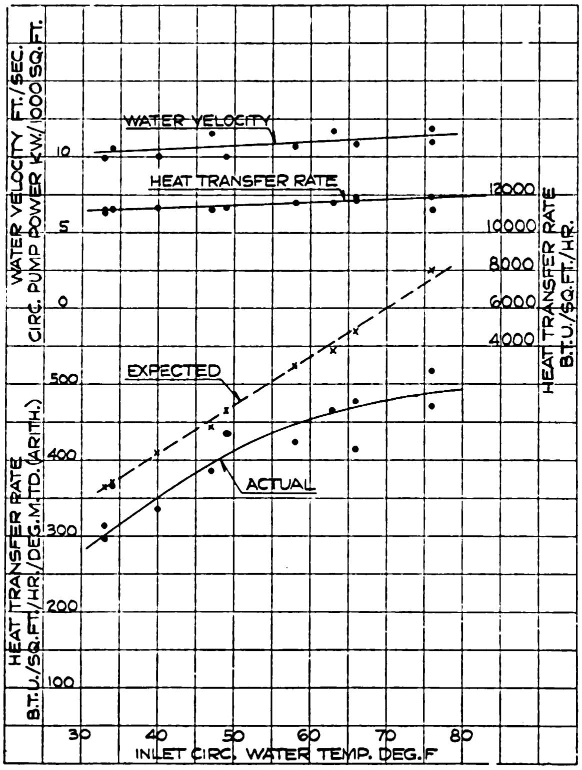

FIG. 21—PERFORMANCE OF NO. 2 CONDENSER, TWIN BRANCH STATION.

As has been said before, no circulating water pumps are necessary due to an existing dam. The top of the dam and the tops of the condensers are at the same elevation, producing an adequate flow of circulating water. Regulation of circulating water is accomplished by throttling the discharge valves of the condensers. Due to the excellent quality of circulating water, not much trouble is experienced with dirty tubes.

Reversal of Circulating Water

These condensers are so designed that the flow of circulating water can be reversed with the machine in service. The flow has been reversed with as much as 10,000 kw. on the turbine with only momentary depression of vacuum. One water box is provided with a 48-in. inlet and 60-in. outlet, and the other is provided with a 60-in. inlet and 48-in. outlet. With the proper manipulation of the intake and discharge valves, the flow can be reversed. However, due to ½-in. mesh traveling screens located at the crib house, reversing has not been found necessary, as any trash which passes through the screens will pass through the tubes.

STATEMENT BY THE MILWAUKEE ELECTRIC RAILWAY & LIGHT COMPANY, MILWAUKEE, WIS.

The condenser installed in the latter part of 1926 with No. 6 unit (30,000 kw.) at Lakeside is a Wheeler single-pass, with 25,000 sq. ft. of surface.

Hourly readings of significant data are taken by the operators, from which Fig. 22 and Table XXII was prepared. Heat input to the condenser was calculated from turbine loads. The expected performance is based on guarantees which were for one circulating water temperature only, but a curve following the trend of observed data and passing through the guarantee point was constructed. Since the unit has been operated throughout the year as a base load unit, no corrections were necessary for load variations. Corrections were made for variations in circulating water temperature.

Raw water leakage into the condenser has been difficult to maintain desirably low. The tubes are rolled at one end and packed with corset lace packing at the other. The ferrules have now been taken up as much as possible, so

TABLE XXII

AVERAGE OPERATING PERFORMANCE OF UNIT NO. 6 CONDENSER LAKESIDE STATION OF THE MILWAUKEE ELECTRIC RAILWAY & LIGHT CO.

YEAR 1928

1. Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
2. Heat transferred per hr. per sq. ft. of surface, B.t.u.	9,594	9,292	9,254	9,360	9,169	9,193	8,888	8,894	8,947	8,834	8,810	9,100
3. Lb. of circ. water per hr. pr. sq. ft. of surface						996 ap	proxim	ate .				
4. Av. velocity of circ. water in tubes, ft. per sec.						6.78 a	pproxi	mate				
5. Inlet circ. water temp., °F	41.2	45.3	42.9	42.7	50.5	53.7	60.9	68.6	57.5	51.7	45.7	34.6
6. Temp. rise of circ. water, °F	9.3	9.1	9.5	9.3	8.8	9.1	9.0	9.4	8.8	8.6	9.2	9.1
7. Arithmetic mean temp. difference between circ. water and steam, °F	23.9	22.4	26.9	21.2	19.9	18.9	16.6	15.4	16.0	18.5	20.5	22.1
8. Arithmetic coefficient of heat transfer	401	415	344	442	461	486	535	578	559	478	430	412
9. Expected heat transfer coefficient with clean tubes	490	509	499	498	532	549	584	619	567	540	510	485
10. Ratio of actual to expected heat transfer	0.82	0.81	0.69	0.89	0.87	0.88	0.92	0.93	0.98	0.88	0.84	0.85
11. Air leakage, cu. ft. per min.	7.5	9.4	10.2	10.3	10.2	8.0	9.6	9.2	8.4	8.0	7.3	7.6
12. Depression of condensate temp., °F	6.9	5.6	8.6	4.5	2.6	0.7	*	*	*	*	3.2	4.6
13. Leakage of circ. water, %	0.19	0.22	0.15	0.28	0.17	0.20	0.05	0.10	0.06	0.13	0.32	0.38
14. Frequency of and methods used in cleaning tubes**	2	1	2	1	1	2	2	3	1	1	2	½
15. Hours in service	673	641	679	622	643	664	633	663	684	670	571	578
16. Power requirement of circ. water pumps, kw. per 1,000 sq. ft.					8	appro	ximate					

*Thermometer in error. **Rubber plugs.

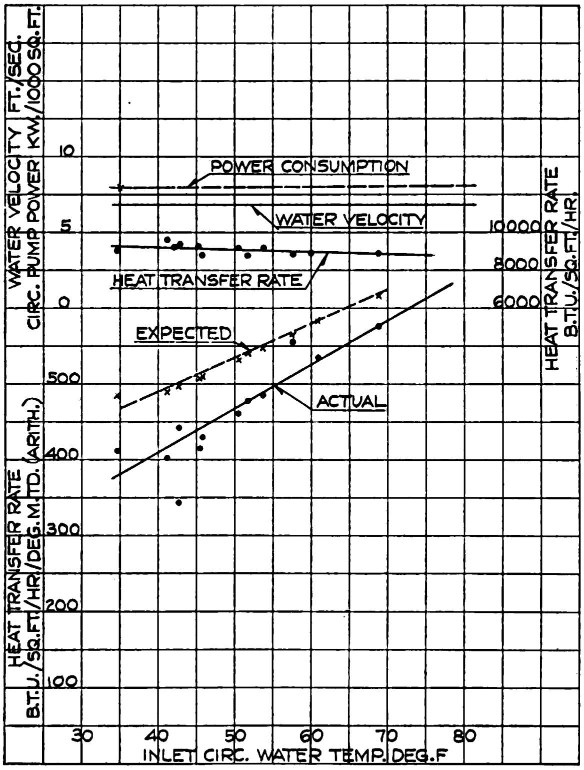

FIG. 22—PERFORMANCE OF NO. 6 CONDENSER, LAKESIDE STATION.

that condenser must be entirely repacked in the near future. Leakage lower than about 0.4 per cent cannot now be obtained.

STATEMENT BY THE NEW YORK EDISON COMPANY, NEW YORK, N. Y.

Condensers No. 1 and 2 at the East River Station were installed during the year 1927 and are identical, being of the single-pass type with single water boxes, and were manufactured by the Foster-Wheeler Corp. Each has 47,500 sq. ft. of surface and is supplied by two turbine driven circulating water pumps, each having a capacity of 45,000 g.p.m. These pump turbines operate condensing. Table I includes some design characteristics.

Table No. XXIII gives the monthly averages of daily observations of performance. Fig. 23 gives a comparison of the performance data for the condenser.

The tubes are cleaned regularly with air and water every other night and by sandblasting twice a year.

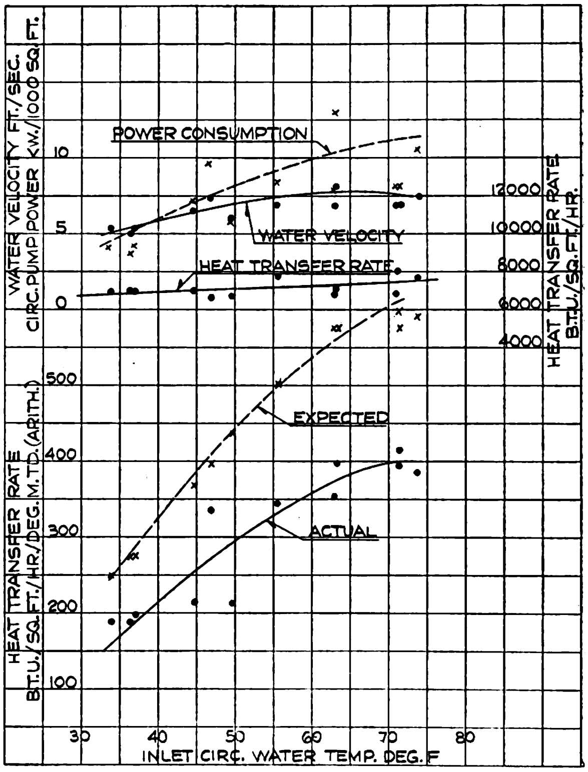

FIG. 23—PERFORMANCE OF NO. 1 CONDENSER, EAST RIVER STATION.

TABLE XXIII

AVERAGE OPERATING PERFORMANCE OF NO. 1 CONDENSER
EAST RIVER STATION OF THE NEW YORK EDISON CO.
YEAR 1928

1. Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
2. Heat transferred per hr. per sq. ft. of surface, B.t.u.	6,950	7,030	6,960	7,020	6,670	6,840	6,820	7,720	8,010	7,120	7,660	6,660
3. Lb. circ. water per hr. per sq. ft. of surface	703	670	707	867	800	900	912	1,000	914	1,080	924	970
4. Av. velocity circ. water in tubes, ft. per sec.	5.28	5.04	5.31	6.52	6.00	6.76	6.86	7.52	6.87	8.13	6.94	7.27
5. Inlet circ. water temp., °F.	33.8	36.5	37.0	44.7	49.6	63.1	71.3	73.7	71.2	63.2	55.5	46.9
6. Temp. rise of circ. water, °F.	9.9	10.5	10.1	8.3	8.6	7.6	7.5	7.7	8.8	6.6	8.3	6.9
7. Arithmetic mean temp. difference between circ. water and steam, °F.	37.0	37.8	35.1	30.4	31.4	19.3	17.3	20.1	19.4	17.9	22.3	20.0
8. Arithmetic coefficient of heat transfer	188	186	199	231	212	354	394	384	413	398	344	333
9. Expected heat transfer coefficient with clean tubes	250	275	276	369	436	575	598	590	576	574	500	397
10. Ratio of actual to expected heat transfer	0.75	0.68	0.72	0.63	0.49	0.62	0.66	0.65	0.72	0.69	0.69	0.84
11. Air leakage, cu. ft. per min.	2.70	2.00	1.90	2.30	3.40	8.60	10.49	3.22	7.70	3.50	6.40	3.80
12. Depression of condensate, °F.	7.6	6.2	8.7	5.3	8.3	5.7	2.5	3.0	4.8	7.1	8.0	10.1
13. Leakage circ. water, %*	......	......	......	......	......	......	......	......	......	......	......	......
14. Frequency of and methods used in cleaning tubes**	......	......	......	......	......	......	......	......	......	......	......	......
15. Hours in service†	......	......	......	......	......	......	......	......	......	......	......	......
16. Power requirement of circ. water pumps, kw. per 1,000 sq. ft.	4.1	3.7	4.2	7.1	5.8	7.9	8.0	10.5	8.0	13.0	8.4	9.5

*Average is 0.16%.
**Every other night ¼ to ½ of the tubes are cleaned with water and air. Twice a year tubes are sand blasted.
†No data available.

A constant check of the condition of the condensate is maintained by a salinity indicator, and titration tests are made every two hours.

A constant vacuum is maintained on the tail-pipes.

STATEMENT BY THE NORTHERN STATES POWER COMPANY OF MINNEAPOLIS, MINN.

No. 1 condenser at High Bridge Station was installed in 1924, has 40,000 sq. ft. of cooling surface, serves a 30,000-kw., 17-stage, G. E. turbine and was built by Worthington. Table II includes design characteristics.

Table XXIV gaves the monthly averages of the performance for a load of 24,000 kw., as indicated by the operating records. These data were collected from the daily operating records and are, therefore, not of a high degree of accuracy, but every effort was made to eliminate the effect of observational error. The quantity of the condensate was taken from the condensate meter, and the amount of circulating water was assumed to remain constant since the pump runs at constant speed.

The curve of the actual monthly averages of the coefficient of heat transfer is shown, together with the curve of expected coefficient of heat transfer in Fig. 24. The expected heat transfer values, based on manufacturer's guarantees, were not available; therefore the values shown were calculated from the expected minimum absolute pressure as determined by condenser performance immediately after cleaning. These values are, therefore, possibly a little higher than the manufacturer's guarantees would be. The expected minimum absolute pressure cannot be maintained in operation because the condenser tubes foul very quickly after cleaning.

TABLE XXIV

AVRERAGE OPERATING PERFORMANCE OF NO. 1 CONDENSER, HIGH BRIDGE STATION OF THE NORTHERN STATES POWER CO.

	Nov. 1927	Dec. 1927	Jan. 1928	Feb. 1928	March 1928	April 1928	May 1928	June 1928	July 1928	Aug. 1928	Sept. 1928	Oct. 1928
1. Heat transferred per hr. per sq. ft. of surface, B.t.u.	5,310	5,220	5,440	5,320	5,100	5,050	5,310	5,380	5,380	5,310	5,360	5,540
2. Lb. circ. water per hr. per sq. ft. of surface	533	533	533	533	533	533	531	531	531	531	532	532
3. Av. velocity circ. water in tubes, ft. per sec.	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2
4. Inlet temp. circ. water, °F.	35.5	32.6	33.3	33.2	33.9	42.2	66.9	67.2	76.7	73.2	64.8	55.4
5. Temp. rise of circ. water, °F.	9.8	9.6	10.2	9.8	9.4	9.3	10.0	10.1	10.1	10.0	9.9	10.4
6. Arithmetic mean temp. difference between circ. water and steam, °F.	27.3	29.9	33.4	29.7	29.5	23.0	17.0	17.6	14.9	14.0	14.7	20.4
7. Arithmetic coefficient heat transfer	194	174	163	179	173	220	312	306	360	380	365	271
8. Heat transfer coefficient with clean tubes	226	212	219	218	220	288	474	481	547	532	462	382
9. Ratio of actual to clean tube transfer	0.86	0.82	0.74	0.82	0.79	0.76	0.66	0.64	0.66	0.71	0.79	0.71
10. Air leakage, cu. ft. per min.	2.7	2.4	2.7	2.3	2.4	2.3	2.4	2.3	2.3	2.2	1.9	1.9
11. Depression of condensate temp., °F.	7.2	6.5	6.2	5.3	6.2	5.8	4.6	4.5	3.2	2.3	3.0	5.5
12. Leakage circ. water, %**	......	......	......	......	......	......	......	......	......	......	......	......
13. Frequency of cleaning tubes	4	4	5	7	9	8	7	7	10	7	9	6
14. Hours in service	366	562	682	650	595	465	474	580	480	617	471	430
15. Power requirement of circ. pump, kw. per 1,000 sq. ft.	**	**	6.6	6.4	6.3	6.3	6.6	6.3	6.7	6.6	6.4	6.0

**No data available for these items.

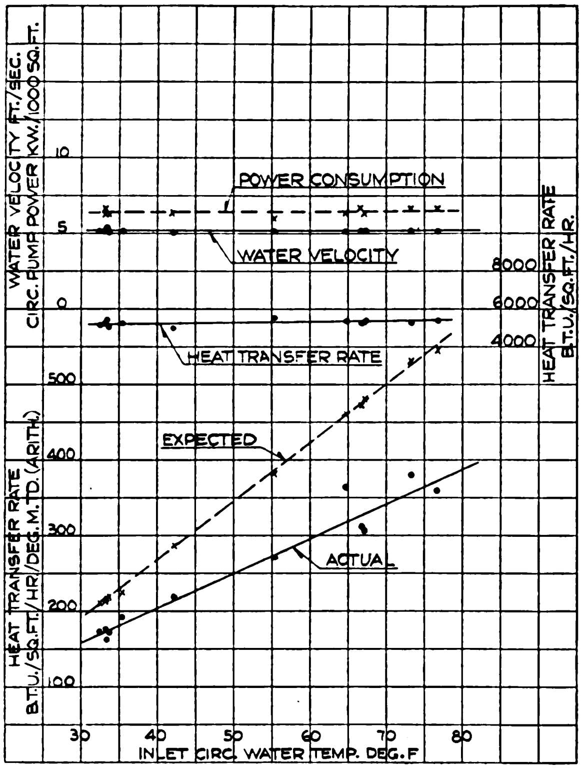

FIG. 24—PERFORMANCE OF NO. 1 CONDENSER, HIGH BRIDGE STATION.

Frequency of Cleaning

The condenser is cleaned by forcing rubber plugs through the tubes with an air gun. The rubber plugs have been very satisfactory in removing the soft, slimy deposit which collects in the tubes during operation. The frequency of cleaning depends upon the following considerations:

1. Difference between actual and expected vacuum.
2. Saving due to decreased absolute pressure.
3. Cost of cleaning.
4. Loss due to generating load on less efficient unit during cleaning period.
5. Rate at which tubes foul after cleaning.

It will be noted that the frequency of cleaning varies from 4 times per month in the winter to 10 times in the summer as shown in Table XXIV.

The condenser is equipped with one duplex driven circulating pump. Under normal conditions the motor drive is used. The steam turbine is used only for feed water heat balance or in case of electrical disturbances.

STATEMENT BY THE PENNSYLVANIA POWER & LIGHT COMPANY, ALLENTOWN, PA.

Description of Condenser and Cooling Pond

Condenser No. 3 was installed at Pine Grove early in 1926, is a 50,000-sq. ft., 2-pass, counter-flow, divided water box type, and was made by the Worthington Pump & Machinery Corp. The manufacturers specify 45,000 g.p.m. of circulating water at full load of 300,000 lb. of steam per hour; velocity of circulating water 5.2 ft. per second, based on 4340 tubes per pass. It is equipped with two sets of Worthington steam jet air removal pumps, either of which is capable of carrying off sufficient non-condensable vapor to maintain the expected vacuum under normal conditions. The condensate is removed from the hotwell by either of two motor-driven centrifugal pumps, each of which is large enough to carry the resultant condensate from a full load on the unit. Table II includes a number of the design characteristics.

The circulating water is handled by two motor-driven pumps. The motors may be run at either of two speeds, 442 r.p.m. or 294 r.p.m. Two-speed motors are used because of the two different methods of discharging the circulating water. This water may be returned to the cooling pond by use of a set of sprays, in which case the higher speed is used, or it may be pumped into a discharge water channel. The cold water discharged from the pumps enters the condenser from the bottom, passes through the lower tubes and returns through the upper tubes to the discharge lines.

A description of the layout of the cooling pond will explain the difference between the free discharge into the channel and the discharge through sprays. The pond is essentially rectangular, with its longer dimension north and south and is situated to the east of the plant. It serves two 12,500-kw. turbine condensers as well as the one under discussion. It receives its fresh water make up from the northeast corner, and the excess is discharged over a spillway at the southwest corner. Along the whole west side of the pond, and separated from it by a concrete wall, runs the discharge channel. The only connection in use during normal operation between the pond and the channel is at the southwest corner of the pond adjacent to the previously mentioned spillway, and there is no other outlet from the channel. With this arrangement it is readily seen that, when water is discharged into the channel, it can only run in one direction, and when water is plentiful and a large quantity is flowing over the spillway a large proportion of the discharge water will take this course. In dry weather, when water is scarce and very little finds its way over the spillway, the water from the channel flows into the body of the pond and eventually circulated back to the intake. The intake is situated approximately halfway up the length of the pond on the west side, and consists of an underground duct passing under the channel, and into a screen house equipped with traveling screens for removing the larger of the foreign materials carried along by the water. The circulating pumps take their suction from the screen house. The sprays are extended out over the greater portion of the surface of the pond, and the selection of spraying or channel discharge is accomplished by means of remote control motor operated valves.

Choice between the two methods of disposing of circulating water depends on the following conditions: Relative humidity, temperature of air and temperature of the pond; rather than on any consideration of station loading or other conditions within the plant.

It has been found by experiment that both circulating pumps are necessary for the most economic operation, regardless of whether the discharge is sprayed or emptied directly into the channel. With only one pump working, the vacuum in the condenser falls appreciably, but may be held at a sufficiently high value to allow a normal loading of the unit in case of emergency.

The condenser is equipped with a vacuum breaking line which is extended up to the level of the turbine operating floor, ending in a valve with a water seal. This is for convenience in shutting down the machine.

Due to the nature of the design of the unit as a whole, the quantity of water condensed in the main condenser is not equivalent to the quantity of steam fed to the turbine. Bleeding from the 7th, 11th and 14th stages of the turbine accounts for the difference. None of this extracted steam finds its way back to the main condenser.

Method of Obtaining Data

No daily records are available on the quantity of condensate removed from the hotwell, but there is a Builders Iron Foundry mercury manometer and venturi tube permanently installed for test purposes, so that it is possible to get this information at any time. Other condenser operating data are obtained by means of two 3-pen Foxboro recorders which include exhaust steam temperature, condensate temperature, and injection and discharge circulating water temperatures on each of the two sides of the con-

TABLE XXV

AVERAGE OPERATING PERFORMANCE OF NO. 3 CONDENSER
PINE GROVE STATION OF THE PENNSYLVANIA POWER & LIGHT COMPANY

YEAR 1928

1. Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
2. Heat transferred per hr. per sq. ft. of surface, B.t.u.	4,430	4,440	4,370	4,590	4,770	4,850	4,700	4,850	4,730	4,750	4,580	4,480
3. Lb. of circ. water per hr. per sq. ft. of surface	526	515	511	520	538	537	544	536	560	558	575	585
4. Av. velocity of circ. water in tubes, ft. per sec.	6.1	6.0	5.9	6.0	6.2	6.2	6.3	6.2	6.5	6.4	6.6	6.8
5. Inlet circ. water temp., °F.	65.7	58.0	65.2	68.2	76.0	81.6	82.9	88.4	82.9	80.0	74.2	68.3
6. Temp. rise of circ. water, °F.	8.3	8.7	8.6	8.9	8.8	9.0	8.7	9.1	8.4	8.5	8.0	7.7
7. Arithmetic mean temp. difference between circ. water and steam, °F.	16.2	20.5	15.9	18.7	18.7	18.9	12.9	14.9	15.7	16.4	13.7	13.2
8. Arithmetic coefficient of heat transfer	274	217	275	245	255	256	365	325	301	290	334	339
9. Expected heat transfer coefficient with clean tubes	378	369	361	379	397	400	402	397	404	405	394	396
10. Ratio of actual to expected heat transfer	0.73	0.59	0.76	0.65	0.64	0.64	0.91	0.82	0.74	0.72	0.85	0.86
11. Air leakage, cu. ft. per min.					Not	measu	red					
12. Depression of condensate temp., °F.	1.9	0.8	1.0	1.8	1.6	0.7	0.6	0.3	1.0	1.0	0.9	0.3
13. Leakage of circ. water, %					Not	measu	red					
14. Frequency of and methods used in cleaning tubes	1	0	0	0	0	0	1	0	0	1	0	0
15. Hours in service	682	677	723	703	733	720	728	635	708	662	402	729
16. Power requirement of circ. water pumps, kw. per 1,000 sq. ft.					Not	measu	red					

denser. A Tyco barometric type mercurial vacuum gage equipped with a vernier is used to obtain the vacuum at the exhaust. These instruments, together with a high water alarm in the hotwell and the usual allotment of pressure and vacuum gages on the condenser and auxiliaries, furnish the operating guide and source of daily records. Also all necessary pipe lines have thermometer wells installed at convenient points for test work, so that all important temperatures may be observed on calibrated mercury thermometers.

In addition to the daily records, a test is run each week to determine the operating characteristics of the unit as a whole. All pertinent condenser data are taken in these tests, and the information derived consists of such items as coefficient of heat transfer, comparison of actual back pressure to expected back pressure in which corrections are made for injection water temperature, rise in temperature of the circulating water and quantity of steam handled; as well as those items more readily obtained through daily routine readings. Records of these tests are tabulated on specially designed report forms and the more important items are plotted in curve form, each year being included on one set of sheets. The tests are always run with the load on the unit as nearly the same from week to week as is possible, the only variations being due to governor characteristics, slight changes in system frequency, etc. The pre-arranged test load for unit No. 3 is 27,000 kw., which is the point of best economy, according to the manufacturer's specifications. At this load and with normal turbine stage bleeding conditions the condenser receives an average of about 240,000 lb. of steam per hour or 80 per cent of its rated capacity.

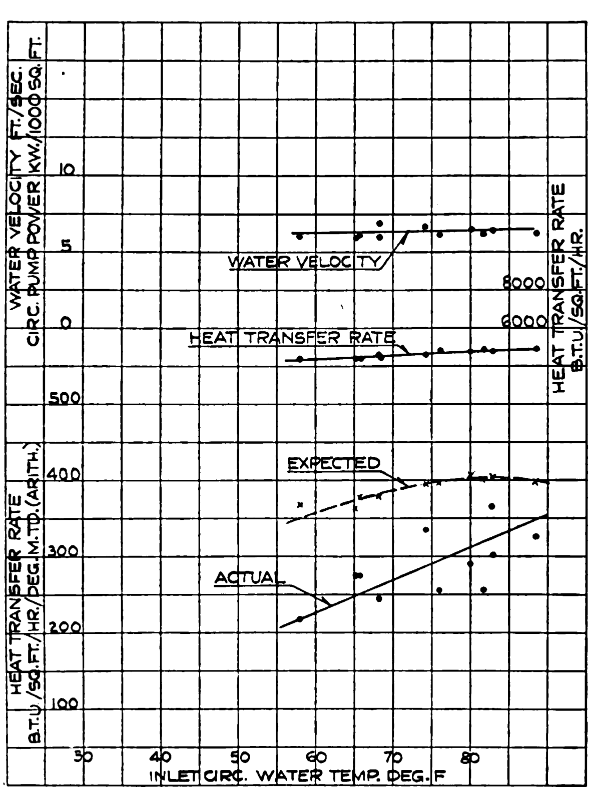

FIG. 25—PERFORMANCE OF NO. 3 CONDENSER, PINE GROVE STATION.

The tests just described form the basis for the operating data given in Fig. 25 and Table XXV.

With the back pressure largely dependent on the temperature of injection water and with the peculiar temperature characteristics of the cooling pond, the results of the weekly tests form an excellent basis for comparative condenser performance. Peculiar temperature characteristics of the spray pond refer to the fact that the water temperature is dependent on quantity of rainfall over a given period rather than on outside air temperature over that period. From this it will be seen that comparisons by months are not important, for although the average air temperature throughout any given month of a year may be similar to that of the same month of another year, the pond temperature may vary, due to difference in rainfall, to such an extent that condenser performance during these months will be entirely different.

The important parts of the daily records are also plotted up in curve form, similarly to the test data. The curves on condenser performance then form a part of the complete set of operating data curves giving information on all sections of the plant.

Cleaning of Tubes

The operation of the condenser has been very satisfactory. With clean tubes it is possible to approach very closely to the expected back pressure. For several weeks, under normal conditions, after a tube cleaning the difference between the actual and expected figures will run less than 0.10-in. Hg. This difference will increase until the next cleaning.

The water boxes of the condenser are cleaned periodically. As it is possible to operate with only one circulating pump and one-half of the condenser active, the other half may be cleaned while the unit is in operation but this method is not generally employed. Once a month, usually the last Sunday, the unit is taken out of service for miscellaneous work and the water boxes and tube sheets are cleaned at this time.

The tubes are cleaned by shooting rubber plugs through them with compressed air, approximately every three months. The unit is not removed from service for this job alone, but under circumstances similar to those mentioned in the preceding paragraph. On a few occasions a tube has been found to have worked loose, but, after tightening up the ferrules, tests have shown no indication of leakage. The tubes are ferruled at one end and are packed with corset lacing type packing.

No major troubles have been encountered. Occasional small air leaks have been discovered around pipe joints, and immediately patched up with shellac. In case of a large leak a temporary job was done with the shellac, and later at an opportune time the joint was renewed. A periodic water pressure test forms the principal method of detecting leaks.

STATEMENT BY THE PHILADELPHIA ELECTRIC COMPANY, PHILADELPHIA, PA.

Condensers No. 10 and 11 were installed at the Richmond Station during the year 1925. Design data are shown in Table II and operation data in Fig. 26 and 27 and Tables XXVI and XXVII.

Hourly readings of turbine load, circulating water temperatures entering and leaving the condensers, condensate flow, condensate temperature, barometer and condenser vacuum are taken in conjunction with other necessary plant readings. These data are assembled on plant log sheets for observation by the plant supervisors and for record in the central office.

Table XXVI and XXVII give the monthly averages resulting from readings taken from log sheets for one hour each day when the unit was carrying its average maximum load, or as near that value as could be obtained. The quantity of circulating water as given was computed from curves of heat absorbed by the water, obtained by assembling data given on numerous turbine tests and the actual temperature rise. The expected heat transfer rates as shown are based on manufacturers' guarantees. The other figures given are either actual instrument readings or values computed from such readings.

"The condensers are completely cleaned every two weeks, which results in our taking one unit out of service every week-end. Richmond Station has shown the lowest B.t.u. rate of any steam plant on the system, and it is found most economical in studying system loading to allocate most of the steam load to this station. Again by careful consideration of the monetary value of unit change in vacuum, average change in vacuum for a given time between cleanings, the cost of the cleaning and the loss due to outage of the units, the above schedule was found to be most feasible.

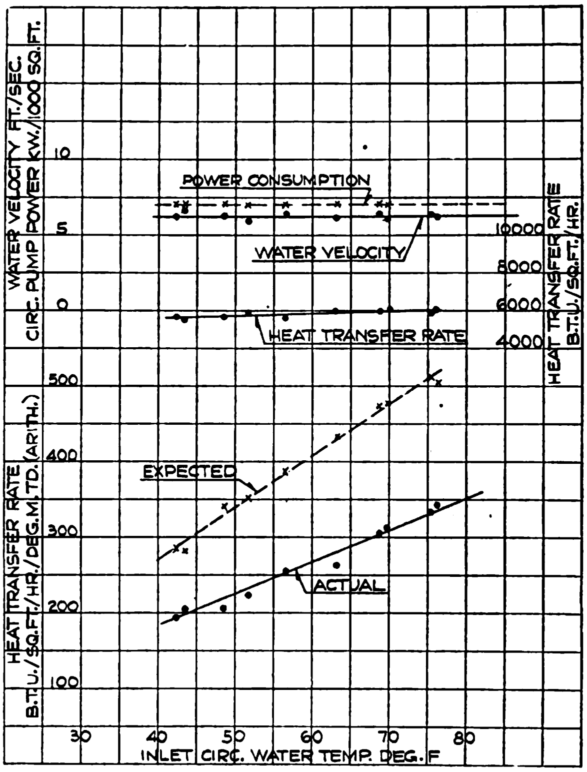

FIG. 26—PERFORMANCE OF NO. 10 CONDENSER, RICHMOND STATION.

TABLE XXVI

AVERAGE OPERATING PERFORMANCE OF NO. 10 CONDENSER
RICHMOND STATION OF THE PHILADELPHIA ELECTRIC CO.
YEAR 1928

1. Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
2. Heat transferred per hr. per sq. ft. of surface, B.t.u.	......	......	5,500	5,700	5,630	5,980	5,880	6,090	6,125	6,030	5,860	5,670
3. Lb. circ. water per hr. per sq. ft. of surface	......	......	604	570	580	575	575	569	552	559	532	573
4. Av. velocity circ. water in tubes, ft. per sec.	......	......	6.7	6.3	6.4	6.4	6.4	6.3	6.1	6.2	4.9	6.4
5. Inlet circ. water temp., °F	......	......	43.5	48.7	56.6	68.8	75.4	76.1	69.9	63.1	51.8	42.4
6. Temp. rise of circ. water, °F	......	......	9.1	10.0	9.7	10.4	10.2	10.7	11.1	10.8	11.0	9.9
7. Arithmetic mean temp. difference between circ. water and steam, °F	......	......	26.8	27.6	22.1	19.6	17.7	17.8	19.6	23.0	26.2	29.3
8. Arithmetic coefficient heat transfer	......	......	205	206	255	305	332	342	312	262	224	194
9. Expected heat transfer coefficient	......	......	282	342	389	473	511	505	479	433	352	289
10. Ratio of actual to expected heat transfer	......	......	0.728	0.603	0.656	0.645	0.650	0.678	0.652	0.605	0.636	0.672
11. Air leakage, cu. ft. per min	......	......	5	5	5	5	5	5	5	5	5	5
12. Depression of condensate temp., °F	......	......	8.0	6.6	4.2	3.8	2.8	2.3	2.1	3.1	4.4	6.5
13. Leakage circ. water, lb. per hr	......	......	696	556	626	......	......	211	245	300	278	314
14. Frequency of and methods used in cleaning tubes			Every	two w	eeks b	y rubb	er plug	metho	d			
15. Hours in service	......	......	400	589.5	533.5	254.8	531.3	648.5	662.8	668.3	674	672
16. Power requirement circ. water pumps, kw. per 1,000 sq. ft.	......	......	7.01	......	......	......	......	......	......	......	......	7.01
17. Av. load on unit, 1,000 kw	......	......	52.7	53.8	52.8	54.6	52.8	54.6	55.6	55.3	55.1	54.2
18. Condensate, 1,000 lb. per hr	......	......	424.1	464.5	461.2	488.0	466.3	495.5	493.6	485.3	464.1	444.8
19. Temp. condensate, °F	......	......	66.8	74.7	79.4	89.8	95.4	97.0	93.0	88.4	79.1	70.1

TABLE XXVII

AVERAGE OPERATING PERFORMANCE OF NO. 11 CONDENSER
RICHMOND STATION OF THE PHILADELPHIA ELECTRIC CO.

YEAR 1928

1. Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
2. Heat transferred per hr. per sq. ft. of surface, B.t.u.	5,770	5,700	5,740	5,870	5,710	5,860	5,930	6,140	6,170	6,070	5,860	5,700
3. Lb. circ. water pr. hr. per sq. ft. of surface	516	500	533	529	497	497	520	534	510	494	496	513
4. Av. velocity circ. water in tubes, ft. per sec	5.7	5.5	5.9	5.8	5.5	5.5	5.8	5.9	5.6	5.5	5.5	5.7
5. Inlet circ. water temp., °F	36.7	36.1	41.1	50.1	56.8	67.0	75.5	77.3	69.2	63.4	52.3	42.4
6. Temp. rise of circ. water, °F	11.2	11.4	10.8	11.1	11.5	11.8	11.4	11.5	12.1	12.3	11.8	11.1
7. Arithmetic mean temp. difference between circ. water and steam, °F	29.4	28.4	24.8	22.5	20.9	17.7	16.1	16.0	18.2	22.3	25.2	27.6
8. Arithmetic coefficient heat transfer	196	201	231	261	274	331	368	384	339	272	232	206
9. Expected heat transfer coefficient	320	310	353	392	400	425	454	462	435	416	386	354
10. Ratio of actual to expected heat transfer	0.612	0.649	0.655	0.655	0.685	0.780	0.810	0.831	0.780	0.654	0.600	0.581
11. Air leakage, cu. ft. per min	5	5	5	5	5	5	5	5	5	5	5	5
12. Depression of condensate temp., °F	2.8	1.8	1.3	0.7	0.8	0.1	0.5	0.4	0.8	1.1	2.1	2.6
13. Leakage circ. water, lb. per hr	99	69	......	123	274	95	193	178	137	48	54	96
14. Frequency of and methods used in cleaning tubes			Ever	y two	weeks	by ru	bber p	lug me	thod			
15. Hours of service	688	516	665	515	527	484	526	441	579	700	662	681
16. Power requirement circ. water pumps, kw. per 1,000 sq. ft.	5.47	......	......	......	......	......	......	......	......	......	......	5.47
17. Average load on unit, 1,000 kw	55.6	55.1	55.3	56.0	53.7	54.0	53.5	55.0	56.2	55.6	55.0	54.6
18. Condensate, 1,000 lb. per hr	455	444	444	466	473	470	476	492	486	482	458	446
19. Temp. condensate, °F	68.9	68.4	70.0	77.5	82.7	90.5	96.8	98.7	92.7	90.8	81.3	73.0

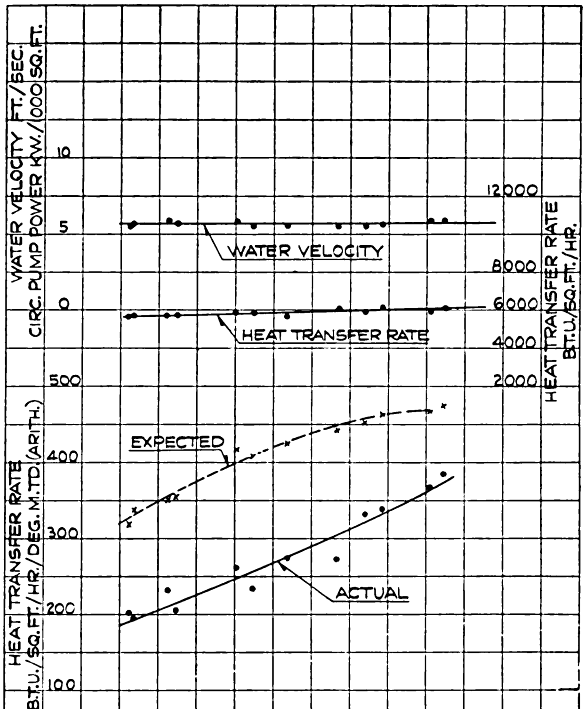

FIG. 27—PERFORMANCE OF NO. 11 CONDENSER, RICHMOND STATION.

No serious trouble has been encountered due to leakage of water, and continual vigilance on the part of the operators has kept the air leakage within reasonable limits.

STATEMENT BY THE PUBLIC SERVICE COMPANY OF COLORADO

No. 1 condenser at the Valmont Station, installed in November, 1924, is a Westinghouse horizontal two-pass surface condenser, laned around the outside of the tubes, with 30,000 sq. ft. of cooling surface including the air cooler.

No. 2 condenser was installed in October, 1926, is a two-pass Wheeler shallow type, 13 ft. 6 in. wide and 8 ft. deep, with 30,000 sq. ft. of surface. Tubes are arranged on the Wheeler multi pitch plan to allow a uniform distribution of steam throughout the condenser.

Both condensers are equipped with two circulating water pumps, one of which is dual driven by a constant speed a-c.

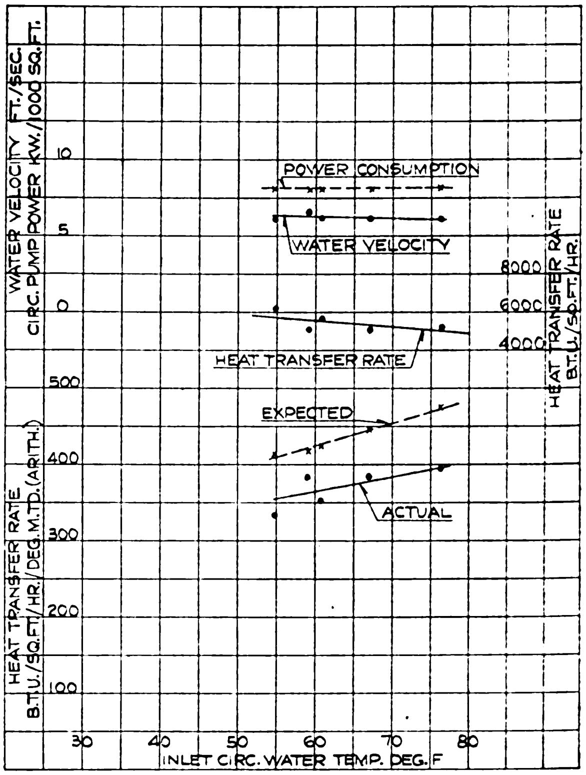

FIG. 28—PERFORMANCE OF NO. 1 CONDENSER, VALMONT STATION.

TABLE XXVIII

AVERAGE OPERATING PERFORMANCE OF NO. 1 CONDENSER
VALMONT PLANT OF THE PUBLIC SERVICE COMPANY
YEAR 1928

1. Month	Jan.	Feb	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
2. Heat transferred per hr. per sq. ft. of surface, B.t.u.	......	......	......	6,193	5,650	5,011	5,216	......	......	6,151	......	......
3. Lb. circ. water per hr. per sq. ft. of surface	......	......	......	619	628	629	621	......	......	661	......	......
4. Av. velocity of circ. water in tubes, ft. per sec.	......	......	......	6.1	6.2	6.2	6.1	......	......	6.5	......	......
5. Inlet circ. temp., °F	......	......	......	54.8	60.7	67.0	76.3	......	......	59.2	......	......
6. Temp. rise circ. water, °F	......	......	......	10.0	9.0	8.0	8.4	......	......	9.3	......	......
7. Arithmetic mean temp. difference between circ. waters and steam, °F	......	......	......	18.6	16.1	13.0	13.2	......	......	16.1	......	......
8. Arithmetic coefficient of heat transfer	......	......	......	333	351	385	395	......	......	382	......	......
9. Expected heat transfer coefficient with clean tubes	......	......	......	413	426	446	477	......	......	417	......	......
10. Ratio of actual to expected heat transfer	......	......	......	0.81	0.82	0.86	0.83	......	......	0.92	......	......
11. Air leakage, cu. ft. per min	......	......	......	4	3	3	3	......	......	6	......	......
12. Depression of condensate temp., °F.*	......	......	......	0	0	0	0	......	......	0	......	......
13. Leakage circ. water, %	......	......	......	0	0	0	0	......	......	0	......	......
14. Frequency of and methods used in cleaning tubes	......	......	......	0	0	0	0	Cleaned with acid		0	......	......
15. Hours in service	50	64	92	294	737	720	298	20	70	399	50	10
16. Power requirement of circ. water pumps, kw. per 1,000 sq. ft.	......	......	......	8.1	8.1	8.1	8.1	......	......	8.1	......	......

*No depression because of drains entering hot well.

TABLE XXIX

AVERAGE OPERATING PERFORMANCE OF NO. 2 CONDENSER
VALMONT PLANT OF THE PUBLIC SERVICE COMPANY
YEAR 1928

1. Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec,
2. Heat transferred per. hr. per sq. ft. of surface, B.t.u.	7,762	7,806	7,779	8,086	......	......	5,078	6,445	6,195	6,283	6,102	6,079
3. Lb. circ. water per hr. per sq. ft. of surface	739	729	720	742	......	......	758	732	762	722	735	454
4. Av. velocity circ. water in tubes, ft. per sec	7.3	7.2	7.3	7.3	......	......	7.5	7.3	7.6	7.3	7.3	4.5
5. Inlet circ. water temp., °F	43.5	45.3	49.2	51.3	......	......	76.3	75.4	71.0	64.8	53.4	45.1
6. Temp. rise circ. water, °F	10.5	10.7	10.8	10.9	......	......	6.7	8.8	8.1	8.7	8.3	13.4
7. Arithmetic mean temp. difference between steam and circ. water, °F	25.7	25.9	25.1	27.2	......	......	10.3	13.6	13.8	15.0	16.3	20.2
8. Arithmetic coefficient of heat transfer	302	301	310	298	......	......	493	474	459	419	375	301
9. Expected heat transfer coefficient with clean tubes	382	390	434	424	......	......	430	418	462	476	412	309
10. Ratio of actual to expected heat transfer	0.79	0.77	0.71	0.70	......	......	1.15	1.13	0.99	0.88	0.91	0.97
11. Air leakage, cu. ft. per min	2	2	2	2	......	......	3	2	2	2	2	2
12. Depression of condensate temp., °F	6.5	6.3	4.2	5.0	......	......	2.0	3.0	3.2	2.7	4.0	4.7
13. Leakage circ. water, %	......	......	......	......	......	......	......	......	......	......	......	......
14. Frequency of and methods used in cleaning tubes	0	0	0	0	Cleaned with Muriatic Acid Solution	0	0	0	0	0	0	0
15. Hours in service	695	633	690	427	0	0	455	724	650	355	674	734
16. Power requirement of circ. water pumps, kw. per 1,000 sq. ft.	8.6	8.6	8.6	8.6	......	......	8.6	8.6	8.6	8.6	8.6	4.2

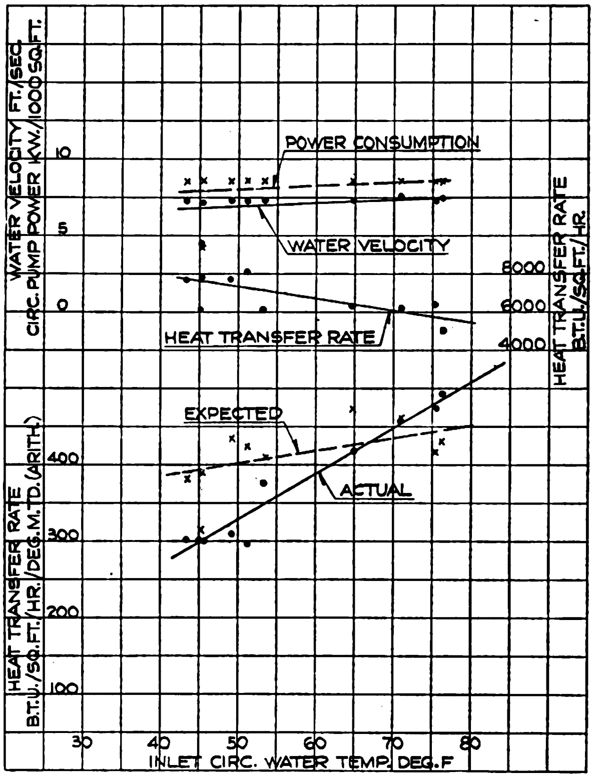

FIG. 29—PERFORMANCE OF NO. 2 CONDENSER, VALMONT STATION.

motor and a steam turbine. The other is driven by a constant speed a-c. motor. Thus there is either one or two pump operation, as conditions and economies warrant.

The data for the calculations in Fig. 28 and 29 and Tables XXVIII and XXIX were obtained from daily log sheets and recorder charts and averaged for each month; and, while not taken under test conditions can be considered fairly accurate.

The quantity of steam condensed was measured by means of a Bailey flow meter, which is periodically checked by weighed water tests.

The expected coefficients of heat transfer were calculated from manufacturers' guarantees and from tests run shortly after the condenser was installed.

A daily test for chlorides was run on the condensate, and it may safely be assumed from these tests that the condenser leakage did not exceed 0.3 per cent at the loads chosen.

The source of supply of circulating water is an 120-acre artificial lake supplied by water from the adjacent mountains. The water is free enough from organic and suspended matter, so that No. 1 condenser was in operation almost four years before it was considered to be in need of cleaning, a thin carbonate scale having formed in the tubes. This was removed by using a 10-per cent solution of muriatic acid.

STATEMENT BY THE TOLEDO EDISON COMPANY, TOLEDO, OHIO

The condenser on No. 3 unit at Acme Station, manufactured by the Wheeler Condenser & Engineering Corp. is 45,000 sq. ft. arranged for two passes of the circulating water. The more important design characteristics are included in Table II.

Observations for checking the performance of condensers at this station are made at frequent intervals. The quantity of circulating water is calculated from the turbine load and temperature rise of circulating water at the time of observation.

The important factor in determining when the condensers need cleaning is vacuum. Curves of standard performance covering the operating load range of the turbine have been plotted against vacuum and inlet temperature of circulating water, and from these curves comparison between expected vacuum and actual vacuum for any load can be readily made; and the degree of need for cleaning determined. Under average conditions a loss of 0.15 in. hg. vacuum over a period of one week will cause an increase in steam consumption equivalent to the cost of cleaning the condenser, so the condensers are cleaned over the week-end of the current week in which the vacuum reaches a point where it is 0.15 in. hg. low with usual day run load on the unit.

Average performance of the condenser on No. 3 turbine is given in Fig. 30 and Table XXX. The heat transfer rates secured in actual operation are less than expected in all cases, since the actual values represent the performance of tubes that are in just an average state of cleanliness.

TABLE XXX

AVERAGE OPERATING PERFORMANCE OF NO. 3 CONDENSER, ACME STATION OF THE TOLEDO EDISON CO., YEAR 1928

1. Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.
2. Heat transferred per hr. per sq. ft. of surface, B.t.u.	5,916	5,983	5,856	5,400	5,385	5,386	5,910	5,920	5,876	5,950	5,914
3. Lb. circ. water per hr. per sq. ft. of surface	600	600	600	600	600	600	600	600	600	600	600
4. Av. velocity circ. water in tubes, ft. per sec.	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7
5. Inlet circ. water temp., °F	50	50	50	51	63	67	78	78	69	61	52
6. Temp. rise circ. water, °F	10	10	10	9	9	9	10	9	10	10	10
7. Arithmetic mean temp. difference between circ. water and steam, °F	27	27	27	27	17	16	16	17	16	17	25
8. Arithmetic coefficient heat transfer	219	222	216	200	317	337	367	370	367	350	237
9. Expected heat transfer coefficient with clean tubes	300	300	300	300	400	385	410	405	375	360	300
10. Ratio of actual to expected heat transfer	0.73	0.74	0.72	0.66	0.79	0.87	0.90	0.91	0.98	0.97	0.79
11. Air leakage, cu. ft. per min.	16	15	15	16	16	14	14	16	15	14	14
12. Depression of condensate temp., °F.†	4	4	3	3	3	3	2	2	2	3	3
13. Leakage of circ. water, %	0.3	0.4	0.2	0.3	0.4	0.3	0.3	0.4	0.3	0.3	0.3
14. Frequency of and methods used in cleaning tubes*	1-R	1-R	1-R	......	1-S	......	1-O	1-R	1-R	1-R	1-R
15. Hours in service	683	673	732	668	678	692	670	712	632	720	700
16. Power requirement of circ. water pump, kw. per 1,000 sq. ft.	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9

*R—Cleaning with rubber plugs.
S—Cleaning with sand blast.
O—Cleaning with solution of Oakite.
†Depression of condensate partially offset by hot drains.

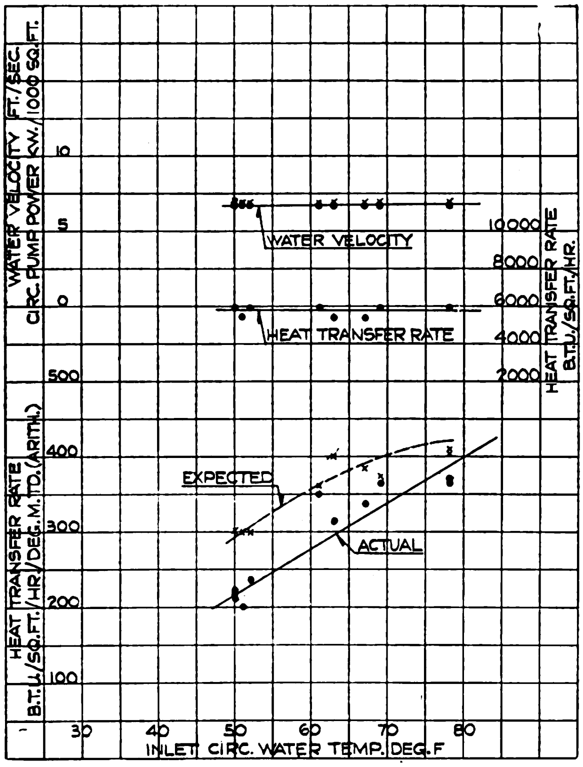

FIG. 30—PERFORMANCE OF NO. 3 CONDENSER, ACME STATION.

It will be noted that the difference between actual and expected heat transfer is greater during the winter months. This is due to an increase in the mean temperature difference between steam and circulating water caused by low circulating water temperature and does not mean that the total work done by the condenser during the winter is less than that done during the summer months.

Cleaning Condenser Tubes with Oakite

Performance of this condenser during the past five months shows considerable improvement over that for the first half of the year. This improvement in performance resulted from cleaning all tubes with a solution of test X Oakite. A solution of this material at about 180 deg. fahr. is passed through each tube. The tubes are then flushed out with hot water and shot with rubber plugs. The tube surfaces are left clean and smooth, and the performance of the condenser is restored almost to that of a new condenser.

Recirculation of Cooling Water

During the winter season the condensing water obtained from the Maumee River is at a low temperature. From December to February the water is always below 40 deg. fahr. and a greater portion of this time it is as low as 33 to 34 deg. fahr. Naturally this produces a considerable chilling of condensate, which reduces the overall economy of steam condensing and stage heating operation.

Early this year a plan was put into effect of recirculating condensing discharge water into the intake channel outside the screens in order to hold the temperature of inlet condensing water up to a point consistent with the best economy of steam condensing and stage heating combined.

Decreases in circulating water temperature bring about good substantial increases in vacuum down to a temperature of about 55 deg. fahr. Further decreases from this point down to the minimum of 33 deg. fahr. cause little or no improvement in vacuum, but lower the temperature of condensate leaving the hotwell. Since the low stage heaters heat the condensate to approximately saturation temperature of the bled steam, the depression in condensate temperature increases the amount of steam bled by the low stage heaters, and consequently the total steam consumption of the main units in restoring condensate temperature.

All circulating pumps at this station are duplex steam and electric driven and are arranged so that any desired ratio of load between the two drives can be obtained for the purpose of regulating the amount of exhaust steam to the deaerator heaters. Circulating water pumpage is constant throughout the year, it having been found that it is more profitable to recirculate condensing water and maintain the most economical balance between condensing and stage heating than it is to operate without recirculation of condensing water and reduce pumpage as the inlet temperature decreases.

No serious trouble from leakage has been experienced with this condenser. The amount of leakage present has not been a detriment due to the system of feeding all boilers, except one, with condensate since there has been no perceptible scale, and alkalinity has been maintained at a higher point than would be the case if there were no condenser leakage.

STATEMENT BY THE UNITED ELECTRIC LIGHT & POWER COMPANY, NEW YORK, N. Y.

Westinghouse condensers No. 6 and 7 at the Hell Gate Station, which are of the radial flow type and equipped with divided water boxes, were installed during 1924 and 1925. The condensing surface in No. 6 condenser is 63,000 sq. ft. and in No. 7 condenser 65,000 sq. ft.

Operating data for these condensers are given in Fig. 31 and 32, and Tables XXXI and XXXII.

The condenser performances were taken from the actual log sheet entries and, for each month, an average for the entire range of operation during that period was used. These figures, of course, do not give strictly correct results, but will show approximately the condenser performances. The quantity of circulating water was determined from the amount of steam condensed and the temperature

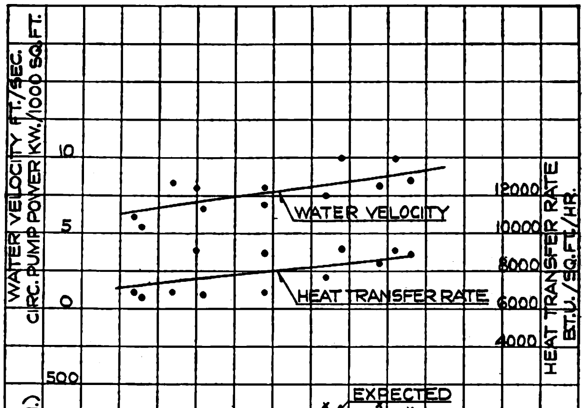

FIG. 31—PERFORMANCE OF NO. 6 CONDENSER, HELL GATE STATION.

TABLE XXXI

AVERAGE OPERATING PERFORMANCE OF NO. 6 CONDENSER
HELL GATE STATION OF THE UNITED ELECTRIC LIGHT & POWER COMPANY

YEAR 1928

1. Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
2. Load, 1,000 kw.	38.3	38.0	36.1	36.0	36.0	38.6	41.6	42.6	43.4	44.3	43.4	43.7
3. Heat transferred, B.t.u. per hr. per sq. ft. of surface†	6,890	6,890	6,655	6,770	6,930	7,670	8,410	8,900	9,060	9,250	9,020	9,110
4. Lb. circ. water per hr. per sq. ft. of surface†	861	626	555	677	693	767	841	890	1,007	1,028	820	828
5. Velocity of circ. water in tubes, ft. per sec†	8.4	6.1	5.4	6.6	6.8	7.5	8.2	8.5	9.8	10.0	8.0	8.0
6. Inlet circ. water temp., °F	42	37	38	46	54	62	69	73	71	64	54	45
7. Temp. rise circ. water, °F	8	11	12	10	10	10	10	10	9	9	11	11
8. Arith. mean temp. difference between circ. water and steam, °F	25.0	29.5	30.0	28.0	24.0	24.0	21.0	23.0	20.5	24.5	25.5	29.5
9. Arith. coefficient of heat transfer	276	234	222	242	289	320	401	387	442	378	354	309
10. Expected heat transfer with clean tubes	389	400	423	426	463	474	475	466	455	435	440	455
11. Ratio of actual to expected heat transfer	0.71	0.59	0.53	0.57	0.62	0.68	0.84	0.83	0.97	0.87	0.81	0.68
12. Air leakage, cu. ft. per min.	2.5	......	3.0	3.0	......	4.5	2.5	3.0	......	4.5	4.0	3.5
13. Depression of condensate temp., °F	0	1	2	3	2	0	0	0	0	0	0	0
14. Leakage of circ. water, %¶	......	......	......	......	......	......	......	......	......	......	......	......
15. Frequency of and methods used in clean tubes*	1-M	......	......	......	1-M	......	1-M	1-M	1-M	......	1-M	......
16. Hours in service	599	573	618	526	586	604	618	668	617	639	609	622
17. Power requirement circ. water pumps, kw. per 1,000 sq. ft.	1.70	1.63	1.76	1.50	1.67	2.86	2.92	3.16	2.92	3.02	1.73	1.77

*M—"Conco" metal plugs.

†Effective tubes considered only, i. e., plugged tubes allowed for.

¶Leakage very small.

TABLE XXXII

AVERAGE OPERATING PERFORMANCE OF NO. 7 CONDENSER
HELL GATE STATION OF THE UNITED ELECTRIC LIGHT & POWER COMPANY

YEAR 1928

1. Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
2. Load, 1,000 kw.	37.8	37.5	35.8	35.5	38.2	40.7	41.7	41.7	41.7	42.9	42.0	42.0
3. Heat transferred, B.t.u. per hr. per sq. ft. of surface†	6,250	6,200	6,000	6,020	6,110	6,610	7,250	7,525	7,450	7,665	7,500	7,360
4. Lb. circ. water per hr. per sq. ft. of surface†	695	477	462	501	555	601	659	684	677	852	682	566
5. Vel. of circ. water in tubes, ft. per sec†	7.9	5.4	5.2	5.7	6.3	6.8	7.5	7.7	7.7	9.7	7.7	6.4
6. Inlet circ. water temp., °F	42	37	38	46	54	62	69	73	71	64	54	45
7. Temp. rise circ. water, °F	9	13	13	12	11	11	11	11	11	9	11	13
8. Arithmetic mean temp. difference between circ. water and steam, °F	26.5	31.5	29.5	26	23.5	20.5	21.5	19.5	19.5	22.5	24.5	26.5
9. Arithmetic coefficient of heat transfer	236	197	203	232	260	323	337	386	382	341	306	278
10. Expected heat transfer coefficient with clean tubes	432	430	447	464	490	490	465	479	470	451	439	439
11. Ratio of actual to expected heat transfer	0.55	0.46	0.45	0.50	0.53	0.66	0.73	0.81	0.81	0.76	0.70	0.63
12. Air leakage, cu. ft. per min.	2.5	......	3	3	......	4.0	2.0	3.5	......	4.0	4.0	3.5
13. Depression of condensate temp., °F	0	0	0	0	0	0	0	0	0	0	1	0
14. Leakage circ. water, %¶	......	......	......	......	......	......	9	......	......	......	......	......
15. Frequency of and methods used in cleaning tubes*	1-M	......	......	1-M	......	......	1-M	1-M	1-M	1-M	......	1-R
16. Hours in service	650	600	658	621	649	631	660	610	573	630	613	628
17. Power requirement circ. water pumps, kw. per 1,000 sq. ft.	1.57	1.45	1.59	1.50	1.57	2.38	2.49	2.30	2.16	2.38	1.48	1.48

*M—"Conco" metal plugs; R—Franklin Rubber plugs.

†Effective tubes considered only, i. e., plugged tubes allowed for.

¶Leakage very small.

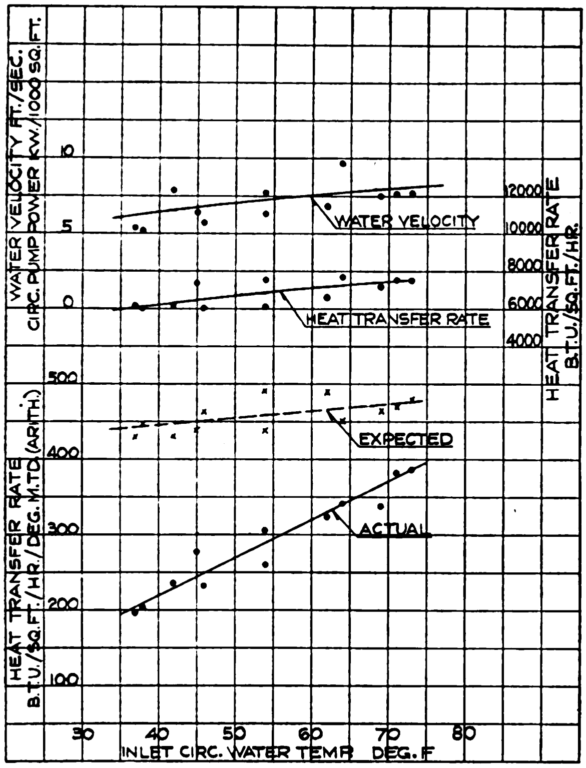

FIG. 32—PERFORMANCE OF NO. 7 CONDENSER, HELL GATE STATION.

rise of the circulating water. The amount of steam condensed was computed from the kw. load carried by the turbine and test water rates, the test water rates being corrected for average actual condition. In computing the heat transfers and velocity of circulating water in the tubes, the number of plugged tubes was taken into consideration.

As no individual power consumption data for the circulating pumps were available, these data had to be estimated from the service hours, high and low speed periods and kw. rating of the motors at high and low speeds. The per cent leakage of circulating water is kept so low that it may be considered negligible. The tubes in No. 6 condenser are ferruled, using corset lacing for packing at both ends, while No. 7 condenser tubes are rolled at the entrance end and ferruled at the other end.

Normally these condensers are not cleaned while in service. At times, however, it is necessary to make use of the divided water boxes while the unit is in operation in removing trash from the tube sheets.

As may be seen from Tables XXXI and XXXII, there is only a small amount of air leakage. Air is removed from the condenser by means of steam jet air evactors.

STATEMENT BY THE WEST PENN POWER COMPANY, PITTSBURGH, PA.

Condensers No. 3 and 4 at the Springdale Station were installed during the year 1924 and are identical 55,000-sq. ft. Westinghouse units of the radial flow type equipped with divided water boxes to permit cleaning while in operation. Table II includes a number of the design characteristics.

Daily observations are made of the performance of all of the condensers at the Springdale Station by a member of the test organization at a time of the day when the turbines are normally highly loaded. The loads on the individual turbines are held constant during the time the readings are taken. As facilities are not available for accurately measuring the steam condensed, this is computed from the kw. load carried by the turbine. The quantity of circulating water is determined from the amount of steam condensed and the temperature rise of the circulating water.

Table XXXIII gives the monthly averages of daily observations of performance. The monthly averages are also plotted in Fig. 33. The expected heat transfer values shown are based upon the manufacturer's guarantees. Correction is made for the variation in load, inlet water temperature and quantity of circulating water from the values upon which the guarantees were based. Performance equal to these expected values is obtained when the condenser tubes are cleaned and the air leakage is low.

It will be noted that, with the exception of one month, the average heat transfer is below the expected value with clean tubes. This lower heat transfer is permitted because the saving due to the improved vacuum is not considered sufficient to pay for the more frequent cleanings that would be required. It was found economical to clean the condenser

TABLE XXXIII

AVERAGE OPERATING PERFORMANCE OF NO. 3 CONDENSER
SPRINGDALE STATION OF THE WEST PENN POWER COMPANY

YEAR 1928

1. Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
2. Heat transferred per hr. per sq. ft. of surface	6,050	5,400	6,020	5,830	5,820	5,050	5,320	5,240	5,080	5,210	5,680	5,820
3. Lb. circ. water per hr. per sq. ft. of surface	528	500	510	540	647	620	610	620	636	620	565	555
4. Av. velocity circ. water in tubes, ft. per sec.	5.5	5.3	5.4	5.7	6.8	6.5	6.4	6.5	6.6	6.5	5.9	5.8
5. Inlet circ. water temp., °F.	35.0	35.0	37.0	45.0	59.0	65.0	72.0	76.0	67.0	59.0	44.0	36.0
6. Temp. rise of circ. water, °F.	12.0	11.0	10.0	11.0	9.0	8.0	9.0	8.0	8.0	9.0	10.0	10.0
7. Arithmetic mean temp. difference between circ. water and steam, °F.	37.0	33.5	29.0	20.5	18.5	14.0	14.5	16.0	16.0	19.5	22.0	26.0
8. Arithmetic coefficient of heat transfer	164	160	173	284	314	362	367	328	318	267	258	224
9. Expected heat transfer with clean tubes	234	219	216	284	353	390	425	438	392	360	284	244
10. Ratio of actual to expected heat transfer	0.70	0.73	0.80	1.00	0.89	0.93	0.86	0.75	0.81	0.74	0.91	0.92
11. Air leakage, cu. ft. per min.	4.0	3.0	5.0	3.0	3.0	5.0	5.0	5.0	5.0	4.0	3.0	3.0
12. Depression of condensate temperature, °F†	0	0	0	0	0	0	0	0	0	0	0	0
13. Leakage circ. water, %	0.54	0.54	0.33	0.20	0.15	0.11	0.07	0.14	0.29	0.22	0.16	0.21
14. Frequency of and methods used in tube cleaning*	1-R	1½-M	1-M	1-M	1-M	2-M	2-M	2-M	1-M	1-M	1-M	1-M
15. Power requirement circ. water pumps, kw. per 1,000 sq. ft.	6.9	6.1	6.3	7.2	10.3	9.5	9.3	9.5	10.0	9.5	7.9	7.6

*R—Cleaning with rubber plugs.
M—Cleaning with metal plugs.
†No depression of condensate due to hot drains entering hotwell.

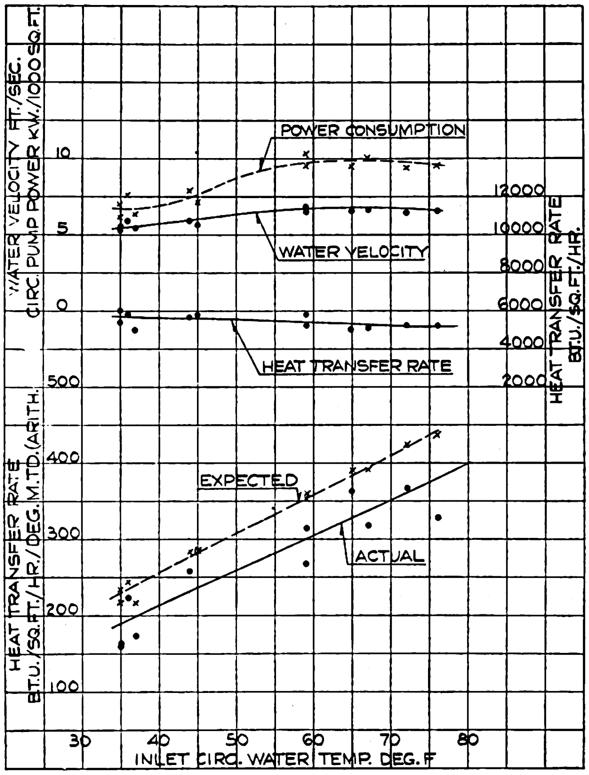

FIG. 33—PERFORMANCE OF NO. 3 CONDENSER, SPRINGDALE STATION.

tubes twice as frequently in the summer months as in the winter months.

From the daily observations of performance the difference between the actual and expected vacua are determined. This value is of use in determining when it is economical to clean the condenser tubes. The decision as to whether or not to clean the condenser tubes is based upon a consideration of the following data:

1. Difference between actual and expected vacua.
2. Saving in dollars per unit change in vacua.
3. Rate at which tubes will foul after cleaning.
4. Cost of cleaning.
5. Loss due to outage necessary to permit cleaning.

Each of the two circulating pumps with which No. 3 and No. 4 condensers are equipped are driven with variable speed motors. Although the degree of reliability of service required does not permit operation with only one pump in service, the motors are operated at 85 per cent of their full speed when calculations show the saving in circulating pump power consumption balances the loss in output of the turbo-generator. The variation of the circulating water during the different periods of the year will be noted in Table XXXIII.

Considerable difficulty has been experienced in maintaining the leakage of circulating water into the condenser at the desired low value. In both condensers the tubes are rolled at the inlet end and packed with fiber packing at the other end of the tubes. A great deal of attention is necessary to keep the leakage below 0.1 per cent. This trouble with leakage is thought to be due to a slight vibration of the condenser tubes which has, however, never been severe enough to damage them. The use of a heavier tube would probably greatly reduce the trouble with condenser leakage.

During the first year of operation when attempting to operate with one-half of the condenser open, the vacuum would fall so low as to make the condenser water boxes too warm to work in them. After reducing the air leakage to below 5 cu. ft. per min., no further trouble was experienced. The condensers are not normally cleaned while in service, since it is not found economical to clean more frequently than can be done when the unit is out of service for other reasons.

The divided water boxes are found of value in permitting the removal of trash from the tube sheets and making it possible to tighten the tube ferrules with the unit in operation. With heavier tubes or better bracing of the tubes there would probably be no need of tightening the ferrules more frequently than could be done at times when the unit is out of service.

TUBE VIBRATION AND CONDENSER LEAKAGE

Three member companies report that trouble has been experienced from tube vibration. In all cases, No. 18 gage tubes with two support plates were used. In two cases the vibration was severe enough to cause wearing of the tubes in the packing. In one of these two installations holes were worn through the tubes; in another excessive leakage resulted from the tube becoming loose in the packing or pulling loose at the rolled end.

The two severest cases of trouble were eliminated by the installation of tube support sheet sections so as to give the outer rows of tubes in the tube banks five points of support between the tube sheets. In the third case the installation of baffles and the driving of metallic and wooden wedges between the tubes has been tried without material reduction in the condenser leakage. Trouble of this kind is most noticeable with high vacuum operation and efficient turbines delivering exhaust steam with a large moisture content and is ordinarily more prevalent with circulating water temperatures below the average.

It has been suggested that tube vibration can be lessened by the use of heavier gage tubes. Of the condensers for which data are supplied in Tables I and II of this report, two are equipped with No. 16 gage tubes and three with No. 17 gage tubes. The condenser leakage for all of these condensers with heavy gage tubes is negligible.

Mr. Adolph Meyer of the Brown Boveri Company of Switzerland reports that in one case where tube vibration has been experienced with tubes of 1 mm. in thickness (about No. 18 gage) the trouble was remedied by replacing the outer top rows with tubes of 3 mm. thickness. Mr. Meyer also reports the installation of solid brass rods in the outer rows of tubes on which the moisture in the exhaust steam impinged. Moisture content of the steam was 12 per cent.

STATEMENT BY THE DETROIT EDISON COMPANY, DETROIT, MICH.

The Detroit Edison Company in their statement in this report on page 16, giving the operating results with units No. 4 and No. 5 at Trenton Channel, report trouble from tube vibration. They eliminated this by installing segmental plates to support the tubes in the upper section of the tube bank, thereby cutting the distance between original support plates in two.

STATEMENT BY THE UNION ELECTRIC LIGHT & POWER COMPANY, ST. LOUIS, MO.

During the past year this company has had experience with a 56,000-sq. ft. condenser in which excessive vibration was set up in the tubes by very high steam velocities incident to operation at high loads. The vibration caused the tubes to break and pull loose at the rolled end with consequent leakage. The condition was corrected by installing additional segments of tube support sheets spaced midway between the original sheets.

The trouble was noted after a few months' operation when condenser leakage increased abnormally. The condenser serves a 50,000-kw. turbine with an exhaust flow of about 470,000 lb. steam per hour at full load. It is 20 ft. long between tube sheets with two support sheets between, evenly spaced. The tubes, 1 in. O.D., 18 gage, were rolled at one end and packed with corset lacing packing at the other. The vibration caused the tubes to wear at the support sheets and to pull loose at the rolled end. At the other end the packing would hold tightly for a while, causing the tube to rub thin and the packing itself would then become loosened, and leakage would follow. Vibration was apparently severest across the top of the upper tube bank, adjacent to steam lanes, and along the outer four or five rows of tubes extending two-thirds of the way down to the hotwell.

Vibration was temporarily reduced by driving soft wooden slats down between the tubes where vibration was severest. The final solution as applied by the Worthington Pump & Machinery Corp. consists of sections of support sheets placed in three positions: Midway between the two original support sheets and midway between these sheets and the tube heads, thus making five support sheets in all. There are sixteen sections of new support sheets in each of the three positions—the sections being located so as to break up the vibration in the outer tubes which had been affected, and also in that portion of the tube bank which has not been affected. About 2700 of the 10,700 tubes have been given additional support. The additional supporting sheets are cast iron, finished all over with holes drilled and chamfered; maximum inside diameter, 1 1/64 in.; minimum diameter 0.002 less.

The arrangement proved effective, and since its installation no vibration trouble has been experienced.

STATEMENT BY THE WEST PENN POWER COMPANY, PITTSBURGH, PA.

Considerable difficulty has been experienced in keeping the leakage at the desired low value of below 0.1 per cent in the condensers at the Springdale Station. The leakage has been reduced to nearly this value in summer months, but in the winter months increases to a maximum of approximately 0.5 per cent. Condensers are opened about once a week for tightening the ferrules.

The tubes in the three largest condensers in the station are rolled into the tube sheet at one end and packed at the other with fiber packing. Although leakage is experienced at both the packed and rolled end, the leakage is materially greater at the packed end.

Leakage is greatest from the tubes impinged upon directly by the entering steam. This seemed to indicate that the leakage is caused by vibration of the tubes. The fact that the condenser leakage increases materially during the winter months when the steam velocity is highest tends to confirm the belief that the trouble is due to tube vibration. It was found upon inspection that the outer rows of tubes in the tube bank were covered with light spots, which were indicative of vibration. These condensers have two tube support plates, thus dividing the length of the tube into three sections, the outer two of which are approximately 7.5 ft. in length and the center approximately 5 ft. Vibration seemed to be confined almost entirely to the outer sections.

At the suggestion of the manufacturer, lattice-work bracing has been installed between the tubes in the two outer sections of two of the condensers. Originally bracing made of copper was used, but later wooden bracing was used, with the expectation that the swelling of the wood upon wetting would hold the tubes more firmly. In one of the condensers the bracing was installed in one direction only.

As no observable improvement was obtained from the bracing of the tubes, a baffle was installed in one of the condensers in order to deflect the steam from the direct flow into the condenser. Although this baffle was designed according to specifications received from the condenser manufacturer, no observable improvement in the condenser leakage has been obtained. At the present time the greatest leakage is in the lower half of the condenser, and baffling the steam so as to make more of it go into the upper half of the condenser is being considered, but has not yet been tried.

The circulating pumps are now being operated to cause the greatest flow of water through the half of the condenser which does not receive the direct flow of the steam. It is questionable whether this operation has resulted in any improvement.

The Duquesne Light Company has condensers of identical design with the exception that they are using No. 16 gage tubes in place of No. 18, and reports no vibration trouble or increased leakage during winter conditions.

EXPERIENCE WITH CONDENSERS HAVING TUBES ROLLED INTO TUBE SHEETS AT BOTH ENDS

Reports have been received from two companies having condensers with tubes rolled into the tube sheets at both ends. In one case a floating tube sheet at one end is used to provide for expansion and contraction. In the other, the stresses due to expansion are taken by the tubes and tube sheets. Leakage of circulating water into the condensate system has been found negligible in both cases and no unusual troubles are reported.

STATEMENT BY THE CONSOLIDATED GAS, ELECTRIC LIGHT & POWER COMPANY, BALTIMORE, MD.

The condenser serving the first unit at the Gould Street Station has been in service since December, 1926, while the condenser serving the second unit was placed in service in May, 1928.

These two-pass condensers are of Wheeler Condenser & Engineering Company manufacture, containing 30,000 sq. ft. of surface, each made up of 7363 tubes; ⅞ in. diameter, 18 gage. The exposed length of the tubes between tube sheets is 17 ft. 9½ in. The tubes are rolled in at both ends, the condenser being provided with no through stays. The stresses, due to pressure differences and to changes in temperature, are taken up entirely by the tubes and tube sheets.

The contamination of the condensate on account of circulating water leaking into the condensate system has always been a source of considerable annoyance due to the very poor quality of circulating water which is occasionally acid and which is always contaminated with a high percentage of organic matter as well as other industrial wastes. The leakage of circulating water into the condensate in the Gould Street condensers may be stated for all practical purposes as being nil.

The resistivity of the condensate, when tested with a standard Leeds & Northrup dip cell, is averaging well in excess of 1,000,000 ohms per cc., being apparently as high as samples of steam taken from a high-pressure steam line.

The average resistivity of condensate from the evaporator condenser, which uses condensate from the main unit as the condensing medium, shows an average resistivity of about 45,000 ohms per cc., despite the fact that the total dissolved solids in the concentrate is maintained at a very low figure.

The boilers in this plant have never been blown down since they were put in service. The total solids in solution in the boiler water have never exceeded 25 grains per gallon, the water being changed in the boilers on an average of once every two or three months, as it is then necessary to do work on the boilers which require the removal of the water.

There has been no trouble due to the loosening up of the tubes on account of starting up the unit on high pressure and establishing vacuum after the turbine has reached a speed sufficiently high to seal the shaft glands, which are of the water seal type.

In the first condenser it has been necessary to plug nine tubes since the unit was place in service, all of these tubes having failed due to defects which were well away from the ends of the tubes, and were apparently due to manufacture, the failures showing up either as split tubes or as very definite pit holes.

There seems to be much less corrosion of the tube ends than is the case with other condensers which are fitted with tubes rolled in at one end and packed at the other end with fiber packing. It is, of course, impossible to state whether this apparent slower rate of corrosion of tube ends is due to the fact that the tubes are rolled in at both ends, or to any one of a number of other conditions which may tend to minimize this particular difficulty.

STATEMENT BY THE TEXAS POWER & LIGHT COMPANY, DALLAS, TEX.

Two of the condensers at Trinidad Station are equipped with floating tube sheets and tubes rolled at both ends. These condensers have now been in service for two and one-half years. Shortly after operations were started there were two or three cases of tubes slipping due to these particular tubes not being properly rolled, an oversight which might very readily occur during erection, and one case where tubes were eroded by water drained from stage heaters into the condenser. Except for these few cases leakage has been low.

Resistance of condensate as shown by Leeds & Northrup conductivity instrument has been consistently over 30,000 ohms at all loads. It is believed that a large proportion of the contamination of condensate is due to solids carried over from the boiler rather than to condenser leakage. One evidence of this is the fact that resistance of condensate is just as high or higher when the turbine is operating at light loads as when it is operating at full load, whereas if the contamination were due to any considerable amount of condenser leakage the reverse would be expected.

Up to the present time there have been no indications of serious deterioration of condenser tubes or of the rubber packing ring between tube sheet and condenser shell.

RATE OF DETERIORATION OF IMPREGNATED, WOOD-PULP CABLE PAPER SUBJECTED TO HEAT ONLY

INTRODUCTION

Research work for the Impregnated Paper Insulated Cable Research Subcommittee, on the effect of temperature on the rate of deterioration of cable paper insulation when not under dielectric stress, has been carried on at the Massachusetts Institute of Technology under Professor Bush since 1922. A complete report on an investigation of manila paper was published in the 1924 annual report of the N. E. L. A. Underground Systems Committee. A final report, which included some supplementary data, appeared in the *A. I. E. E. Journal* for May, 1925, and also in the general serial report of the N. E. L. A. Underground Systems Committee in 1927. A report of a similar investigation of wood-pulp paper insulation was also published in the above mentioned general serial report in 1927.

The results of the latter series of tests very clearly showed that a more extensive investigation of wood-pulp paper insulation should be made, with a larger number of samples over a longer period. A new series of tests was consequently started in 1926, and the complete final report (Report No. 3) was rendered by the Institute on March 15, 1928. This report covered about 25 typewritten pages and included over 150 sets of curves of results. A summary of those portions of the report dealing with test methods, equipment, preparation of specimens, etc., and a discussion of the results are presented in an appendix.

In the next section are given the conclusions which are drawn from the report of the tests made at the Institute.

COMMENTS ON RESULTS

Tests performed on wood-pulp paper, as used by representative American cable manufacturers, gave erratic results which were expected from previous tests of this type. The irregularity is evident in two ways: First, in the curves obtained from individual samples; second, in curves of different samples. The first irregularity is not as pronounced as it was in the first series of tests on wood-pulp paper, probably because the paper from which these samples were made was a more uniform product than the wood-pulp paper previously used (see Fig. 1). The variations between samples, as is shown by the table of distribution with respect to the average, is not very large.

The fact that many of the average curves show relatively small changes in the properties of the samples should not be construed to mean that such conditions actually hold for individual samples of paper as tested. Many of the individual samples show changes of large magnitude, which produce little effect on the average, due to the large numbers of samples.

The power factor curves are reasonably uniform except for occasional large changes of apparently accidental character, but no comparison with previous curves is possible because these are the first power factor curves obtained in the research.

20 Deg. Cent. Curves

The average of all samples at room temperature shows that large changes in the mechanical strengths do occur, even when the paper is not subjected to high temperature. In the average curves (Fig. 2) the paper recovered to almost its original value, but, nevertheless, it was at one time considerably below average. Among the individual curves certain samples give curves lying very definitely below the 100 per cent line after a lapse of time at room temperature and do not fully recover, as did the average sample.

50 Deg. Cent. and 70 Deg. Cent. Curves

The average curves at 50 deg. cent. and 70 deg. cent. (Fig. 3 and 4) show almost the same results as the 20 deg. cent. curves, except that folding endurance drops faster than tensile strength at 50 deg. cent. and 70 deg. cent., and vice versa at 20 deg. cent. A recovery period is present, and the paper regains almost its original state by the end of the test, at both temperatures.

90 Deg. Cent. and 100 Deg. Cent. Curves

The curves at 90 deg. cent., steady; 90 deg. cent., intermittent, and 100 deg. cent. (Fig. 5, 6 and 7) are quite similar to those obtained in the first series of tests at 80 deg. cent. and 90 deg. cent. and reported to the Cable Research Subcommittee on June 15, 1926. The principal exception is in the tearing strength, which in that test increased but here decreased.

At these temperatures definite deterioration occurs in all mechanical tests without recovery. The puncture voltage remains almost constant, as was found before.

Comparison Between 90 Deg. Cent., Steady, and 90 Deg. Cent., Intermittent

There is practically no difference between deterioration at a temperature of 90 deg. cent. continuously applied, or intermittently applied, according to the schedule described in the appendix (see page 10). In making this comparison it should be remembered that the 90 deg. cent. intermittent curves are plotted against calendar weeks and not against actual weeks at 90 deg. cent. The magnitude of the deterioration is slightly less in the intermittent test, but not enough less to conclude definitely that the difference was due to the recovery effects during the periods when the heat was shut off.

Publication No. 289-87. Serial Report, Underground Systems Committee.

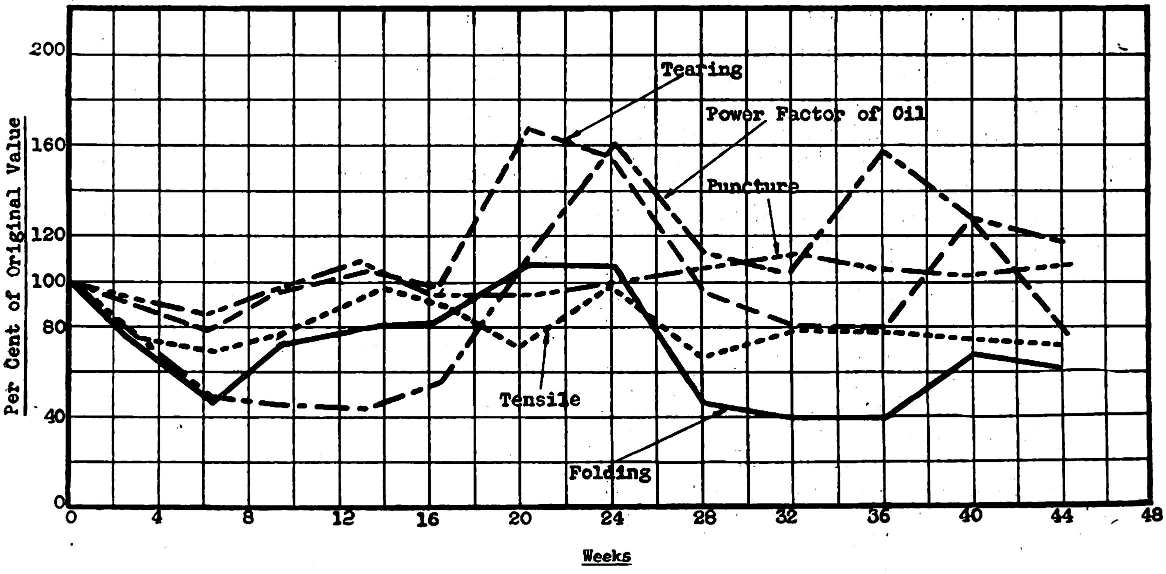

FIG. 1—TYPICAL SET OF CURVES FOR ONE SAMPLE AT ONE TEMPERATURE.

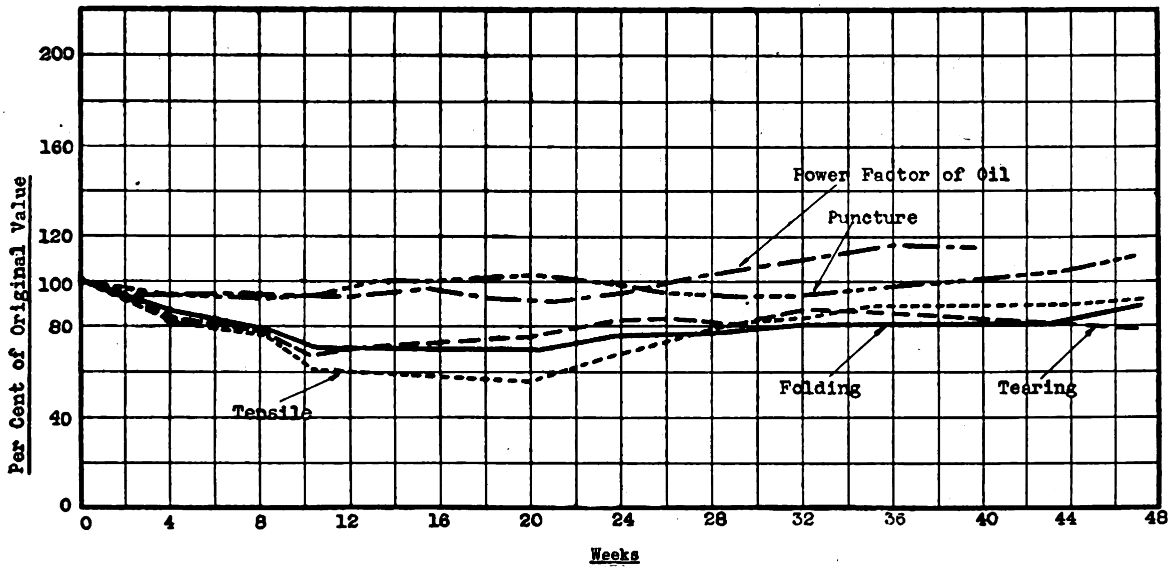

FIG. 2—AVERAGE OF ALL SAMPLES, 20 DEG. CENT.

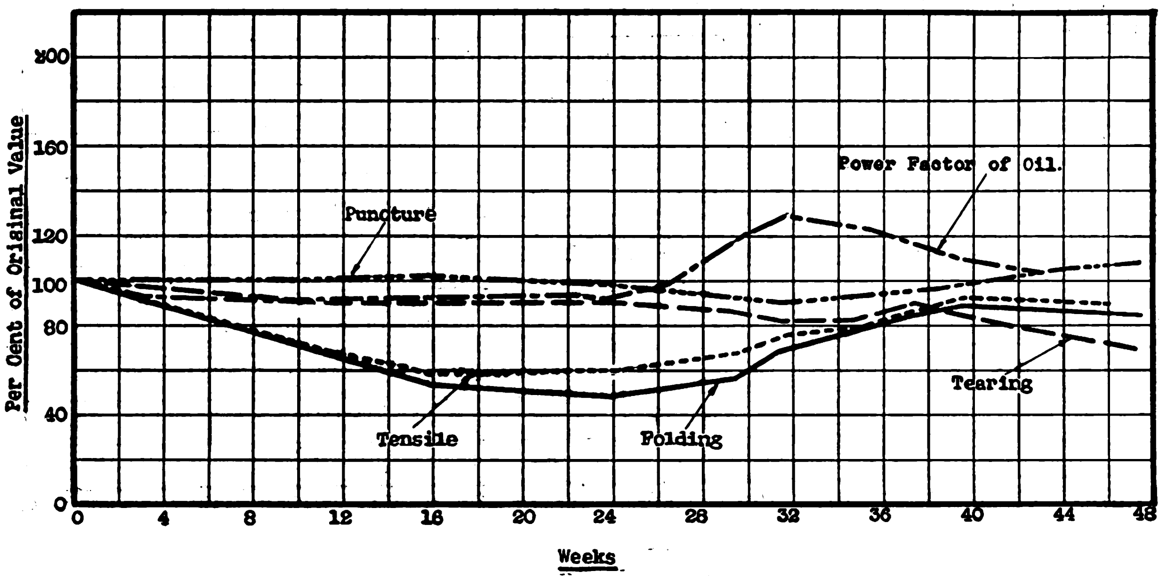

FIG. 3—AVERAGE OF ALL SAMPLES, 50 DEG. CENT.

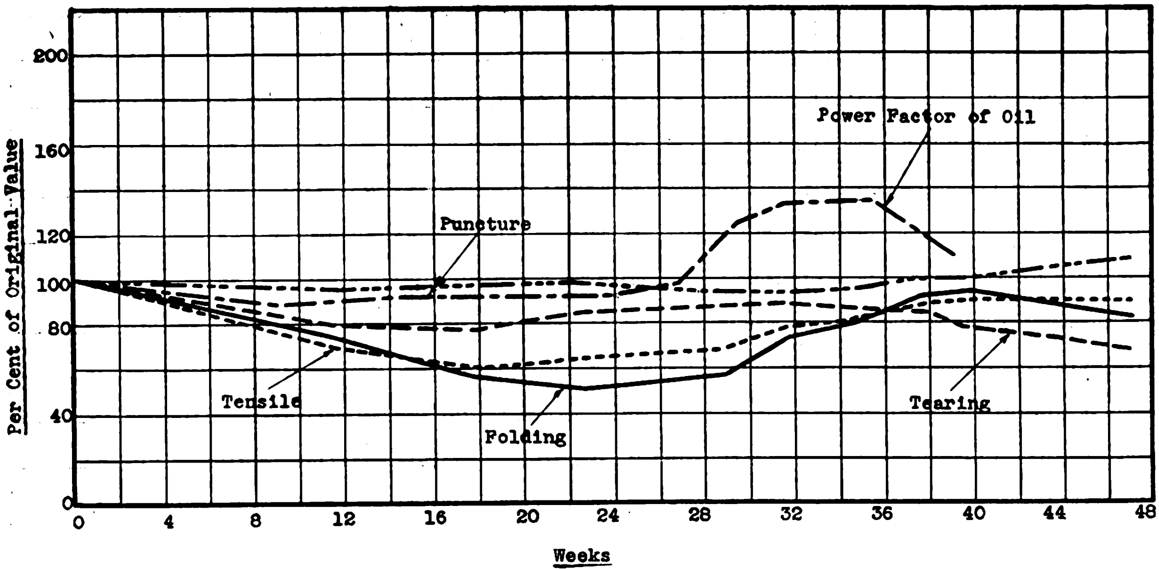

FIG. 4—AVERAGE OF ALL SAMPLES, 70 DEG. CENT.

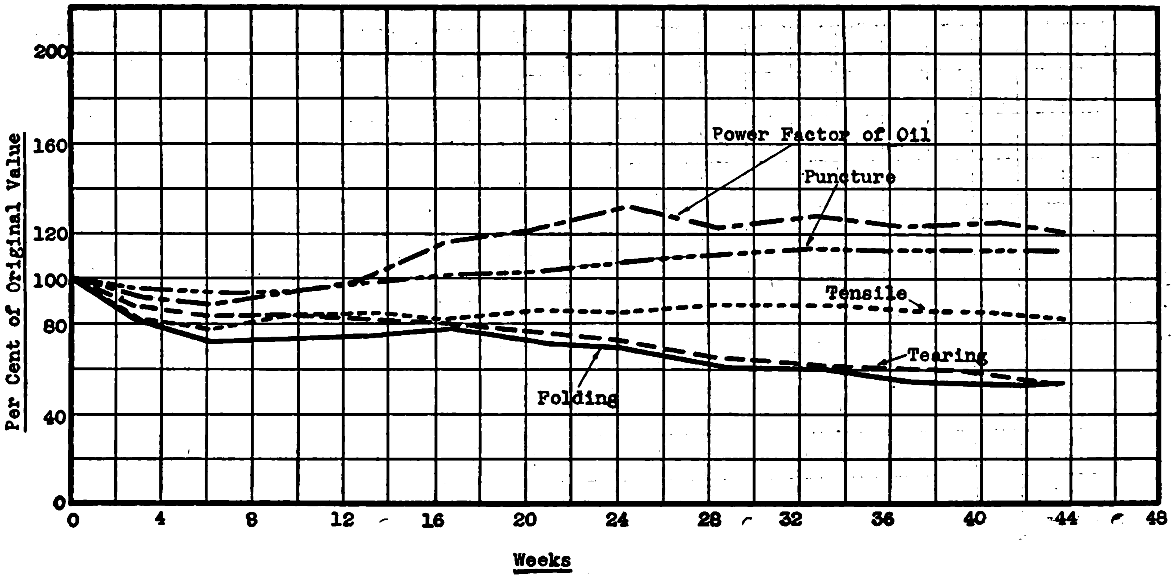

FIG. 5—AVERAGE OF ALL SAMPLES, 90 DEG. CENT. (CONTINUOUS).

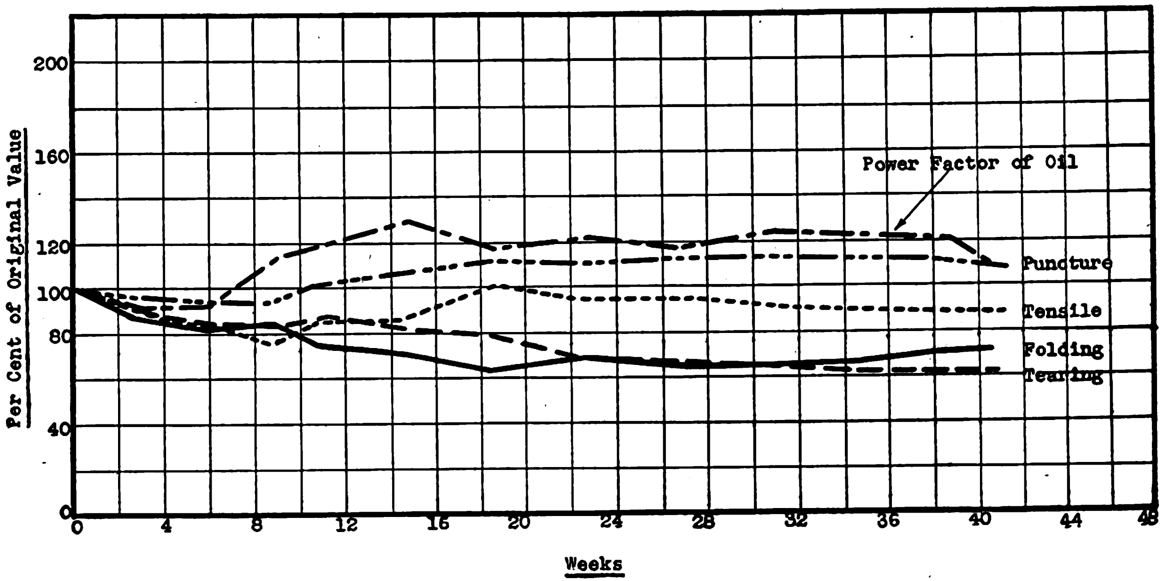

FIG. 6—AVERAGE OF ALL SAMPLES, 90 DEG. CENT. (INTERMITTENT).

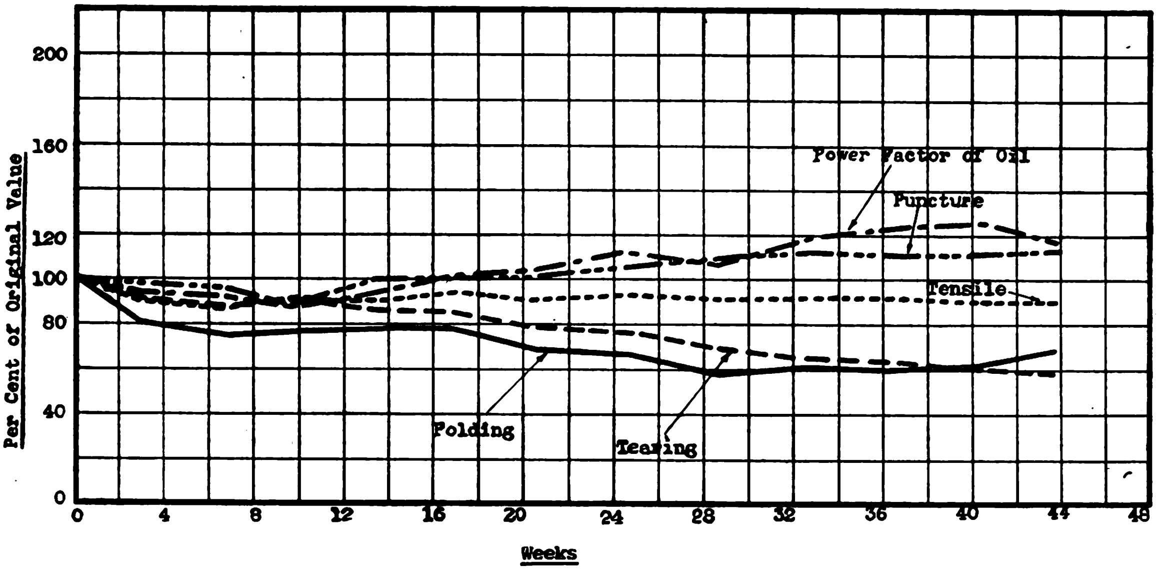

FIG. 7—AVERAGE OF ALL SAMPLES, 100 DEG. CENT.

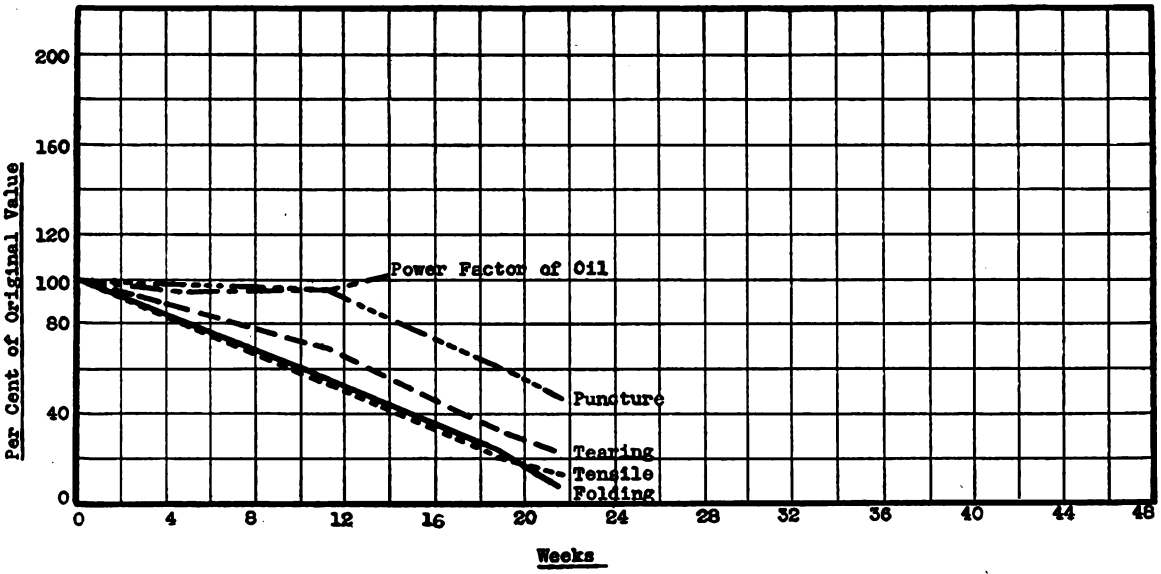

FIG. 8—AVERAGE OF ALL SAMPLES, 140 DEG. CENT.

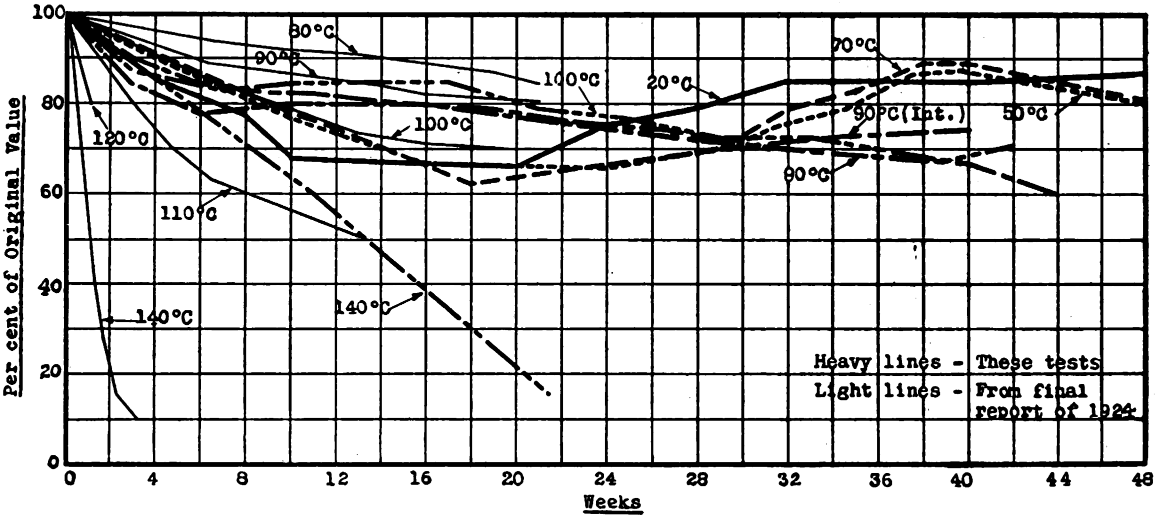

FIG. 9—GRAND AVERAGE, ALL MECHANICAL TESTS OF ALL WOOD-PULP PAPER SAMPLES.

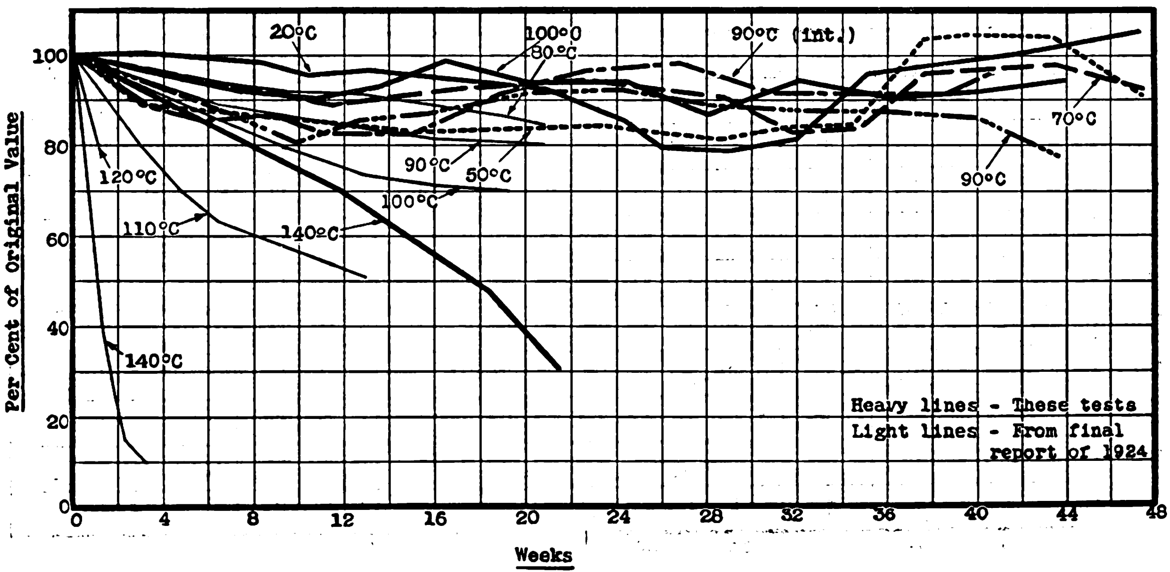

FIG. 10—GRAND AVERAGE, ALL MECHANICAL TESTS OF TWO MANILA SAMPLES ONLY.

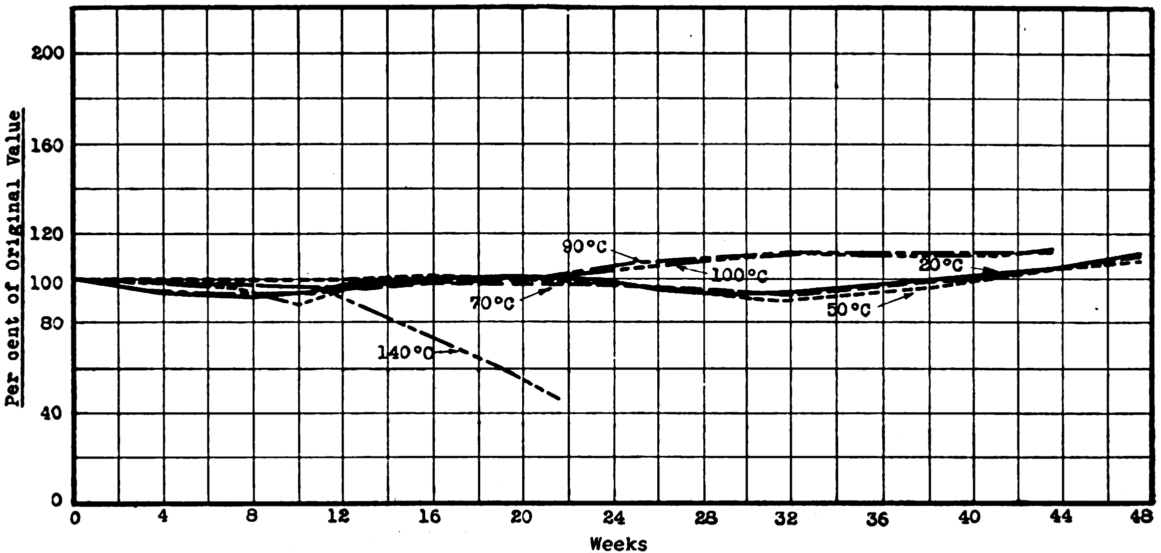

FIG. 11—AVERAGE DIELECTRIC STRENGTH, ALL SAMPLES.

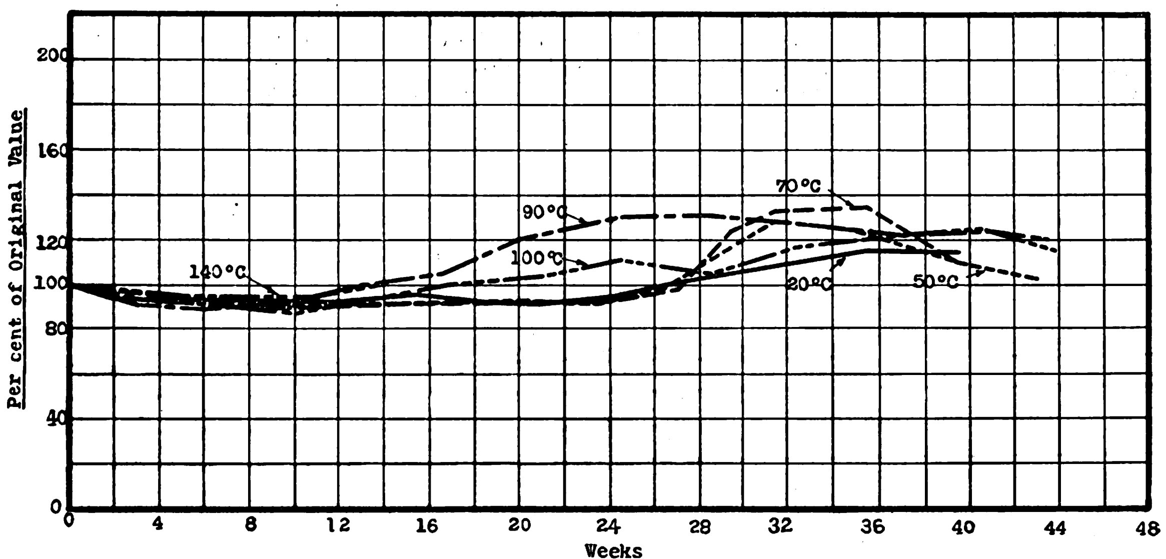

FIG. 12—AVERAGE POWER FACTOR, ALL SAMPLES.

The comparison is clearer when it is realized that in the 90 deg. cent intermittent curves, the samples were at a temperature of 90 deg. cent. for only about one-quarter the elapsed time. If only the time at maximum temperature were considered, the time scale would be one-quarter as great as it is plotted, and the curves compressed to that amount.

140 Deg. Cent. Curves

Mechanical deterioration (Fig. 8) is very rapid till complete destruction is reached, after a short time. Puncture voltage does not decrease as rapidly nor as completely.

Comparison Between 20 Deg. Cent., and 100 Deg. Cent.

The tests did not disclose any consistent or definite difference in the rate of deterioration as measused by mechanical tests for temperatures from 20 deg. cent. to 100 deg. cent. The puncture voltage is practically constant, with a tendency to increase rather than decrease.

Grand Average—All Mechanical Tests on Wood-Pulp Paper Samples

The combined average of all mechanical tests is given (Fig. 9) in comparison with the corresponding curves made on manila paper in 1924. These results are evident:

(a) The consistent change in trend referred to is conspicuous. The trend is fairly constant, downward, for a few weeks, and then at the lower temperatures (20 deg.-70 deg.) it is upward, to recover over one-half of the loss after 45 weeks. The 90 deg. cent. and 100 deg. cent. curves continued downward.

(b) Wood-pulp paper at temperatures up to 70 deg. cent. deteriorates faster than manila paper at 100 deg. cent. At 100 deg. cent. the wood-pulp paper does not deteriorate as rapidly as the manila paper. At 140 deg. cent. wood-pulp paper is very superior to manila paper.

(c) The 100 deg. cent. and 110 deg. cent. manila-paper curves might have shown a recovery or at least a flattening tendency if they had been extended for a longer time.

Grand Average—Mechanical Tests on Two Manila Samples

The general trend of the curves (Fig. 10) is similar to that of wood-pulp paper and much better than that obtained in the earlier test of 1924.

Dielectric Strength

These curves (Fig. 11) confirm the fact that dielectric strength is not affected by any temperature up to 100 deg. cent. and probably even higher.

Power Factor

The power factor tends to increase very gradually. (Fig. 12).

Summary

Summarizing the results as they are presented in Fig. 9, it is believed that the rate of deterioration of wood-pulp paper is no greater, after the first few months, than that of manila paper. The curves suggest that cable could be operated indefinitely at 100 deg. cent. so far as mechanical strength is concerned with only a loss of about 30 per cent. The flattening effect should, however, be confirmed by still longer tests which include manila paper. The very definite recovery characteristics at lower temperatures are worthy of further investigation as a special research problem.

It is the conclusion of the Committee that wood-pulp, properly treated, can be operated at as high temperatures and give as long life as manila paper.

APPENDIX

SUMMARY OF REPORT OF CABLE RESEARCH* AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Under the Direction of

PROF. VANNEVAR BUSH

Object of Research

This report covers the second series of tests conducted for the purpose of investigating, chiefly by mechanical examination, the rate of deterioriation of impregnated, wood-pulp paper, as used, at the time of starting the research, in cable insulation, when subjected to various constant temperatures in the absence of dielectric stress. It is the third report prepared for the Impregnated-Paper Insulated Cable Research Committee. The first report presented results obtained from tests made on manila hemp rope fiber paper and was dated June 20, 1924. The second report presented results of the first series of tests made on wood-pulp paper and was dated June 15, 1926.

Salaries and other operating expenses for this research have been defrayed by the National Electric Light Association and the Association of Edison Illuminating Companies. The Massachusetts Institute of Technology has furnished space, equipment and supervision. Test samples were, in this case, furnished entirely by the manufacturers associated with the Insulated Power Cable Engineers Association.

Test Methods, Equipment, Etc.

(a) Specimens Used

In previous tests the specimens used were pieces of actual cable cut from 6 to 8 in. long, with the ends sealed by soldering on tin can lids. There were a number of objections to this procedure.

It was an expensive method inasmuch as only a small portion of the paper was used while the copper and lead were sold at scrap value. The time of preparation per specimen was excessive. It was necessary to cut off each piece separately, shape each end of the specimen to fit the nearest size tin can lid, and then solder on the lid. It was not possible to do these operations in bulk by first cutting off all the samples of one size, then shaping all the ends and then sealing all the ends. This would have exposed the paper to the air for too long a time and vitiated the results. It was therefore necessary to complete the preparation of each specimen before beginning the next.

A third objection was the size and weight of the specimen in comparison to the portion of it useful for test purposes. Only a small portion of the paper was used in most cases, and this was obtainable only in short strips from a short length of cable. Moreover, it was often necessary to discard much of the paper on account of wrinkles.

The excessive bulk of the specimen was also objectionable from the standpoint of using the available oven volume to the greatest extent. The five ovens used could hold about 500 specimens. It was found possible to increase this capacity to about 2000 specimens by changing their form.

The uniform specimen used in all the tests covered by this report, was designed to meet the above objections without destroying the value of the specimen as an index of the behavior of the paper in actual cable under the conditions of the test. The specimens were simply rolls of paper tape representing the paper to be investigated, wound on copper cores and then impregnated by standard processes. The required number of specimens of each of the various samples of paper were prepared by the cable manufacturers according to very detailed instructions which were given them. All of the cable manufacturers cooperated in preparing and furnishing these specimens.

Fig. 13 shows the appearance of the standard specimen before being impregnated. The spindle on which the paper is wound is of copper and is 1 in. in diameter. The paper tape is 1 in. wide, and is wound on the spindle under approximately the same tension as the manufacturer normally uses for cable. After winding, the roll of paper is tied with strong thread and slipped into the can. It is separated from the bottom of the can by a circular piece of cardboard, and held in place by a piece of cardboard bent into a V, with the apex resting on the sample, and the two ends caught under the rim at the top of the can.

After the mechanical preparation of the specimens, they were impregnated in position in the cans, and then the tops sealed on the cans. The standard procedure was to treat these specimens in the impregnating process as if they were actual cable, and to seal them immediately by pressing on the lids. The lids of the cans were made oversize and had to be forced into place, making a seal which was airtight

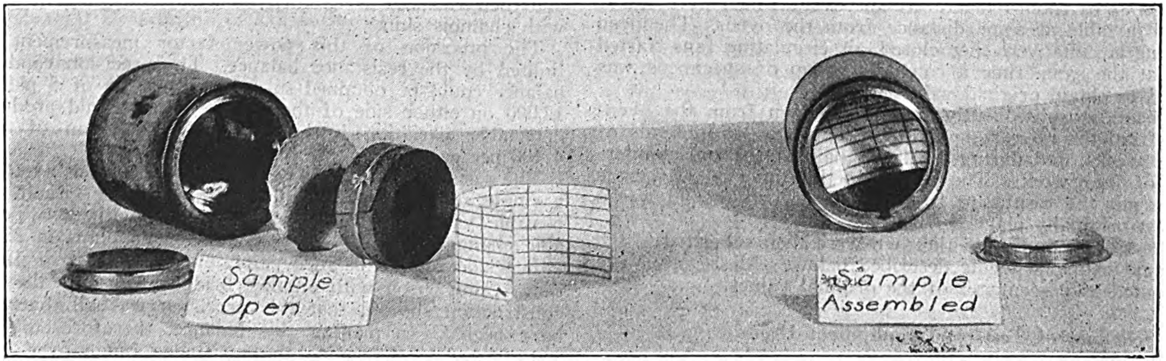

FIG. 13—STANDARD SPECIMEN BEFORE IMPREGNATION.

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* Report No. 3, March 15, 1928.

at atmospheric pressure. The samples thus prepared were then shipped to the Massachusetts Institute of Technology, where the lids were soldered on, using resin as a flux, and a soldering iron rather than a flame, to prevent damage to the specimens. Although pure resin was used as a soldering flux, a number of specimens were tested before and after soldering with an acid paste, to detect the presence of hydrogen ions inside the can. No hydrogen ion concentration could be detected, even near the joint between lid and can. The same test was made on some empty cans to see that no acid traces were left by the manufacturer of the cans. This test indicated that the cans supplied were neutral.

It was intended to have all the specimens made from paper of nominal 5 mil thickness, but this imposed too great a restriction on the manufacturers who supplied the paper, and the plan was abandoned.

This type of specimen had an additional advantage over the former type in that it could be opened with a can opener to extract the paper. Formerly, a shaper was used to split the lead sheath, in order to cut to uniform depth and not damage the paper immediately under the sheath too much.

A total of 22 kinds of paper was submitted. Of these 18 were wood-pulp, and 2 manila and wood-pulp combined. Two manila paper samples were included as a check on the previous work on manila paper.

(b) General Procedure

The specimens were held at the following constant temperatures during the course of these tests: 20 deg. cent. (room temperature), 50 deg. cent., 70 deg. cent., 90 deg. cent. and 140 deg. cent. In addition, an intermittent temperature run was made with the temperature varying between approximately 50 deg. cent. and 90 deg. cent., according to a definite schedule, as follows:

The heating circuit was closed every week-day morning at 9 o'clock. The maximum temperature was reached at about 10:30 a. m., where it was held until 4:30 p. m., at which time the heating circuit was shut off. The minimum temperature was reached at about 8 p. m. On Saturdays this oven was shut down at 1 p. m. and remained off until the following Monday morning. The minimum temperature obtainable was determined by the conduction of heat through the walls from the adjoining oven.

In preparing the oven used for the test at 50 deg. cent., it was found that heat conduction from the other ovens was sufficient to keep the average temperature above 50 deg. cent. Accordingly, air at 35 deg. cent. was admitted to the oven by means of a pipe, from the small room which contained the ovens. The electric heating coils and temperature controls could then be used to maintain 50 deg. cent.

The temperature controls were adjusted, with the ovens empty, to give the desired average temperature. The settings of the temperature controls were adjusted by means of calibrated thermocouples located in each oven, disregarding the temperature scale furnished with the controls, except as a means of recording the constancy of temperature.

The specimens were then stacked in the ovens, except for the group of room temperature specimens which were placed under a table at some distance from the ovens. The oven heating circuits were then closed, air circulating fans started and at the same time a complete group of specimens was tested to obtain original values.

Specimens subsequently were withdrawn from the ovens and from the room temperature group, first at intervals of three weeks, and during the latter half of the run at intervals of four weeks. The change in time interval was made to permit the results to be extended beyond the 40 weeks of test originally planned.

The specimens thus withdrawn were then subjected to the regular testing schedule described below. All results were computed as percentages of the original values.

(c) Schedule of Tests and Equipment Used

The tests made on these specimens were, in general, the same as those made on the previous series of woodpulp paper tests, with the addition of a power factor test made on the excess oil contained in the tin cans, and a slight change in making the voltage puncture tests.

1. *Folding endurance*—Ten tests per specimen on strips one centimeter in width, made under a tension of 0.75 kilogram, on the Institute Folding Endurance Tester.
2. *Tensile strength*—Ten tests per specimen made on a standard Schopper tensile machine. The full width of the sample was used in each case.
3. *Tearing strength*—Five tests per specimen using four strips per test, made on the Elmendorf tearing machine.
4. *Puncture voltage*—Ten tests per specimen between brass electrodes, one centimeter in diameter. Previous to these tests a single pair of electrodes had been used, between which one piece of paper at a time was placed and broken down. In order to save time on this test, a group of ten pairs of electrodes was built, which could accommodate all the strips from one specimen at one time. The high voltage was then applied successively to each pair of electrodes, using a motor-driven rheostat in the field circuit of the supply alternator to insure the same rate of change of applied voltage for each test strip. This method took only about half the time previously required.
5. *Power factor of oil*—One test per specimen made between brass plates, machined flat, 4 in. in diameter, and spaced 0.009 in. apart, the measurements being made on a General Radio capacity bridge (Wien type) using a 1000-cycle tuning fork oscillator at the source of supply. The constants of the apparatus were combined in a calibration curve, which facilitated the computation of the power factor for a large number of specimens.

This equipment was installed in the eighth week of testing. The group of room temperature specimens withdrawn for test at that time was used to provide "original" values. It will be noticed in the curves at 20, 50, 70 and 140 deg. cent. that the power factor curves do not extend as far as the others due to the lag in starting the test. The runs at 90 deg. cent., steady, 90 deg. cent., intermittent, and 100 deg. cent. were started much later than the others, so that the power factor tests at these temperatures are coincident with the other tests.

The procedure was to fill the space between the plates with compound taken from the can under test. All air pockets were worked out of the space as far as possible, and the spacing between plates adjusted. The variation in power factor caused by air caught between the plates was found to be negligible. The measurement of the power factor was accomplished by using the method of substitution to determine the capacitance and equivalent series resistance of the cell containing the oil. The capacitance was determined directly from the difference in the readings of a precision condenser necessary to balance the bridge, without and with the power factor cell in parallel respectively. The resistance balance was obtained by means of a decade resistance box in the other variable arm of the bridge.

A calibration curve was drawn which permitted the computation of the desired power factor directly as the product of the decade box reading and a constant obtained from the calibration curve, this constant being a function of the difference in the readings of the precision condenser.

After each power factor measurement the cell was emptied and then cleaned, using ether as a solvent and wiping dry with chamois skin.

The precision of this power factor measurement was limited by the resistance balance. The precision condenser balance could be obtained so that a variation of 5 parts in 12,000 on either side of the balance point would produce a detectable variation in balance, or a precision of about 4/100 per cent.

The resistance balance was very poor, however, even with a single stage audio amplifier in the detector circuit. The possible variation in resistance readings without a detectable change in balance was as high as 25 ohms in 250 on either side of the balance point, or a precision of 10 per cent. Comparison with another bridge of exactly the same construction showed that this precision was all that could be expected. In making this balance, therefore, the procedure was to determine the resistance range over which the balance was apparently constant, and then take the midpoint between the two extremes as the reading. This error is not important, however, because the experimental variations in power factor were large compared to the amount of error.

All tests, except those of puncture voltage, were made in the specially constructed low humidity room as described in preceding reports. Briefly, it consisted of a small room completely enclosed in thick, moisture-proof walls. Entrance was made through a thick door built similar to a refrigerator door. Outside the room a large tank containing anhydrous calcium chloride was set up, through which the air of the room was continually circulated, removing the moisture. Inside the room an automobile radiator was mounted, through which cold water was constantly circulated. The purpose of this was to maintain a fairly constant low temperature in the room and prevent perspiration from the test man from increasing the humidity. The measurement of humidity was made by means of an ordinary sling psychrometer, mounted vertically and using a small fan to obtain the required circulation about the wet and dry bulbs.

The puncture voltage tests were made in the high-voltage laboratory where the humidity could not be controlled. Tests made on these samples, however, showed that no appreciable change of puncture voltage occurred even when the samples were exposed to the air until saturated.

(d) Number of Tests Made

Number of samples:	
Wood-pulp paper	18
Manila paper	2
Wood-pulp and manila	2
Total	22
Number of specimens per temperature	330
Number of temperatures	7
Total number of specimens	2,310
Number of individual tests per specimen	36
Total number of individual tests scheduled to be made	83,160
Reduction for specimens not used in 140 deg. cent. test	2,370
Net total of tests made	80,790

Comparing this figure with the total of tests covered by the preceding report (23,600—final report of June 15, 1926, on manila paper), a ratio of approximately 3.5 is obtained. This ratio is low, in view of the increased capacity of the ovens from using the specially prepared specimens. The previous figure, however, included a large number of tests made to determine the effect of humidity on the mechanical properties of the paper. Tests made to determine the effect of moisture absorbed by the paper tested at this time were not included in the above number, although the number is about 3300.

Discussion of Results

(a) General Description of Curve Sheets

A total of 152 curve sheets are included in the complete report but only one, a reasonably typical one, is reproduced here (Fig. 1) as an example. These curve sheets showed the results of tests made on the individual samples at the various test temperatures. The curves are plotted as percentages of original value (ordinates) against time of heating in weeks (abscissæ). Seven curves are included for each sample of paper tested, corresponding to temperatures of 20 deg. cent., 50 deg. cent., 70 deg. cent., 90 deg. cent., 90 deg. cent. intermittent, 100 deg. cent. and 140 deg. cent. respectively. The temperature is shown on each curve sheet as part of the horizontal scale marking, i.e., "Weeks at —— deg. cent." On each sheet the legend at the lower right-hand corner contains the serial number of the curve, the code letter of the sample, the original values of the tests made for each sample, and the identification of the lines used in plotting the results of the various tests made.

(b) Curves of Individual Samples

As in the previous results obtained from tests of this type, the most noticeable characteristic is the erratic course of the curves. Fig. 1 is reasonably typical—some of the curves were much more erratic and some less erratic. Broken line plots are drawn in all cases, although the characteristics could be represented by smooth curves in some cases.

From glancing through the curve sheets corresponding to any particular temperature, it is apparent that some grouping of samples is possible. Using the complete curves contained in this report, it will be possible to draw comparisons of this nature.

The distribution of the samples relative to the average results obtained can be found, approximately, by superposing the average curves on each set of individual curves, using the average curve at the same temperature as the individual curve in each case. Having thus superposed the curves, we can note whether the characteristics of the individual curve under consideration lie, in general, above, below or along the average curves.

This has been done, using only the tests which were made on the paper in estimating the relative positions of the various curves. The power factor curves were excluded because the results of the tests on the paper are those primarily wanted and also because the large variations in the power factor (which will be discussed later) made it possible to completely reverse the normal classification based on paper tests only.

The tabulation given below shows the results of such an examination at each temperature, based on a total of 22 samples and therefore including the two manila paper samples. The figures are, of course, only approximate.

TABLE I

DISTRIBUTION WITH RESPECT TO THE AVERAGE

Temperature Deg. cent.	Number of Avg. Samples Per cent	Number of Samples Above Avg. Per cent	Number of Samples Below Avg. Per cent
20	55	22½	22½
50	50	27	23
70	55	22½	22½
90 (steady)	50	30	20
90 (intermittent)	50	27	23
100	50	27	23
140	75	10	15

This tabulation does not take into account the absolute values obtained in the various tests made on the paper, but only the deterioration expressed as a percentage of original value. Similar tabulations may be prepared showing the distribution with respect to any particular kind of test, using either absolute values or relative deterioration.

Most of the samples had the same classification at each temperature up to 100 deg. cent., although a few changes did occur. The manila paper samples, incidentally, were in almost every case classified as *above* average.

Referring to the tabulation given, it will be seen that for temperatures up to 100 deg. cent., a little more than half the samples show average characteristics. The remaining samples are divided with slightly more below average than above. The number, however, above average includes the manila paper samples. If these were discarded in getting the distribution, we should get about 60 per cent average, 25 per cent below average and 15 per cent above average. The distribution at 140 deg. cent. is largely grouped near the average; in fact, only one or two samples show any tendency to depart from the average to a large extent.

It is apparent from these considerations that the average curves are not derived from widely divergent values, in general, but from individual characteristics, the majority of which are grouped near the average. It should be noted here that samples classified as above or below average are in most cases slightly above or below average, and do not contribute widely divergent data toward the final result.

The individual curves of power factor (of oil) show a number of cases where sudden temporary increases of power factor occurred, and also a number of cases where the power factor curve as a whole increased considerably, and went off the curve sheet altogether. In these latter cases the value of the ordinate off the sheet is printed at the top of the abscissa to which it applies.

In the case where the power factor curve shows a sudden increase and then a decrease, it is undoubtedly an accidental change, and the point should be treated as doubtful. With a spacing of only 0.009 in. between the plates in the measuring cell, small foreign particles were very apt to cause such discrepancies. Usually such readings were not noticed until the data were plotted and then it was too late to make another test. The test routine did not permit the time necessary to check each test, as it was made, against the previous results. Also, there were many large increases in power factor of a legitimate nature, and it would be futile to attempt to distinguish the good and the poor readings as they were obtained. These apparently accidental high readings are included in the curves as a matter of record.

(c) Average Curves

Fig. 2 to 8 inclusive show the results of averaging all samples, for each kind of test, at temperatures of 20 deg. cent., 50 deg. cent., 70 deg. cent., 90 deg. cent., 90 deg. cent. (intermittent), 100 deg. cent. and 140 deg. cent. respectively. In addition, these curves are partly smoothed by plotting each point as the average of the true ordinate at that time, and the true ordinates immediately before and after the time under consideration.

With the exception of the 20 deg. cent. series the folding endurance test shows the greatest tendency to change, of all the tests. In the 20 deg. cent. series the tensile strength decreases more than folding endurance, but recovers and finishes at the 47th week slightly greater than the folding endurance. In the 140 deg. cent. series, the tensile strength and folding endurance curves are almost coincident.

For purposes of comparison, the average curves can be divided into four groupings according to temperature, as follows: Group I—20 deg. cent. curves only; Group II—50 deg. cent. and 70 deg. cent. curves; Group III—90 deg. cent., 90 deg. cent. (intermittent), and 100 deg. cent. curves; Group IV—140 deg. cent. curves only. (See also Fig. 9.)

1. *Group I, 20 deg. cent.* The greatest change was found in the tensile strength, which decreased to 55 per cent at the 20th week, and then recovered, reaching 92 per cent at the 47th week. Folding endurance and tearing strength went very closely together, reaching minimum values of 70 per cent and 67 per cent respectively, and recovering to 89 per cent and 79 per cent respectively at the 47th week. Puncture voltage decreased to 92 per cent at the 8th week, increased to 102 per cent at the 20th week, decreased to 93 per cent at the 29th week, and increased to 112 per cent at the 47th week. On the average, the puncture voltage was practically constant at room temperature. The power factor of the oil decreased at first, reaching 91 per cent, at the 21st week, but increased to 115 per cent at the 39th week, and was again sloping slightly downward at that time.

2. *Group II,* 50 *deg. cent. and* 70 *deg. cent.* The folding endurance curves at both temperatures are almost coincident, with the minimum of 50 per cent at the 23rd week and a final value of 84 per cent at the 47th week. The tensile strength curves are also very close together, reaching 60 per cent at the 17th week and having a final value of 90 per cent at the 47th week. The puncture voltage curves are similar at both temperatures, and both reach 110 per cent at the 47th week from a minimum of about 92 per cent at the 32nd week. The power factor curves in both cases remain practically constant at about 90 per cent between the 10th and 25th weeks. They then increase to about 130 per cent at the 32nd week and decrease to 110 per cent at the 39th week. This part of the curve is undoubtedly incorrect, and was probably caused by incorrect spacing of the plates between which the test was made, at the 32nd week. The correct power factor curve is almost a constant upward slope from about 92 per cent at the 24th week to about 110 per cent at the 40th week.

3. *Group III,* 90 *deg. cent. and* 100 *deg. cent.* The curves are characterized by general slopes in one direction, without the recovery phenomena found in the two preceding groups. The folding endurance decreases in the first 6 weeks to points between 70 per cent and 80 per cent. The slope then changes, so that at the 36th week the group average is about 60 per cent folding endurance. This is a decrease of slope from 4 per cent per week to about 0.5 per cent per week. The tensile strength has a slight tendency to show a recovery period in both the 90 deg. cent. tests, but at 100 deg. cent., its slope is generally downward. The 36th week value of tensile strength for the whole group, however, is about 90 per cent. The tearing strength at all three temperatures reached about the same point as folding endurance at the 36th week, namely, 60 per cent, but it showed a fairly constant average slope throughout. The puncture voltage decreased slightly for the first ten weeks at a rate less than 1 per cent per week, and then increased at a nearly constant rate, reaching a group average of 112 per cent at the 36th week. The power factor curve shows a decrease in the first 6 weeks on both 90 deg. cent. sheets to about 90 per cent, and then increases to a final value of 122 per cent at the 36th week. Slight irregularities in the power factor curves occur similar to those found in Group II, but not as pronounced. The power factor at 100 deg. cent. decreases for the first 10 weeks to 86 per cent and then increases to 122 per cent at the 36th week, which is the same as the two 90 deg. cent. values at that time.

4. *Group IV,* 140 *deg. cent.* Both folding endurance and tensile strength decrease together at a constant rate, reaching a value of only 10 per cent at the 22nd week, when the test ended. The tearing strength decreased more slowly, reaching about 20 per cent at the 22nd week. The puncture voltage was almost constant for the first 11 weeks at 100 per cent, but dropped from there to 45 per cent in the last 11 weeks. The power factor test remained constant for the first 11 weeks and then started to go up, but due to its late start went only to the 14th week. Too short a time is involved in this curve to make it a reliable indication of the behavior of power factor at 140 deg. cent.

REPORTS OF
PUBLIC RELATIONS NATIONAL SECTION COMMITTEES 1928-1929

(For Personnel of Committees see Appendix 4)

Executive Committee

J F Owens, *Chairman*

Convention Address by Chairman Owens (see p. 17)

Cooperation with Educational Institutions Committee

Carl D Jackson, *Chairman*

No Serial Report

Customer Ownership Committee

W H Hodge, *Chairman*

Serial Report, Publication No. 289-78 (see p. 1506)

Information Bureau Organizations Committee

T A Kenney, *Chairman*

No Serial Report

Industrial Relations Committee

Homer E Niesz, *Chairman*

Serial Reports

Pub. No.	
289-44	Training for Better Public Contact—II—Analysis of Public Contact Work (see p. 1529).
289-83	Training for Better Public Contact—III—Building and Conducting the Training Program (see p. 1535).
289-108	Training for Better Public Contact—IV—Measurement of Results Obtained by a Public Contact Training Program (see p. 1547).
289-56	Health Promotion in the Public Utility Industry—Its Necessity and Importance (see p. 1552).

Manufacturers' Advertising Committee

T J McManis, *Chairman*

No Serial Report

Public Speaking Committee

W S Vivian, *Chairman*

Serial Report, Publication No. 289-77 (see p. 1562)

Relations with Financial Institutions Committee

A W Robertson, *Chairman*

No Serial Report

Women's Committee

Miss Sophia Malicki, *Chairman*

Convention address by Miss Malicki (see p. 162).

CUSTOMER OWNERSHIP COMMITTEE

Data collected under the direction of the Customer Ownership Committee of the N. E. L. A. for the year 1928 show a marked decrease in this form of financing compared with the five preceding years. Although five companies were added to those reporting, having engaged in customer ownership activities, or a total of 251, the total number of new shareholders added and the number of shares sold, were considerably less than in 1927. For 1928 apparently 202,380 new shareholders were obtained compared with 249,491 in 1927; shares sold in 1928 were 2,081,071 compared with 3,581,206 in 1927.

The total number of home shareholders added by the customer ownership plan by the companies reporting was computed to be 1,884,148, as of Dec. 31, 1928.

Decreasing activities during 1928 were anticipated, and it is believed do not indicate any real loss of interest in customer ownership on the part of electric light and power companies. The results for the year seem merely to reflect the general conditions bearing upon the financing of capital requirements. These requirements to a larger degree than formerly were supplied by the sale of common stock. The popularity of electric light and power securities in general (to which customer ownership activities in past years contributed in no small degree) with the increasing demand of the investing public for common stock investments, brought about a period which dictated the wisdom of a larger proportion of financing by means of common stock issues. This period followed one whereby a large part of financing requirements were most advantageously handled by bond issues. Because of these facts it was inevitable that the amount of preferred stocks which could be issued, and at the same time preserve well-balanced financial structures (enabling the ingress of capital on the lowest average terms) was curtailed. Inasmuch as the majority of companies have maintained a policy of restricting customer ownership distribution to preferred stock, the effect upon this particular form of financing is obvious.

Many companies which were formerly active in customer ownership distribution and which are firmly committed to the policy as most desirable, were compelled to cease temporarily the sale of preferred stock in 1927 and to a greater extent in 1928, principally for the reasons cited. Managements usually have regretted the necessity of such a course and have studied ways and means to maintain customer ownership distribution continuously. Thus far, however, no generally accepted plan has been developed, insofar as the committee knows, which solves the problem. It seems fair to assume that the conditions militating against building up the number of home shareholders in many localities will eventually correct themselves and resumption of activities by companies forced to discontinue may be confidently expected.

The year 1928 witnessed a general trend toward lower rates of dividends on the preferred stocks issued and sold, the rate in some instances being as low as 5½ per cent.

Your committee continued to support the plan of cooperation with the National Better Business Bureau, toward the protection of the holdings of shareholders, which was fully described in last year's report. The following letter was sent to member companies over the signature of the chairman:

> "The Customer Ownership Committee has directed me, as Chairman, to call your attention to the 1928 Convention report of the Committee and the plan outlined and recommended for cooperation with the National Better Business Bureau.
>
> "This plan aims to offer a specific service toward the protection of the holdings of customer-shareholders. The National Better Business Bureau is an established institution of high reputation, with a responsible Board of Directors. It is devoted to the suppression of fraud, misrepresentation and questionable methods applied to the exploitation of the public, and has a successful record.
>
> "Your Committee recommends that you seriously consider the service which the Bureau offers and determine the value of such services to your organization. Necessarily, the annual financial subscription which your company may make to the Bureau must be a matter of mutual negotiation.
>
> "The officers of the National Better Business Bureau will communicate with you direct, and it is hoped that you will give them opportunity to fully present their proposal."

March 6, 1929, the chairman reported to the Public Relations National Section that the response of member companies, in the way of subscriptions to the National Better Business Bureau, was not considered satisfactory, and offered a resolution, which was adopted, the substance of which was as follows:

> "Attention is further directed to the importance of protecting utility stockholders through the National Better Business Bureau, and also to the desirability of utilizing the services of that Bureau toward preventing abuse of Customer Ownership principles by irresponsible companies and persons controlling a limited number of utility properties.
>
> "The chairman therefore recommends that the foregoing be brought before the executive committee of the National Electric Light Association with the request that the executive committee take suitable action to urge Member Companies, and particularly holding companies of a national or semi-national character, to extend a suitable measure of financial support to the National Better Business Bureau."

This resolution was endorsed by the Executive Committee, and in April, 1929, was approved by the Public Policy Committee.

Under date of April 20, 1929, the general manager of the National Better Business Bureau submitted a compilation of the amounts contributed by electric light and power companies, both to that body and to the local Better Business Bureaus. This showed the following:

Publication No. 289-78, Serial Report.

Annual subscription to National Better Business Bureau	$6,800
Special subscription to National Better Business Bureau	1,000
Total to National Better Business Bureau	$7,800
Annual subscription to local Better Business Bureau	6,915
Total	$14,715

The companies subscribing to the National Better Business Bureau were as follows:

Byllesby Engineering & Management Corporation.
Brooklyn Borough Gas Company.
Brooklyn Edison Company.
Columbia Gas & Electric Company.
Commonwealth Edison Company.
Consolidated Gas Company of New York.
H. L. Doherty & Company.
Detroit Edison Company.
Eastern Connecticut Power Company.
Georgia Power Company.
International Utilities Corporation.
Middle West Utilities Company.
Midland Utilities Company.
Pennsylvania-Ohio Electric Company.
Pennsylvania Water & Power Company.
Peoples Gas Light & Coke Company.
Portland (Ore.) Electric Power Company.
Public Service Corp. of Northern Illinois.
Public Service Corp. of New Jersey.
San Antonio Public Service Company.
Standard Gas & Electric Company.
United Companies.
Central Maine Power Company.
New England Public Service Company.
National Electric Power Company.
Utilities Securities Company.

There are 42 local Better Business Bureaus in the United States and one in Canada. Of these it was found that companies were contributing annual amounts to 31 local bureaus, were not contributing to 5, while 7 bureaus had not reported.

The companies listed as contributing to local bureaus were as follows:

Akron, Ohio, Northern Ohio Power & Light Company.
Baltimore, Md., Consolidated Gas, Electric Light & Power Company of Baltimore.
Chicago, Ill., Commonwealth Edison Company.
Cincinnati, Ohio, Union Gas & Electric Company.
Detroit, Mich., Detroit Edison Company; Consolidated Power Company (Jackson, Mich.).
Fort Wayne, Ind., Indiana Service Corporation.
Hartford, Conn., Hartford Electric Light Company.
Indianapolis, Ind., Indianapolis Power & Light Company.
Lima, Ohio, Ohio Power Company.
Providence, R. I., Narragansett Electric Light Company.
Scranton, Pa., Scranton Electric Company.
Utica, N. Y., Utica Gas & Electric Company.
Kansas City, Mo., Kansas City Power & Light Company.
Cleveland, Ohio, Cleveland Electric Illuminating Company.
Toledo, Ohio, Toledo Edison Company.
Dayton, Ohio, Dayton Power & Light Company.
Philadelphia, Pa., Philadelphia Electric Company.
Boston, Mass., Edison Electric Illuminating Company; Gas & Electric Improvement Company; Malden Electric Company.
Portland, Ore., Portland Electric Power Company.
Stockton, Cal., Western States Gas & Electric Company (controlled by Pacific Gas & Elec. Co.).
Tacoma, Wash., Tacoma Railway & Traction Company.
Dallas, Tex., Dallas Power & Light Company.
Peoria, Ill., Illinois Light & Power Company; Central Illinois Light Company.
San Diego, Cal., San Diego Cons. Gas & Electric Company.
Seattle, Wash., Puget Sound Power & Light Company.
Oakland, Cal., Pacific Gas & Electric Company; Great Western Power Company.
Canton, Ohio, Ohio Power Company.
Birmingham, Ala., Birmingham Electric Company.
Long Beach, Cal., Southern California Edison Company.
Rochester, N. Y., Rochester Gas & Electric Corp.
Houston, Tex., Houston Lighting & Power Company.

Among the bureaus not reporting is that at Louisville, Ky., to which the Louisville Gas & Electric Company is a subscriber.

Confusion has existed in the past as to subscriptions as between the national and local bureaus. Toward clarification the general manager of the National Better Business Bureau submitted the following:

> "It is my opinion that most of the public utility companies are making a fair pro rata subscription to the income of the local Better Business Bureaus. Some of them, however, could be increased, thereby materially aiding the program in the financial field in which the local bureaus are engaged. Of course, those bureaus not now receiving support should be accorded consideration as soon as possible.
>
> "In a Better Business Bureau executive conference held in St. Louis it was decided that the operating companies located in local bureau communities should subscribe directly to the local Better Business Bureaus, while those outside those vicinities should subscribe to the National Better Business Bureau. This plan may modify our present arrangement, but we believe that it will effect efficiency in operation and simplicity in obtaining subscriptions."

Your committee renews its recommendations that careful consideration be given to effective cooperation with both national and local Better Business Bureaus, that this work be financially supported, and that the whole question of helping shareholders safeguard their investments be constantly studied in order to render the most effective and practical assistance.

During the year a case (Murphy v. the Wyandotte County Gas Company), involving customer ownership, was decided by Judge Pollock in the United States Court, Kansas District First Division. This decision was in favor of the company, and the opinion discusses customer ownership in a most interesting manner. It is one of few, if it is not the only, legal action involving customer ownership principles and activities, and the opinion is incorporated as part of this report, as Appendix A.

Your Committee submits the customary statistical reports, and desires to express its appreciation of the services rendered therewith by Fred W. Herbert, director service department, N. E. L. A.

TABLE I

DATA ON CUSTOMER OWNERSHIP

SUMMARY OF INFORMATION REPORTED BY 251 ELECTRIC LIGHT AND POWER COMPANIES

Total population of territory served	85,564,726
Total number of customers served	17,935,530
Gross electric earnings of combined companies reporting (1928)	$1,171,105,657
*Number of individual stock sales through Customer Ownership Plan	1,884,148
Shares of stock sold through Customer Ownership Plan ($100 par.)	18,800,307
Percentage of electric customers buying stock under Customer Ownership Plan	10.5%
Percentage of shares sold on deferred payment plan (1928)	16.2%
Weighted average selling cost per share	$3.12

SUMMARY BY YEARS

Year	*Sales Made	Shares of Stock Sold	Number of Additional Companies by Years Adopting Customer Ownership Plan
1914	4,044	92,310	7
1915	4,357	57,130	3
1916	3,681	38,183	4
1917	8,242	82,007	8
1918	5,186	42,388	7
1919	19,872	194,021	12
1920	53,063	454,139	34
1921	118,544	830,222	37
1922	156,725	1,450,707	49
1923	279,186	1,806,300	24
1924	294,467	2,478,165	23
1925	236,043	2,926,271	18
1926	248,867	2,686,187	2
1927	249,491	3,581,206	18
1928	202,380	2,081,071	5
	1,884,148	18,800,307	251

*In the compilation of these statistics, each separate purchase of stocks has been recorded by many of the reporting companies as being the acquisition of an additional "stockholder." There are possibilities of duplications, arising from:

(a) Repeat purchases of stock of the same company by the same individual.

(b) The purchase of stock in two or more companies by the same individual.

(c) In addition, the situation is further complicated by the purchase of stocks, by customers, from other sources than through the company's office.

TABLE I—(*Concluded*)

DATA ON CUSTOMER OWNERSHIP

SUMMARY OF SALES IN 1928

Common Stock Shares	56,862
Preferred Stock Shares	2,024,209
Total	2,081,071
Value of stock sold under Customer Ownership Plan, 1928 ($100 par)	
Common Stock	$5,686,200
Preferred Stock	202,420,900
Total	$208,107,100

Analysis of the returns of companies reporting in full on the detailed information asked for on Customer Ownership questionnaires developed the following data.

Of the total individual sales made under Customer Ownership Plan—

87.2% were to Customers
8.7% were to Employees
4.1% to others.

100%

Of the total number of shares of stock sold under Customer Ownership Plan—

85.4% was sold to Customers
9.0% was sold to Employees
5.6% was sold to others.

100%

Average percentage employee stockholders to total employees	15.4%
Average number of shares per employee	10.7
Average number of shares per customer	10.3

THE TEN CARDINAL RULES OF CUSTOMER OWNERSHIP

Prepared by the Customer Ownership Committee of the National Electric Light Association

1. The sale of the securities must be direct from company to customer or through an agency expressly created for the purpose and controlled by the company.

2. The safety of the securities offered must be amply protected by property and earnings.

3. A minimum rate of dividends must be provided for insofar as honest judgment based on experience can foresee.

4. A reliable resale market must be maintained in some manner so that shareholders who wish to dispose of their holdings can do so promptly at nominal expense.

5. A partial payment purchase plan must be operative in order to give every customer who can save a small amount monthly full opportunity to become a shareholder, and to encourage thrift.

6. The proprietary interest and responsibility of shareholders must be emphasized and the shareholders supplied regularly with information regarding their company and its affairs.

7. Loss of capital by shareholders in hazardous and fraudulent offerings from various sources must be guarded against by the rendering of authentic information and advice to shareholders.

8. The number of shareholders must be increased steadily and efforts should be made to avoid large individual accumulations of stock.

9. Employees must be carefully instructed in order that all representations made to customers or others are in line with the facts.

10. Managements must realize that customer ownership multiplies their obligations to the public and intensifies the trust reposed in them. It does not replace the constant striving for higher efficiency, good service, reasonable rates, courtesy and progressive public relations policies.

TABLE II

SUMMARY BY STATES

State	Population Served	Customers Served	Number of Stock Sales	Shares Sold
Alabama	2,165,020	186,171	39,363	318,077
Arizona	122,790	22,819	2,887	18,355
Arkansas	558,932	94,072	13,531	99,360
California	4,472,816	1,651,655	215,916	4,178,811
Colorado	1,090,000	299,703	68,692	697,086
Connecticut	928,497	236,517	12,510	71,796
Delaware	....	....	....	....
District of Columbia	572,000	134,505	11,722	70,000
Florida	1,068,389	207,807	12,562	171,573
Georgia	2,246,110	142,924	7,072	72,986
Idaho	416,632	77,916	14,105	60,399
Illinois	6,189,126	1,734,466	186,233	1,343,619
Indiana	2,498,332	460,226	51,787	475,446
Iowa	2,340,000	425,384	38,414	215,290
Kansas	1,660,689	146,811	26,396	211,116
Kentucky	1,971,360	227,215	44,166	539,015
Louisiana	1,351,345	62,246	25,174	34,406
Maine	429,862	94,700	18,649	162,964
Maryland	1,051,000	54,588	33,343	285,467
Massachusetts	2,020,500	121,442	30,785	83,252
Michigan	3,350,027	917,579	61,540	625,394
Minnesota	1,788,922	407,055	88,869	1,061,124
Missouri	3,207,426	580,326	54,133	428,962
Mississippi	412,427	68,909	3,118	67,164
Montana	68,910	18,011	5,854	25,965
Nebraska	824,923	154,094	10,746	105,027
Nevada	37,805	10,075	4,276	9,424
New Hampshire	216,650	46,603	9,129	79,585
New Jersey	3,164,736	1,031,345	116,502	759,951
New Mexico	3,500	670	248	20
New York	10,034,832	3,271,268	157,636	1,181,185
No. Carolina	1,538,714	98,287	6,842	101,416
No. Dakota	195,100	22,757	6,032	71,928
Ohio	5,759,266	1,410,077	72,060	1,336,558
Oklahoma	1,254,428	209,034	42,317	460,705
Oregon	730,910	163,736	34,146	259,777
Pennsylvania	6,179,274	870,761	100,006	1,030,682
Rhode Island	484,573	115,893	12,429	43,280
So. Carolina	416,651	21,451	1,887	18,355
So. Dakota	489,000	41,992	11,217	66,934
Tennessee	1,266,062	262,854	21,608	231,964
Texas	2,880,151	530,152	33,717	399,932
Utah	423,316	171,252	16,491	130,317
Virginia	1,198,924	203,230	21,962	153,919
Vermont	38,000	6,903	1,231	12,363
Washington	1,195,022	174,042	25,382	239,127
West Virginia	547,643	101,548	11,548	73,421
Wisconsin	1,904,884	446,018	79,450	641,389
Wyoming	44,250	10,878	3,169	22,222
Canada	2,755,000	187,563	17,296	53,199
Totals	85,564,726	17,935,530	1,884,148	18,800,307

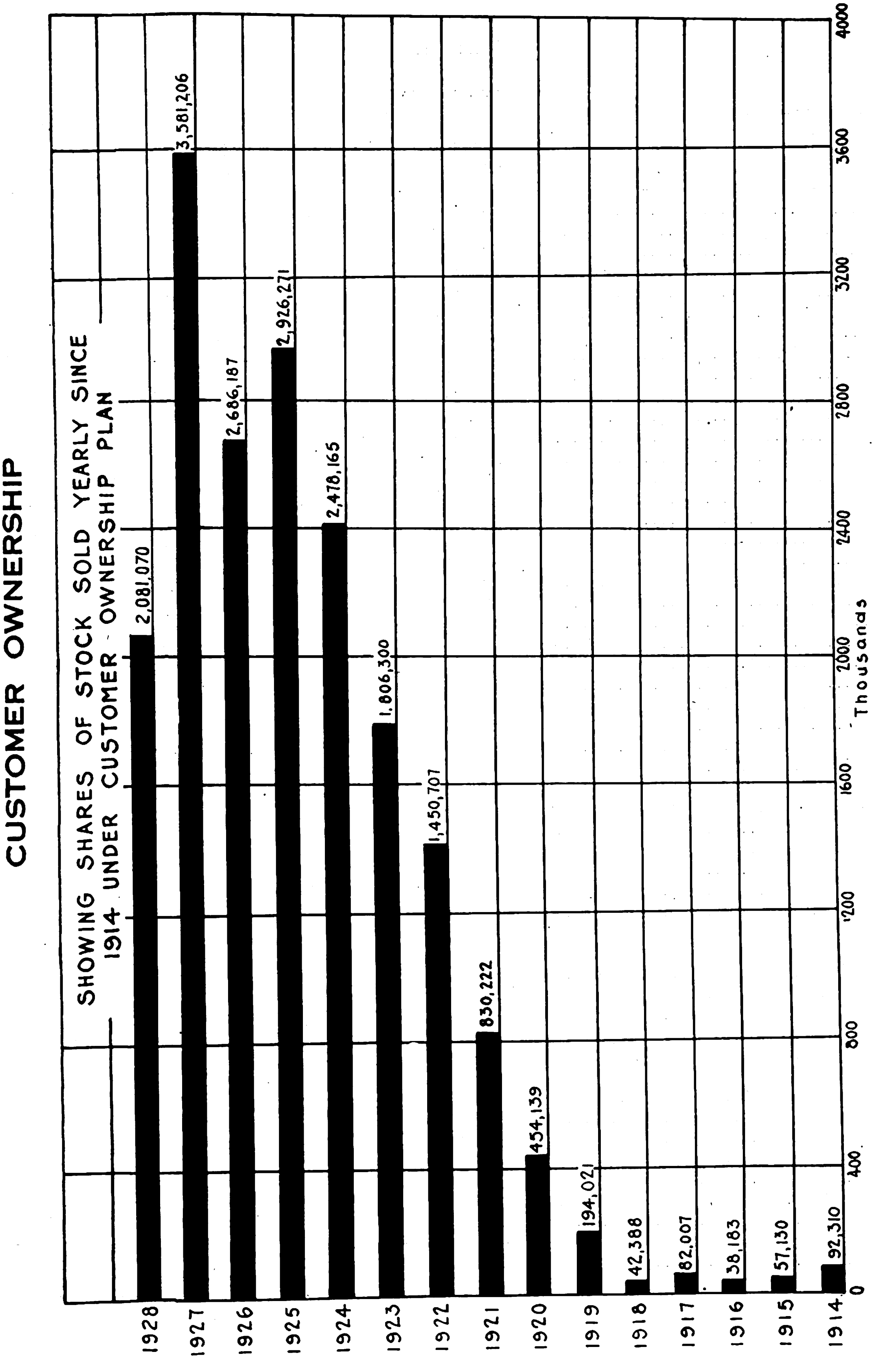

CUSTOMER OWNERSHIP
SHOWING SHARES OF STOCK SOLD YEARLY SINCE 1914 UNDER CUSTOMER OWNERSHIP PLAN
1928
2,081,070
1927
3,581,206
1926
2,686,187
1925
2,926,271
1924
2,478,165
1923
1,806,300
1922
1,450,707
1921
830,222
1920
454,139
1919
194,021
1918
42,388
1917
82,007
1916
38,183
1915
57,130
1914
92,310
0
400
800
1200
1600
2000
2400
2800
3200
3600
4000
Thousands

FIG. 1

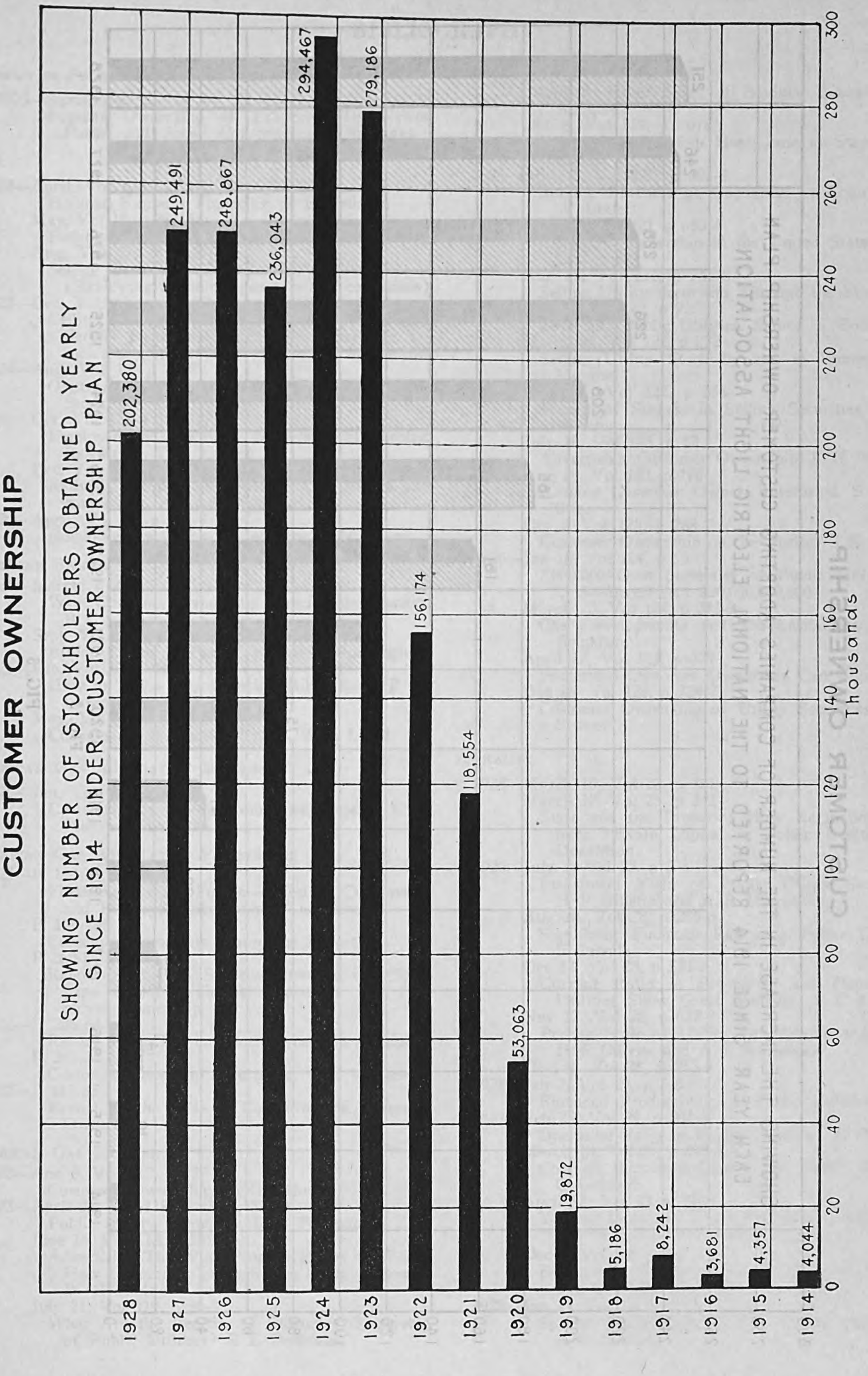
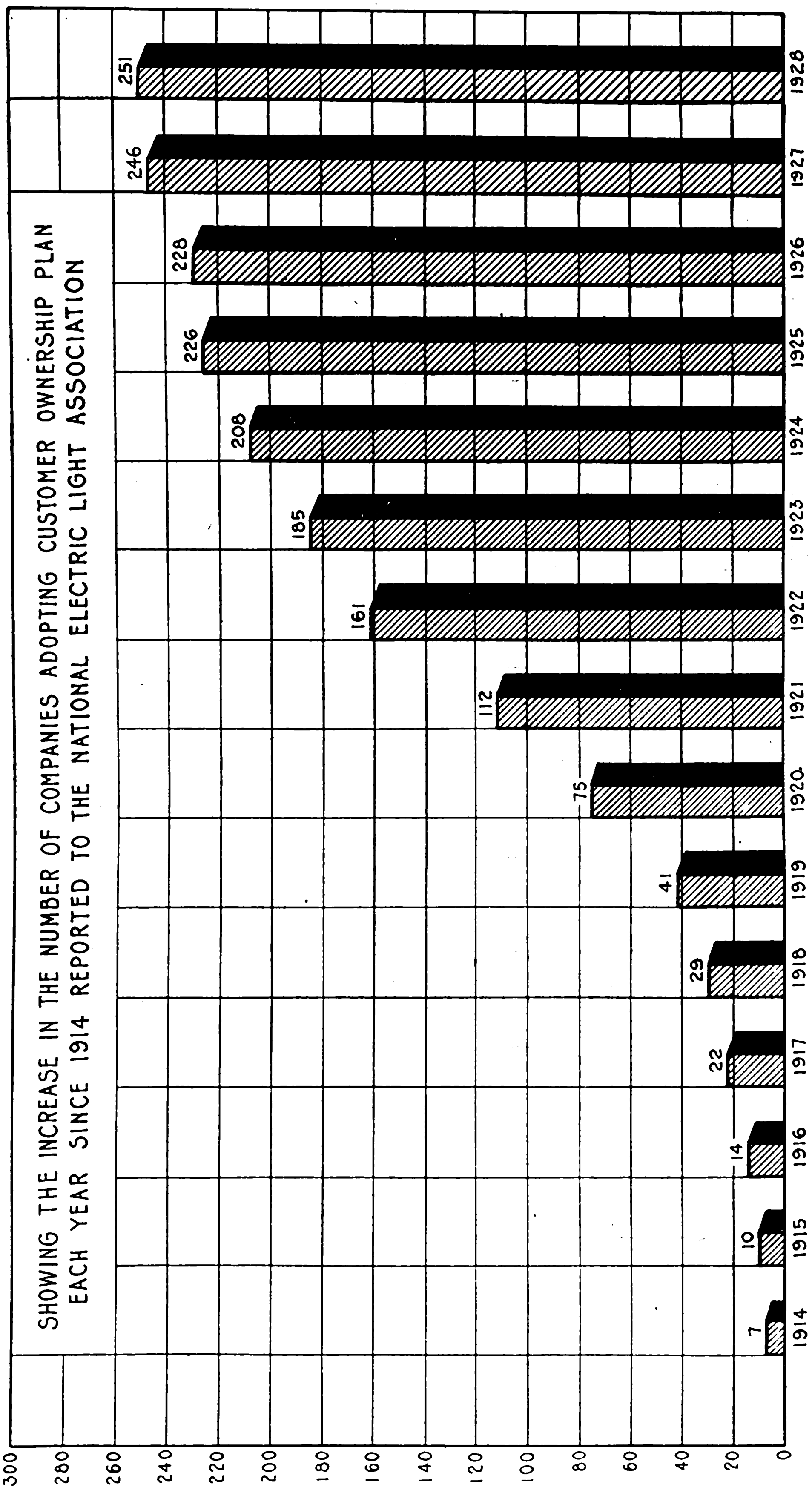

CUSTOMER OWNERSHIP
SHOWING NUMBER OF STOCKHOLDERS OBTAINED YEARLY SINCE 1914 UNDER CUSTOMER OWNERSHIP PLAN
1928
202,380
1927
249,491
1926
248,867
1925
236,043
1924
294,467
1923
279,186
1922
156,174
1921
118,554
1920
53,063
1919
19,872
1918
5,186
1917
8,242
1916
3,681
1915
4,357
1914
4,044
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
Thousands

FIG. 2



CUSTOMER OWNERSHIP

SHOWING THE INCREASE IN THE NUMBER OF COMPANIES ADOPTING CUSTOMER OWNERSHIP PLAN EACH YEAR SINCE 1914 REPORTED TO THE NATIONAL ELECTRIC LIGHT ASSOCIATION

FIG. 3

FIG. 3

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APPENDIX A

U. S.

Murphy v. The Wyandotte County Gas Company (Dist. Ct., Dist. Kan., 1st Div., November 2, 1928).

In suit by holder of one share of stock of corporation to restrain it from using its employees in selling securities of another corporation which owned majority of stock of former, and no other stockholder joined suit, nor did it appear that value of plaintiff's stock was impaired, bill dismissed under Equity Rule 27—"Customer ownership" and "employee ownership" of securities of public utilities discussed.

The opinion of Pollock, Dist. J., follows in full:

This suit is brought by plaintiff as minority stockholder in defendant corporation, and as alleged in the bill of complaint, for the benefit of all other minority shareholders in said corporation, to restrain the corporation from employing its official force, agents, servants, and employees in the performance of duties and services for the sale, use and benefit of a corporation created under the laws of the state of Delaware called the Cities Service Company, the owner of the majority of the capital stock of defendant company. The business which the bill seeks to restrain the defendant company from doing for the holder of the majority of its capital stock, consists in putting on selling campaigns to sell to customers of defendant company and others, shares of stock and securities of the Cities Service Company, said Cities Service Company being a mere holding company, owning and holding a majority of the shares of stock in defendant company and thus controlling, through a majority vote of its shares, the choice of officers and directors in defendant corporation.

The purpose for which defendant company was incorporated under the laws of this state as expressed in its charter and as admitted in the pleadings is as follows:

> "Of supplying gas to the public, and that defendant is possessed of the powers necessary and incident to the carrying out of such purpose."

Now the question presented is this: Is the engaging in a campaign of selling the stock, bonds and other securities of the Cities Service Company, the owner and holder of the majority of the capital stock of defendant company, through the direction and under the authority of the officers and directors of defendant corporation, by those in the employ of defendant and paid their salaries and wages out of the treasury of defendant company alone during working hours, for which time defendant company pays and is entitled to the services of such employees, so foreign to the lawful purpose for which defendant was incorporated as to be *ultra vires* and an abuse of the trust created between defendant company and its stockholders created by those purchasing the majority of its stock, and by such majority holding, electing its governing bodies?

While two questions are presented, the answer to both will be found in the answer to one other question: Does "customer ownership" and "employee ownership" of stock bear a rational relationship to the success of a corporation? If it does, the decision of the Board of Directors, if made in good faith, cannot be reviewed by the courts. The Courts have enough to do without sitting as a board of review over the acts of boards of directors.

There is little room for dispute as to the law applicable; much more room for fair argument as to the facts. If the officers of defendant company are using the machinery of the corporation, their own time and that of the employees, their lists of customers, and the name of the corporation, to sell stock of another company, it can be, and should be enjoined at the instance of any stockholder. In the first place the company was granted a charter for the purpose of selling gas, and not selling stock. It can't go into the stock selling business, even if a commission on the sales went directly into the corporate treasury, and even if it was a profitable business, for the simple reason that it has no corporate authority to do so. A minority stockholder can stop it, for the reason that when he acquired his stock he had a right to rely on the corporation staying in the business he wanted to invest his money in, and not going into another business he didn't want to go into. It makes no difference whether the other business is more profitable; the stockholder may insist on the officers sticking to the particular business he set into, until the charter is changed by the necessary vote of the stockholders. *Hawes* v. *Oakland,* 104 U. S. 450; 6 *Fletcher on Corps.* 6900; *Dodge* v. *Woolsey,* 18 How. 331, 15 L ed. 401; *Smith* v. *Title and Trust Co.,* 225 U. S. 180; *C. J.* 14A. p. 155.

The Kansas statute authorizing a corporation to own stock of another company in a similar line of business (17-603) has nothing to do with this case. The defendant company does not buy, sell, or own any of the securities of the Cities Service Company.

Aside from the question of *ultra vires,* there is another reason; a board of directors is under a fiduciary obligation to every stockholder. If an officer of a corporation, a board of directors, or a majority of the stockholders, use their power for their own profit, rather than for the good of the corporation, it may be enjoined. Where the majority of the stock is owned by another corporation, dealings between the two must be rigidly scrutinized.

> "Under the circumstances disclosed in the evidence, the fact that the American Tel. & Tel. Co. controlled the Company and the Western Electric Company is not important beyond requiring close scrutiny of their dealings to prevent imposition upon the community served by the Company, but the Court recognized and applied this rule."

Houston v. *S. W. Bell Tel. Co.,* 259 U. S. l. c., 323.

> "The defendants have criticised this payment because the close relationship between the American Tel. & Tel. Co. and the plaintiff may overburden the plaintiff with an undue expense account for the benefit of the American Tel. & Tel. Co. This subject and this danger have been considered in many other cases, and it has been held that such a relationship between the two companies may require a close scrutiny of the intercorporate dealings."

N. W. Bell Tel. Co. v. *Spillman,* 6 Fed. (2d) 664 l. c.

> "One who owns the majority of the stock of a corporation and who dominates and controls such corporation may contract with the corporation, and such contract will be upheld where the consideration moving to the corporation is adequate, where the terms of the contract are fair to the corporation, and where the contract will further the best interests of the corporation. But a court of equity will hold such majority stockholder to the observance of the highest rectitude in dealing with the corporation, and where the contract is unfair or unconscionable, where the consideration is inadequate, or where the contract is not for the best interests of the corporation, but subserves the selfish interests of such stockholder, it will set aside such contract at the instance of the corporation or its minority stockholders."

Heim v. *Jobes,* 14 Fed. (2d) 32 l. c., 8th C. C. A.
Wheeler v. *Bank,* 159 Fed. 391. 8th C. C. A.,

speaking through Mr. Justice Sanborn:

> "The holder of the majority of the stock of the corporation has the power, by the election of biddable directors and by the vote of his stock, to do everything that the corporation can do. His power to control and direct the action of the corporation places him in its shoes, and constitutes him the actual, if not the technical, trustee for the holders of the minority of the stock."
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> "This devolution of unlimited power imposes on the single holder of the majority of the stock a correlative duty, the duty of a fiduciary or agent, to the holders of the minority of the stock, who can act only through him, the duty to exercise good faith, care, and diligence to make the property of the corporation produce the largest possible amount, to protect the interests of the holders of the minority of the stock, and to secure and pay over to them their just proportion of the income and of the proceeds of the corporate property."

It is, of course, also true that after giving to such transactions the close scrutiny required by the law, if there is no fraud and no subterfuge, and the propriety of the transaction is none of business judgment, the courts will not interfere.

> "There is nothing to indicate bad faith. So far as appears, plaintiff in error's board of directors has exercised a proper discretion about this matter requiring business judgment. It must never be forgotten that while the State may regulate with a view to enforcing reasonable rates and charges, it is not the owner of the property of the public utility company and is not clothed with the general power of management incident to ownership. The applicable general rule is well expressed in *Public Utilities Commission* v. *Springfield Gas & Electric Co.* 291 Ill. 209, 234.
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> " 'The commission is not the financial manager of the corporation, and it is not empowered to substitute its judgment for that of the directors of the corporation; nor can it ignore items charged by the utility as operating expenses unless there is an abuse of discretion in that regard by the corporate officers.'
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> "See *I. C. C.* v. *Rwy. Co.,* 209 U. S. 108; *Rwy. Co.* v. *Wisconsin,* 238 U. S. 491; *People* v. *Stevens,* 197 N. Y. 1; *Tel. Co.* v. *Commission,* 262 U. S. 276, 288."

> "Within the limits of their authority directors or trustees possess full discretionary powers, and in the honest and reasonable exercise of such powers they are not subject to control by the stockholders or by the courts at the instance of a stockholder. A distinction has been admitted between the jurisdictions of courts of equity to accord relief at the suit of stockholders where the action is to redress breaches of trust on the part of directors or to recover damages from the same, and the want of jurisdiction in such courts, where the object of the bill is to influence corporate action, or where in its result it will have this effect. The true distinction is between acts in excess of the powers of the directors and in breach of their trust, and acts which are within their powers and which merely involve an exercise of the discretion committed to them. The rule is that in the absence of usurpation, of fraud, or of gross negligence, courts of equity will not interfere at the suit of a dissatisfied minority of stockholders, merely to overrule and control the discretion of the directors on questions of corporate management, policy, or business. Certainly in the absence of any action by the stockholders to control the directors, the courts will not interfere at the instance of the minority stockholders with the acts of the directors, which are within the scope of their powers and are not fraudulent or in breach of trust." *C. J.* 14A. 83.

This brings us to the controlling question in the case: are these stock selling campaigns put on in order to dispose of the stock of the Cities Service Company, for its benefit—to find a market for stock otherwise not available? If so, the relief prayed for should be granted. On the other hand, if it is an effort made, in good faith, to further the corporate business of the defendant, the court cannot interfere. The question of whether or not the stock sold is a good investment is quite beside the question. Courts cannot act as guardians of the investing public; that function, if it is properly a governmental function at all, is for the legislature and blue-sky boards of their creation.

It must be conceded that the business of selling gas to the public is a broader one than the construction of mains, connecting houses, and rendering bills. A public utility must find and satisfy its customers; it lives in an atmosphere of legislation; unfriendly legislators, whether in the City Hall or in the State House, by restrictive or unfair enactments directly affect the balance sheet of the corporation and the dividends of the stockholders. An unfriendly public too often makes itself felt in the actions of legislators who are hypersensitive to public opinion. Gas competes with coal and electricity for its market, and whatever tends fairly to increase the market is legitimate. Small corporations and large ones, in private business and public utilities, have from time immemorial "placed" part of their stock with good customers, either actual or potential. The bill in this case alleges that, "the present and future success of said defendant company depends in substantial part on its relations with the general public in this community."

This is, of course, true. In the past few years the matter of customer ownership has received the attention of the boards of directors of a great many corporations. The fact that many of the greatest of them have adopted it as a business policy is proof enough that it is a matter of business judgment. The railroads, the telephone companies, the electric power companies, the street car companies, provide easy means of inducing their customers to become owners. Invitations to become interested in the company are found inside telephone booths; placards invite passengers on street cars to, "Ask the motorman about our stock"; the periodicals carry advertisements of the wide dissemination of stock among patrons of the advertisers.

If a board of directors believes it will advance the interests of the company to interest its patrons in its problems; to give financial interest to its customers who will recommend to their neighbor its service over that of its competitor; to displace an unfriendly and suspicious public with one which is financially interested in its welfare; if done in good faith, there is nothing illegal about it. The decision of *Thrailkill* v. *Railroad Company,* 246 Fed. 687 (8th C. C. A.) controls in principle. The defendant in that case paid a commission to real estate agents for selling land in which the railroad had no interest. Such sales, however, brought settlers to the land, and settlers meant freight business. The contract was held valid and within the corporate power.

The fact that the stock sold is not that of the defendant, but that of its parent company, is not controlling. That situation exists in many instances. If the defendant company prospers, its prosperity is reflected in the value of the stock of the parent company sold to the public. Such prosperity is a degree removed, the value of the stock sold depending on the prosperity of other subsidiaries, but the legal situation is not changed by the extent or directness of the interest. The customer still can help himself by helping the defendant company in its problems. I conclude, therefore, that if these stock-selling activities are conducted in good faith, and for the *sole* purpose of giving its customers a financial interest in the business, and thus improving its balance sheet, there is no reason for judicial interference.

As to "employee ownership" the question is even more free from doubt. An employee who has a financial interest in the company he works for is apt to be a better employee; he gives better measure for his wage; he is more contented with his job; less apt to be disgruntled when called upon to do extra work; and much less apt to strike. All over the country employers are seeking to interest their employees in the business, for it is a proper rule of human nature that a man's heart is close to his pocket-book. In small business, he is given a bonus depending on the success of the year's work; in larger ones, like the steel companies, the railroads, the great utilities, he is given preferential rights to acquire an interest, on favorable terms, and on long-time payments. The past has proved the economic soundness of the proposition that an employee should have a financial interest in the success of his company.

A great many cases have been decided which have a bearing upon this proposition. In recent years corporations have found it to be sound business to build up a morale among their employees, for the purpose of making their positions attractive so that they can command the services of a better class of employees. The boards of directors have used corporate funds to construct hospitals for the use of their employees; playgrounds for their recreation; have contributed to pension funds and for disability benefits; have granted bonuses, not a part of the contract of employment, for special meritorious service, or because the combination of capital with the work of the employees have resulted in a prosperous year for the company. These cases are gathered in two extensive notes, one appended to the case of *Dodge Brothers* v. *Ford Motor Company,* 3 A. L. R. at page 443; and the other appended to the case of *Putnam v. Juvenile Shoe Corporation,* 40 A. L. R., page 1423. A rather clear distinction was drawn in the *Ford Motor Company* case by the Supreme Court of Michigan, which is this: As far as the Board of Directors in that case believed it to be good business to pay their employees a somewhat higher rate of wage than other industries were paying, it was held to be a valid exercise of corporate power; as far as their actions, however, were dictated by a motive to benefit humanity in general, was held to be beyond the power of the Board of Directors. The Supreme Court of Michigan said:

> "The difference between an incidental humanitarian expenditure of corporate funds for the benefit of the employees, like the building of a hospital for their use and the employment of agencies for the betterment of their condition, and a general purpose and plan to benefit mankind at the expense of others is obvious. There should be no confusion (of which there is evidence) of the duties which Mr. Ford conceives that he and the stockholders owe to the general public, and the duties which in law he and his co-directors owe to the protesting minority stockholders. A business corporation is organized and carried on primarily for the profit of the stockholders. The powers of the directors are to be employed for that end. The discretion of directors is to be exercised in the choice of means to attain that end, and does not extend to a change in the end itself, to the reduction of profits, or to the non-distribution of profits among stockholders in order to devote them to other purposes.
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> "There is committed to the discretion of the directors, a discretion to be exercised in good faith, the infinite details of business, including the wages which shall be paid to employees, the number of hours they shall work, the conditions under which labor shall be carried on, and the price for which products shall be offered to the public."

That leaves but one question and that a question of fact applicable to this case alone. Conceding the right of a board of directors to do these things if done in the sole interest of the corporation, the question still remains of whether, in this case, the directors are so actuated, or whether they are in fact simply using the facilities of the defendant to sell stock for the parent company. If they are so actuated, or if the result of their activity is to benefit only the parent company, then their acts violate their duty to the plaintiff. The amount of the facilities used, the amount of time and energy spent for the improper purpose, is not material, except as it may affect the jurisdiction of a United States District Court. The quality of the act of an officer of a bank who would steal a dollar bill is the same as if he had stolen the bank itself.

Under the circumstances as shown by the evidence in this case, a very difficult question of fact is presented. On the one hand is a presumption that the directors of a corporation are acting in good faith and for the sole interest of the stockholders whom they represent, together with the natural reluctance of courts to interfere in the management of private business; on the other is the even stronger demand that the acts of trustees be rigidly scrutinized, and the jealous regard which courts accord a situation where a trustee is dealing with himself. The Cities Service Company owns a majority of the stock of the defendant company, and through a board elected by that stock, uses the facilities of the company to dispose of securities issued by or owned by itself. Under such circumstances it must clearly appear that its actions are primarily for the benefit of the defendant. It is unnecessary to decide the question, in my judgment, for this reason.

This is an equity case, brought in this court by the holder of one share of stock of the par value of $100.00. The jurisdiction depends on diversity of citizenship. The suit is brought under Equity Rule 27, which reads in part as follows:

> "Every bill brought by one or more stockholders in a corporation against the corporation and other parties, founded on rights which may properly be asserted by the corporation, must be verified by oath, and must contain an allegation that the plaintiff was a shareholder at the time of the transaction of which he complains, or that his share had devolved on him since by operation of law, and that the suit is not a collusive one to confer on a court of the United States jurisdiction of a case of which it would not otherwise have cognizance. It must also set forth with particularity the efforts of the plaintiff to secure such action as he desires on the part of the managing directors or trustees, and, if necessary, of the shareholders, and the causes of his failure to obtain such action or the reasons for not making such effort."

The rule is well settled that a stockholder may enjoin the doing of an *ultra vires* or illegal act; or enjoin a threatened act of a board of directors who are acting in their own interest and not that of the corporation; or where the board fraudulently refuses to prosecute a claim belonging to the corporation. All such suits are brought for the benefit of the corporation.

14 *C. J.* 924;
Thompson on Corporations, Sec. 4563 *et seq.*

For the purpose of jurisdiction of the United States Courts it is settled that the amount in controversy is the value of the right of the corporation, and not the right of the plaintiff stockholder. The thing in controversy is the right of the corporation. *Larabee* v. *Dolley,* 175 Fed. 365 (reversed on other grounds); *Hutchinson Box Board Co.* v. *Van Horn,* 299 Fed. 424 (8 C. C. A.) and cases therein cited.

It appears in this case that the plaintiff owns but a single share of stock of the par value of $100.00; notwithstanding the invitation to other stockholders to join in the suit, no other has done so; it does not appear that the things complained of have impaired the value of the plaintiff's stock.

> "If the injury is slight and affects all stockholders alike and no other stockholder complains, it will not ordinarily afford ground of equitable relief."

Thompson on Corporations, Sec. 4567.

In *General Investment Co.* v. *Lake Shore Ry Co.* 269 Fed. 235 (6th C. C. A.) the court said:

> "Further, we notice that plaintiff owns only one-thousandth of 1 per cent of the capital stock, that no other shareholder has accepted its invitation to join in preventing the imminent irreparable injury, and that this interest plaintiff bought after the consolidation contract was made. He seems to be a volunteer rather than a conscript. We have, then, a case where a private suitor, with a minimum of ponderable interest, and with no disposition to beware of entrance to a quarrel, is seeking relief upon the sole ground that the public policy of the State is being violated, and where the State authorities have long acquiesced and do acquiesce in any violation there may be. Under such circumstances the court of equity will be strict in requiring the plaintiff to point out with precision and certainty in what respects the law is about to be violated, and to show, clearly and positively, substantial and irreparable injury to its private rights. A measure of imperfection in pleading that might well be overlooked in the ordinary controversy should not be disregarded in such a case as this."

It is the purpose of Equity Rule 27 to protect the United States Courts from imposition. Under the circumstances I do not feel that the plaintiff has brought himself within the rule and authorities cited, and the bill will be dismissed.

TRAINING FOR BETTER PUBLIC CONTACT—II ANALYSIS OF PUBLIC-CONTACT WORK

INTRODUCTION

The results of the survey outlined in the preceding report on public-contact training† indicate that considerable work is being done in this field, but as yet little has been done to definitely establish uniform methods in the attack on the problem. The purpose of this report is to outline a method of analysis of public-contact work which will bring to light the nature and range of contacts, and to arrange this information in suitable form to be used as a basis for the preparation of a training program.

Due to the nature of the electric light and power business, there are a multiplicity and variety of contacts with the public. There are very few departments in an electric utility which do not have at least some contact with the public. In setting up any comprehensive public-contact training program, it is necessary, first, to consider the nature of these contacts and of the problems created by them, and, second, to decide which of these problems that may be grouped for study are to be found in the work of each employe, each division, or department of the organization.

This report deals only with the analysis of the work, and in the next report consideration will be given to suitable training methods. The arrangement of material is suggestive of the items which must be taken into consideration, and in applying this method of analysis to any particular company, each subdivision must be expanded so that it will cover all the details.

PERSONAL REQUIREMENTS

Traits Necessary for Particular Items of Work

Special emphasis has been placed upon the necessity for considering the traits of the individual before he is assigned to a particular line of work. It is especially important that these factors be considered in any job in which a large portion of the time is spent in contact with the customers. While this report is concerned primarily with an analysis of the work with reference to training requirements, it must be assumed that reasonable care has been taken in the first place to select from the applicants for any given type of work the persons who are best fitted for it.

The holders of all contact jobs must, first of all, be courteous and reasonable. They must be willing to listen to, consider the statements made by, and to appreciate the needs and wishes of, the customers with whom they deal. While all public-contact employes should possess these traits, each particular job or group of jobs requires the possession of certain other characteristics. Since every employe does not have these to the fullest extent, an effective training program must be so designed as to bring to light and correct any weaknesses.

Physical Characteristics and Appearance Necessary for the Work

A customer quickly reacts favorably or unfavorably to an employe, depending upon his or her apparent fitness to perform the work at hand. To be specific, in the selection of delinquent-bill collectors, a wise department head would select neither undersized men nor men so oversized as to appear to be bullies. In selecting or retaining men who repair customers' appliances, a wise company would not keep men on that particular job who were so obviously crippled as to interfere with their work. In choosing men or women to answer customers' telephone calls, somewhat deaf employes would obviously be misplaced. Just as physical characteristics play a part, so do dress and care of the person. The chief factor which any training program would include on this point would be emphasis on the appropriateness of the clothing worn by the employe concerned.

NATURE OF RESPONSIBILITY

Non-Supervisory

In setting up a training program, consideration must be given to the fact that the nature of the responsibility of members of the non-supervisory force differs from that in the supervisory force. The fact that employes in non-supervisory jobs have largely to do as instructed by superiors has frequently resulted in a lack of study of the requirements of their work. Supervisors have been given blanket responsibility and frequently allowed to devise whatever methods they choose for training and for checking the results of the work of subordinates.

While contact employes are not always under the eye of the supervisor, nevertheless they are acting under his instruction. Each of them is delegated certain responsibilities which are small or large in proportion to the amount and importance of the work, which he does without immediate supervision. Especially in customer-contact positions, the jobs of non-supervisory employes must be carefully analyzed to make certain that there is proper selection and training.

Supervisory

Supervisory jobs carry much greater responsibility. The supervisor is charged with the proper training of his subordinates, and with seeing that his instructions are carried out. The customers generally look to him, more as a representative of the company and management, and expect a broader consideration of the question or problem under discussion. Both the customers and the subordinates look to the supervisor as the spokesman for his par-

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† Training for Better Public Contact—Its Necessity and Importance (Publication No. 278-52).

ticular division. He is considered by his subordinates as setting the standard of manner and attitude in his dealings with customers.

Because of the facts just mentioned, supervisors must be selected for many other reasons than simply that they are good workmen, and their jobs must be analyzed to make certain that they are familiar with the outstanding responsibilities and know how to carry them out properly.

LOCATION OF CONTACT OCCURRENCES

On Customers' Premises

A large number of daily contacts take place in the homes or business places of customers. Employes must understand that, when working in such locations, they are virtually guests. They are in the position of outsiders who, while rendering a service, are nevertheless doing so on someone else's property, and, for this reason, while there, they should especially respect the wishes of the customers as to their actions.

On Company Premises

Another class of contacts occurs when the customer comes to the company's place of business. Here the employe is the host. The customer has come to him for advice or help, or to make a purchase. The employe must remember that he is the host, and that this position requires the same courtesy to a customer as to any other guest.

NATURE OF CONTACT

Contacts with customers fall into three classes: Personal, telephone, and by letter. In studying the nature of each of these types of work, certain factors must be stressed. An employe, for example, should be expected to be courteous in any of the three situations; he should be just as considerate of the customer's viewpoint; and in every case he should be equally careful to correctly and completely explain the company's position.

Personal

Personal contacts are generally the most numerous. In these contacts the employe meets the customer face to face. Here, naturally, personal appearance must receive attention. In addition to that, the employe must be able to readily understand the customer in order to transact business with him.

Telephone

In telephone contacts, proper use of the voice is an important asset because it must be both pleasant and easily understood, as there is no opportunity to please a customer by smiles or other devices which may be used in a personal contact. In order to avoid unnecessary transfers, knowledge of the company is necessary. Any customer naturally becomes extremely irritated if transferred several times in attempting to reach the proper individual or department. Proper methods of answering the telephone are essential to good public relations. Since this type of contact is so important, it deserves special training methods and, therefore, requires special attention in the analysis of public contacts.

Correspondence

In correspondence contacts, aside from the mechanical rules, clearness, completeness, and sufficient friendliness must be stressed so as to get away from the cold formality of the old-time business letter. It should be remembered that, since the letter is the medium of contact, the company's representative should be able to so carefully phrase his statements as to secure the same pleasant reaction from the customer as should be accomplished in a personal interview.

CLASSIFICATION OF CONTACTS

The division of contact work which follows is a theoretical set-up and might not fit, as it stands, the needs of any one company. However, it can be used as a guide in making a set-up in any company. The basis of classification has been chiefly the amount or type of personal contact involved in any particular type of work. It has been found that the contact work in an organization can be divided into certain groups on the basis of the similarity of their public-relations problems. In many companies a contact employe may perform more than one of these lines of work. For this reason contacts have been analyzed from the standpoint of the work rather than of the jobs as found in any particular company.

In analyzing any particular job, having assigned it to a group on the basis of its general characteristics, it is necessary to break it up further. Is it supervisory or non-supervisory? Is it performed on the customer's or the company's premises? Is it carried on face to face, over the telephone, or by correspondence? Is it, from its very origin, likely to be a pleasant or an unpleasant contact?

It is evident that certain traits are necessary for the holder of each position. It is only by breaking up the positions through a study of their various parts, duties and responsibilities that a determination of the traits necessary can be made.

Functions With Incidental Personal Contact

Bill Delivery
Meter Reading

Certain work, while involving a large number of customers daily, only incidentally necessitates personal contact, which in itself ordinarily does not involve many company policies or serious problems. In the work of delivering bills and reading meters, it appears that practically the only contact consists in inquiring for the location of a particular mailbox or meter. However, there are a great many factors which must be taken into consideration in analyzing this work, to determine the necessary traits or qualifications.

How can the bill-delivery boy's position be analyzed in order to know what should be emphasized in a training program? His personal appearance is of importance, because he reaches every customer's home or place of business once a month, and, aside from the meter-readers, he may be the only representative of the company that many customers see at regular intervals. He should be neatly dressed and have an alert appearance. He should be able to so route his bills that he will not have to retrace his steps any more than necessary. He should be able to quickly answer or refer the customer to the individual who can answer such common questions as, "Why didn't I receive my bill last month?" "Why is my bill so large?" Why is my bill late?" and "Where can I pay my bill?"

His job is non-supervisory, and, because he is usually a youngster, his instructions must include many cautions on what to do or what not to do in various circumstances. Since his work is largely on customers' premises, he is to respect the normal wishes of customers by not "cutting across" lawns, slamming doors, and otherwise behaving in an ungentlemanly way. Since he is usually recognizable as the bill deliverer of the company, he must realize that his whole manner is being observed by all who happen to see him, and that they are measuring the company frequently according to the way in which he conducts himself.

His contacts are entirely personal. For this reason, in addition to suitable appearance, his manner of speech must be satisfactory. He must be readily understood, and the information which he gives must be in sufficient detail so that it will be unnecessary for the customer to call the company on the same question.

This brief analysis of the bill-deliverer's job gives an idea of the sort of thing that must be done before any method of training can be set up for any job. It can be seen that about the same problems confront the meter-reader as the bill-deliverer. However, before attempting a training program with meter-readers, it would be necessary to make a similar analysis to determine what additional points should be stressed.

In grouping the various types of work in the divisions which follow, the same idea has been kept in mind, that is, that the chief problems and the chief traits necessary to the holders of public-contact jobs are generally similar within any group.

Functions With Major Personal Contact

Information giving
Cash receiving
Stock transferring
Delivering merchandise
Delivering lamps
Policing
Renewing lamps
Application taking
Telephone service order taking
Using the telephone

This list includes the public contacts in which there is a larger personal element. In all of them, however, the contacts are more likely to be pleasant than disagreeable. They are largely routine transactions which involve personal conversations with customers. It should be noted that the last three types of work in the list may be specially classified because they are carried on chiefly over the telephone. For them, of course, the result of the analysis would be quite different from that for the others.

These positions are all predominantly routine, and the outstanding characteristic necessary in any holder of the routine position involving public contact is that the personal side of the business shall not be completely overshadowed by the routine side, or, stating it differently, the holder of any of these positions must be as proficient, and conscientious in his methods of pleasing the customer, as he is in handling the routine of the job. The very fact that the work is routine and highly repetitive is likely to result in the employe becoming mechanical in his attitude as well as in his work. He must not forget that, while any particular transaction is only one of many similar ones to him, to the customer it presents a real personal problem which he expects to be solved to his satisfaction. It can be seen that some of the work is supervisory and some non-supervisory; some is on customers' premises and some on the company premises; some is face to face and some is via the telephone. They are all more or less routine transactions with a major element of personal contact.

Functions With Ultra-Difficult Personal Contact

Delinquent-bill collecting
(including attorney's office)
Bill or complaint adjusting
Establishing credits

Here are the situations which are disagreeable from the start. All of them involve money either for payments past due or for payments about which there is some question. The problems, therefore, are of a peculiar nature. Obviously in this group certain characteristics are generally necessary. These include open-mindedness in getting the customer's explanation, sense of company responsibility, and positiveness. Since practically all of this work is done by individuals acting alone, they must be especially responsible. They must appreciate not only the necessity for getting money for the company, but also the fact that there are many peculiar conditions affecting the customers' financial situation which must be weighed in making any decision.

Technical Service With Personal Element

Inspecting meters
Inspecting wiring, and new or altered installation
Inspecting conduits
Testing equipment
Obtaining right-of-way

With the exception of the last, which requires some special explanation, all these contacts are more or less routine and should be agreeable. They are largely for the purpose of seeing that equipment is kept at the standard required in order to render the best possible service to customers. The holders of any of these positions should, first of all, be good technicians. No amount of courtesy will overcome faulty performance. They are engaged in a type of work which is largely for the benefit of the customer in that it helps in assuring him that there will be the fewest possible interruptions in his service. Holders of these jobs, however, must not be simply technicians who coldly disregard human curiosity, for example, about subjects with which most laymen are not familiar. Since their work, especially in connection with new construction, may delay or hasten the connection of the service to the company's lines, it is to both the customer's and the company's advantage that men in this service do their work quickly and so well that there is no necessity for immediate repetition.

All these items of work are transacted on the customers' premises, where the employes are likely to be questioned about the process and about many other things of a technical nature. Employes holding such positions should be able not only to do good work, but to show the customer how the work fits in with the general company plan of service to the customer.

Obtaining right-of-way is included in the list above because it is "technical service with a personal element." It obviously demands a much more diplomatic type of person, because very frequently objections have to be removed. It is concerned, too, with seeing that the lines are placed in such a position and route that the customers may get the best possible service, but it involves the additional feature of using one person's property for the benefit of another, the securing of permission to use which requires particular ability.

Mechanical Service With Personal Element

1. Constructing Outside Equipment

Men engaged in this work have rather infrequent conversations with customers, but are seen by, and their talk among themselves is overheard by, many customers. For this reason they must be cautious as to what not to do or say, because of the possible reaction on the customers. Frequently the nature of the work attracts onlookers who ask questions. Proper answering of these questions by the foreman often satisfies a bit of curiosity, which produces a very good effect on the questioner, who is probably also a customer.

2. Installing Inside Equipment

Electrical Mechanics
Meter Setters

Men engaged in this work have frequent contact with the customer in the case of additions to existing service facilities. In the case of new customers, who are anxious to obtain service, these men can help materially in building good customer relations. These employes are among the first to deal with the customer, as they are constantly under the observation of the customer they must be extremely careful in their conversation, actions, and appearance.

3. Maintenance and Repair Service

Answering Trouble Calls
Patrolling Lines
Repairing Appliances
Re-fusing and Repairing Services

Men engaged in these activities are almost always dispatched to a particular location because something has gone wrong with the customer's or company's equipment. In such a case, the customer is naturally irritated because of the interruption. This being true, the employe has the opportunity not only to repair the service and thereby remove the cause of the customer's ill-feeling, but also, by his attitude and actions, to appease the feeling caused by the trouble. Here again, men engaged in these lines of work must be good mechanics. Simply saying, "I am sorry" and not making a satisfactory repair will not satisfy a customer. Similarly, making a repair in a manner which seems to indicate that the repairman would rather be doing something else falls far short of accomplishing its purpose.

Even the appearance of the repairman has its influence on customers' feelings. The clothing worn does not have to be disreputable nor the mechanic's appearance generally untidy simply because he works with tools. His clothing should be appropriate to the work at hand. Since he is answering trouble calls, he should know the kinds of tools and equipment necessary to make the repairs so that he can work rapidly after getting on the job. He must expect and be willing to answer carefully and satisfyingly customers' questions as to the reason for the difficulty. If the interruption to the service was due to some act on the customer's part, the repairman or troubleman should courteously indicate how such an act could be avoided in the future, and thus save the customer time, trouble, and expense.

Sales Contacts

Lighting
Power
Signs and sign lighting
Domestic appliances (stores; house-to-house)
Industrial appliances

Here the utility is definitely seeking to add to its revenue by securing new business. Employes holding positions of this sort should be especially grounded in business ethics, in addition to the usual factors of courtesy which are expected of any employe. They should realize their responsibility in trying not only to sell additional load, but the company as well. Since their work is salesmanship, they should have that skill highly developed. This involves the ability to express themselves clearly and to the point. It involves a knowledge of the services obtainable from competitors.

In selecting salesmen consideration should be given to their honesty, dependability, and forcefulness. They should avoid the use of high-pressure methods and should develop the use of proper load-building methods, which will result in an ultimate satisfaction to the customer and the company alike.

Incidental Social Contacts

Every employe in a company has social contacts of one sort or another. Because he is employed by a utility, he is frequently asked questions about various things connected with his organization. He should be able to answer these questions in such a way as to satisfy the questioner; naturally, he should give adequate answers about his own department and be able to direct the questioner to the proper source of information about any other department.

As a representative of a public utility, he must remember that he is a public servant, and that more is expected of him than of an employe of a purely private industry.

Publicity Activities

The employes who compose the advertising material for the company must be sufficiently familiar with company policies and methods to honestly tell the story of an honest company.

Public Speaking

Any utility employe who addresses audiences under the auspices of his company should be well grounded in the principles of correct speaking and in the fundamental policies of the company which he represents. Only those employes who have indicated to the satisfaction of a responsible member of their organization their ability to represent it properly should be given the privilege of doing so, especially as on many occasions questions are asked of the speaker after his address.

Membership in Civic and Community Organizations

When an employe enters any organization more or less as a representative of his company, he should be sufficiently familiar with company policies and problems to know how to represent his organization in the manner in which it wishes itself represented.

METHODS OF ANALYZING PERSONAL SERVICE ELEMENTS OF PUBLIC-CONTACT JOBS

Having recognized that public contacts may be classified in various ways, decision must be made as to the method to be used in analyzing the work, so as to locate the difficulties which the training program should help to overcome or eliminate. The training method in use for other phases of the work probably will have the greatest bearing on the selection of the method to be used for public-contact training.

Any one of three situations may exist. First, the company may maintain a training department that makes the analysis of the work, prepares the training material, and conducts the training program. In this method, the line organization must cooperate by giving the training department such assistance as it requires in the collection of information about the work. The advantage claimed for this method is that all of the training work is carried on by the experienced training staff, and in addition, the program is carried out with more dispatch and effectiveness.

In the second situation, the training department may exercise functional supervision over these matters, while the line organization departments are held responsible for the training activities. In such a case the training department will furnish staff assistance and consultation to the line organization in the work analysis, in preparing the training material, and in the conduct of the training program. The advantage claimed for this method is that it places the responsibility for training on the line supervisors and insures better cooperation on their part in the training program. It is also claimed that this method tends to emphasize the fact that personal service is as much a part of the contact job as are the mechanical phases of the work. It is also contended that this method is more likely to insure continuity of training effort and follow-up on the part of the supervisors, than is the case where they are relieved of the responsibility for training. However, some students of training feel that it is a waste of time and effort to attempt to get the line organization supervisors to carry on the training program.

The third situation is one in which the company has set up no training department. In such a case, if uniform procedure in public-contact training is to be carried on effectively, a staff man or executive high enough in the company organization to command recognition should be made responsible for promoting and prompting the training activities. In this situation every line department must carry on its training activities. Much time and expense will be saved in such a case, if a staff man can be assigned to follow through with the work analysis, preparation of training material, and at least with the introduction of the training program.

Regardless of which of the three situations exists in the company wishing to inaugurate public-contact training, there are two procedures which may be followed in analyzing the work. In the first, a complete survey is made of the contact jobs. The work is broken down and completely analyzed for the contact difficulties. The solution of these difficulties is developed and suitable corrective methods are selected by the training staff consulting, as necessary, with the line organization. With this information as a basis, the company training program may be prepared.

The second method consists of making a general survey of the contact jobs. From this survey the possible difficulties are classified as to general type. An outline is then prepared, and all of the contact employes are called in in small groups to discuss their jobs for the purpose of bringing to light the difficulties and appropriate remedies. The principal advantage claimed for this method is that the contact employes feel that they have helped to analyze their work, and have contributed to the solution of the difficulties and to the establishment of the standard methods adopted. The training and analysis are combined, and time is saved in getting the ideas across to the employes.

Some contend that public-contact training is only a phase of job training and should be included in the job-training program. The analysis should then cover all phases of the job, and the training material should be set up so as to supply all of the information that the employe must have to properly function in the contact position. It is claimed that this method will tend to establish the personal service elements of a contact job as a definite part of the job requirements, in the minds of both the contact employe and his supervisor.

Others who have studied the situation feel that public-contact training should be separated from other phases of training. They feel that only by such separation can sufficient stress be placed on the importance of the personal service elements of public-contact jobs. Another advantage claimed for such separation is that it helps the public-contact training to go ahead with more dispatch than would be possible if it were combined with other phases of job training. They feel that the analysis should be made separately, and the initial training program carried through, and then on follow-up, the public-contact training can be made a part of the complete job-training program.

The suggested possible methods are by no means all that might be applied. A combination of methods which results in a compromise between the two extremes might be used effectively. In any case, however, a definite program should be worked out and followed through.

NECESSARY ELEMENTS OF A TRAINING PROGRAM

In this report an attempt has been made to analyze the public-contact jobs of the average utility. It has been found that they may be divided according to the personal requirements of the holders of the job; according to whether they are non-supervisory or supervisory; according to the location of the contact; according to the nature of the contact itself; and, finally, according to their classification as to the character and importance of the personal contact phases of the work.

It should be noted that the general analysis of jobs, preceding the preparation of training material for the holders of public-contact jobs, is the same as that preceding the preparation of any other training material. The only difference is that the study is made with particular emphasis on the public-relations aspects of the work.

As indicated before, no public relations training program can be effectively carried out for any class of work which has not first been analyzed as to the necessary traits for those who handle it. A blanket training program, broad enough to cover all contact jobs, would be so broad as to be of little use for any particular contact job. Similarly, any training program which would be properly adapted to one type of work would not be fitted for another, except within the general limits indicated in the various groups, and within the group it would apply only to those factors which are common to all lines of work within the group.

No attempt has been made in this report to analyze in any detail the work of any particular job, except that of the bill-deliverer. Even in the case of the bill-deliverer's work, the brief analysis in this report, which is not complete, would not be sufficient for any one company. Each company must study its own situation, and make sure that every detail of the contact phases of the work has been considered.

The next report will deal with the preparation of training material and the building of a training program based on the facts and requirements brought to light by an analysis of the public-contact elements of the work.

TRAINING FOR BETTER PUBLIC CONTACT—III BUILDING AND CONDUCTING THE TRAINING PROGRAM

INTRODUCTION

In the preceding report of this series (Training for Better Public Contact—Analysis of Public-Contact Work, Publication No. 289-44) are listed, under the heading "Methods of Analyzing Personal-Service Elements of Public-Contact Jobs," a variety of methods which may be used both for analyzing jobs and for setting up training material for use. The latter part of the report was intended as an introduction to the discussion of the preparation of training materials.

Methods of Conducting Training Program

There are many possible methods of carrying on public-contact training. In this discussion only three methods will be presented for the reason that this number will suffice to illustrate the principles and the problems to be encountered. Unless otherwise stated, the term "training" will refer to public-contact training.

First Method

Under the first method the training program is planned and conducted entirely by the training department, or, in a smaller organization, by the staff employe who is responsible for training activities.

Second Method

The second method is one in which the training program is carried on by the supervisors and executives of the various departments in which training is carried on, while the training department or staff training man cooperates with the line organization and functionally directs the training activities.

Third Method

In the third method the training program is planned by the training department or staff training man with the assistance of the department supervisors and executives, but is conducted in the initial training period by the training staff man, with subsequent follow-up and retraining handled by the department with the assistance and advice of the staff training man or men.

The advantages and disadvantages of these methods will be discussed on the basis of the experience and observation of those who have used one or more of the methods.

Before the analysis of the jobs is begun, it is necessary to decide which method of presentation is to be employed, as both the method of making the analysis and of preparing the training material will be influenced by the method of presentation.

The survey (Training for Better Public Contact—Its Necessity and Importance, Publication No. 278-52) indicated that the methods of presentation may include the use of lectures, printed text material, classroom recitations, group conferences or discussion meetings, printed rules and regulations, bulletins and circulars. These may be grouped into two general methods: "Conference" and "Instruction." The determination of which method is to be used may depend upon the experience of the employes involved. Employes of many years' experience do not readily accept or welcome instructions upon points on which they feel that they themselves are authorities.

On the other hand, they are generally willing and anxious to participate in conferences for the discussion and solution of problems when they feel that because of their experience they can help in the shaping of improved plans. When a new employe is hired, however, little can be gained by using the conference method with him, as he is unacquainted with the problems which are to confront him in his new position. He needs and expects instruction in some of its various forms. Similarly, when consideration is being given to putting into effect a new routine or procedure, the experienced employes may contribute valuable suggestions if they are called into conference. When the procedure is agreed upon, however, it must be described in clear, sufficiently detailed instructions.

Analysis of Public-Contact Jobs and Preparation of Training Material

Analysis of the public-contact phases of the work must be made first. As already indicated, one method is to make a complete survey of all jobs involving public contact, to develop a solution to public-contact difficulties, and to select suitable corrective methods, with this work being done by the training staff in consultation with the line organization. Another suggested method is the making of a general survey of contact jobs. with a classification of the difficulties as to general types only, followed by the preparation of a discussion outline. This outline then can form the basis for discussion in group meetings with the line employes for the discovery of the detailed difficulties and the development of appropriate remedies.

In either case the discovery of difficulties and the development of remedies is the underlying purpose of the analysis. Where the first method is used, the training staff retains virtual control of the analysis and attempts to develop, following consultation with the line department, the methods which should be used to solve the difficulties. The advantage of this method is claimed to be the greater speed with which the work can be done.

One of the outstanding advantages claimed for the other method, where the training staff merely develops a discussion outline based on a preliminary survey and then uses this outline as the basis of meetings in which all employes take part, is that

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these meetings themselves virtually become the first step in the training process. The act of analyzing the jobs, of locating the difficulties, of determining the appropriate solutions to them, and of discussing the best methods of putting the solutions into effect, is felt by many to be the foundation of the training program and an important integral part of the actual training.

Either method may be used when either the training staff is charged with the responsibility for the training program, or when the line department is charged with this responsibility.

The preparation of the training material may depend upon whether the particular difficulties to be solved are general for all public-contact positions, or whether they are peculiar to a few. As already mentioned, the basic factor of courtesy should enter into all personal contacts, whether face-to-face, by telephone, or by correspondence. However, the determination as to how a meter-reader shall answer particular questions relating to the meter when they are asked by a housewife is of immediate interest only to the meter-reading group.

General manuals may be prepared covering the common features for each of the three types of public contact. These may be, roughly, of the nature of materials suitable for handing to all new employes who are to be placed in public-contact positions. This training material could include general information regarding the company's business and its policies in relation to public-contact problems. The preparation of training material applied to specific positions, however, must include the various difficulties peculiar to these positions, and the approved solutions for them.

As already stated there is a very definite use for discussion groups for certain types of training. Regardless of who is responsible for the collection and preparation of training material, one method which has been found useful is the division of the employes within a given department into small discussion groups for the purpose of making the analysis. The leader of each group, whether he is a training staff man or a departmental staff man or supervisor, follows a general outline covering the various public-contact phases of the work of the particular division under discussion. An attempt is made to list all of the difficulties with which the workers are confronted. Frequently, of course, merely bringing these difficulties to light indicates methods by which they may be eliminated. Other difficulties, however, such as the answering of questions or complaints based on rates or service, must be considered and suitable answers agreed upon. For example, a question which all receiving tellers hear every day is, "Why is my bill so high?" A satisfactory answer should be prepared and directions given as to what action should be taken if the answer does not satisfy the customer.

It must be borne in mind in the preparation of any training material that it is directed to two general groups: One is the present employes, and the other is the new employes as they enter the company, or as they enter upon a new type of work requiring contact training. Training material then must be set up in such a way as to be readily usable in training new employes.

General Contact-Training Objectives

The purpose of general contact training is to convey to each contact employe and to his supervisor the idea that only the contact employe can carry out the company's responsibility to the customer and the public in personalizing the company's service to the public. To say to the contact employe, however, "You must accept this responsibility," without going into the details of what is included in the personal elements of his job, will not insure uniformity throughout the organization in establishing a high standard of service along this line.

All public-contact training has as its essential object the development of methods and technique of permanently satisfying the needs and wishes of the customers. The experience of a number of companies indicates that the employe's responsibility in this matter can be broken up into the following items for consideration in the training program:

Appearance
Politeness
Speech
Information-Giving
Interest in the Customer.

All of these factors are involved in every face-to-face contact. All except appearance are involved in telephone contact, and all except appearance and vocal speech are involved in correspondence with the customers.

Since this is true, general public-contact instruction material can be prepared on all these factors and made available for distribution to every new employe hired for a public-contact position. In the subject of "Appearance," the care of the person and proper grooming, in addition to maintenance of business-like working conditions, can be indicated. Under the general subject of "Politeness," specific words and acts, which are or are not polite, can be listed and the indication drawn as to which should be used. Under "Speech," the use of proper tone, enunciation, pronunciation and choice of words can be developed. Under "Information-Giving" the importance of completeness, clearness and accuracy in making statements can be shown. Under "Interest in the Customer," the general devices which show immediately the employe's desire to satisfy the wishes and interests of the customer can be pointed out.

Application of Selected Method to a Specific Job

In the discussion of the application of training methods to a specific job, it will be assumed that the training program is planned initially to train an existing personnel. The material developed will be used to train new employes as they enter, but its initial purpose is to get the existing personnel to adopt uniform satisfactory methods in carrying on the personal service elements of the public-contact work.

In order that the differences in the three methods may be clearly set forth, a specific job has been selected. The work of the inside repairman or service man who answers the customer's request for help in case of trouble with wiring or appliances on customer's premises, is a job common to all companies, regardless of size. This job will be analyzed as to the public-contact problems. The methods of setting up training material will be set forth, and the method of training will be outlined under each of the three methods.

Since the initial purpose of the training is to establish improved standards of personal service to the customer, the program will be conducted by the small-group conference method. In addition, the procedure involved in presenting this material by the instructional method will be outlined. It will be assumed that previous agreement had already been reached between the department concerned and the training department providing for training work to be done in the department.

TRAINING DEPARTMENT OR STAFF CONDUCTS TRAINING

Preparation of Preliminary Outline for Analysis

When decision has been made to carry on public-contact training for the specific job in question, and the department head has requested the training department or the staff training man to prepare and conduct the training program, the training man should set about bringing to light the contact problems peculiar to the job in question. As the first step in this procedure, he should prepare an outline to be used in the work analysis of the job. In setting up this outline, the general analysis of contact jobs, as presented in the preceding report, may be used as a guide, and the outline might take on the following form:

Nature of Responsibility: Is it supervisory or non-supervisory?
Nature of Contact: Is the contact face-to-face, by telephone, or by correspondence?
Location of Contact: Is the contact on customer's or company's premises?
Classification of Contacts: Is it likely to be a pleasant or unpleasant contact?
    Are the personal contacts an incidental or a major part of the work?
    Does the nature of the work require technical or mechanical skill?
Personal Requirements: What special traits and physical characteristics are necessary for holders of this contact position?
    Is personal appearance of importance to the holder of this job?

Consultation With the Department Head

When the training man has prepared his outline, and if he is not familiar with all details of the job, and even if he is familiar, it will be good policy to solicit the aid of the department head so as to insure his interest at this point. He will, therefore, in consultation with the department head or with the sub-executive or supervisors designated by the department head, go over the outline carefully step by step. In consulting with the department head or departmental supervisors, the training staff man, using the preliminary outline as a guide, will find, in the case of the inside repairman or service man:

That, in general, the work is non-supervisory, although the man may have one or more employes assigned to help him on some jobs.

That, in general, the contacts with the public are, face-to-face, although, occasionally and incidentally, they may be by telephone and almost never by correspondence.

That the contacts are usually on the customer's premises or in the public thoroughfares, and almost never on company property.

That, in general, although the customer is likely to be irritated by the interruption to his or her service, the customer is glad to see the repairman who comes to remedy a difficulty.

That, because of the nature of the work, the personal service elements of the job are of primary importance.

That the nature of the work requires expert, mechanical skill, without which the employe cannot be effective as a service man.

That, because of the mechanical nature of the work, the employe must have the full use of his hands and should not be handicapped by other deformities.

That the employes must be tactful and alert so as to be able to serve and not offend the customer.

And, finally, that since the employe is representing the company in the customer's home or place of business, his general appearance should be, in keeping with his work, neat and businesslike.

Preparation of Discussion Outlines

Classifying Nature of Contact Job

From the information collected by consulting with the line organization, the staff training man can readily determine which of the fundamentals should be stressed in the training material for the job of the service man.

Appearance plays an important part, because the employe is the representative of the company, and most of his contacts with the customers are in their homes or places of business.

Politeness also plays an important part in making a good impression on the customers for the reason that the contacts in this particular contact job are principally face-to-face.

Speech is also important, and should be dwelt upon in the training program.

Many questions regarding appliances and service facilities in general will be asked, and, therefore, this contact employe must be prepared to answer all reasonable questions.

Since the contacts are face-to-face and involve personal discourse with the customers on a variety of subjects, "Interest in the Customer" should also be stressed.

Thus, it appears that in the detailed study of the service man's job, in the small group discussion meetings, it will be necessary to dwell on each of the five fundamentals which have a bearing on the creation and maintenance of satisfactory public relations.

Setting Up the Discussion Outlines and Conducting the Discussion Meetings

Here, again, although the training man may be intimately acquainted with many or all of the details of the service man's job, it will be well for him to work closely with the department supervisors in the preparation of the discussion outlines.

The aim of the training program should be to develop in the service man the desire and ability to make a satisfactory final impression on the customer in each contact that he makes. Although each of the five major factors which have been listed is found to have a bearing on this man's work, all of them are a part of the basic factor which underlies all of the work—the good final impression on the customer.

Since this is true, a consideration of this over-all aim forms the logical introduction to any series of training meetings. In setting up the outline for a consideration of the final impression desired and the means of producing it, the relative part played by each of the five factors can be developed.

1. Final Impression

Having determined from the analysis of the job the factors which should be considered in the training program, the training staff man will prepare an outline to be used as a guide in his meeting with the supervisors in the department. In this meeting with the supervisors, he will first outline the purposes of the training program which are: To discover the difficulties involved in the job of the service man, to discover solutions or remedies for these difficulties, to obtain approval or acceptance of these solutions, to compile in logical order in appropriate groupings the approved procedures, and, finally, to follow up and re-train in line with the adopted procedures.

Then the staff man will point out to the supervisors that, since the service man's job is a face-to-face contact job, all of the factors should enter into the training program. He will start with appearance and will ask, "Has appearance any effect on establishing a good impression on the customer? If so, what factors enter?" The discussion following will develop the fact that appearance is a decided factor, and some of the points that will probably be raised are that the clothing should be appropriate and as clean as is possible, and many other similar items out of which can readily be drawn the conclusion that evidence of attention to clothing and person is a decided factor in the final impression made on the customer.

The training man will then proceed to the subject of politeness, and to his general question as to whether politeness is important, he will get an assenting answer. Then, to his question as to what constitutes politeness in the job of the service man, he should be able to bring out information that will indicate that politeness is shown by speech, facial expression and personal acts, and, finally, reach the conclusion that politeness is expressed by acts and language, and plays an important part in establishing a good final impression.

The training man will then attempt to find a way in which speech influences the customers' feelings. In discussing this, the choice of words used, the tone of voice and the distinctness of the speech will be found to have a bearing. The training man will then try to find out how information-giving affects the impression which the customer receives. It will probably be brought out that some of the essentials are understanding what the customer wishes to know and then answering the customer's question understandably, and finally it will be developed that in order to meet the other four requirements the service man must be interested in the customer and his problems. Then the training man should attempt to develop at least a general idea of the items which will have a bearing on the final impression and which are not covered by the five major factors. The purpose of this first conference with the supervisors is to sell the supervisors on the methods to be used with the contact employes when they are called in for group conference, and to make them familiar with the material before it is presented to the service men. This will insure their cooperation in the problem as to procedures, and it will also give the training man information and material which he can use in preparing a similar, but more detailed, outline for his meetings with the service men on the subject of final impression.

The training staff man will have added to his own information the ideas of the supervisors as to the means which the service men should employ in creating the best final impression on the customer. He will also have obtained their suggestions as to particular subjects which they feel should be discussed in the meetings of the training man and the service men. When this material has been classified and arranged in logical order, the training staff man will be prepared to hold his first meeting with the service men.

In the first meeting with these men, essentially the same situation and problems will be met as in the first meeting with the supervisors. The purposes will be to acquaint the service men with the proposed procedure and to outline to them the desire to obtain a complete list of the difficulties confronting them, the solutions to these difficulties, and an essential agreement upon the most acceptable solutions. In this meeting, also, the training man will prepare the transition to the following meeting by developing the idea that appearance is one of the most important factors in producing good final impressions.

Throughout the entire series of meetings, essentially the same plan, that is, discussing the factor with the supervisors first and with the service men second, is carried out. Since this is true, it will not be necessary to outline separately the meetings with the supervisors and with the service men on each topic. In each case the staff man uses the supervisors' meeting as the place to crystallize his plans, to secure illustrations and additional suggested questions, and to study the fundamentals of the tentative discussion outline which he has prepared. Also, the supervisors are familiarized in advance with the subjects which the service men are to discuss and can anticipate questions from their men relating to these subjects. The staff man uses the same basic outline, with the service men, which he used with the supervisors, modified by such changes and enlarged by such additions as his meetings with the supervisors indicate are necessary. These additions are chiefly in the form of questions suggested by the discussion with the supervisors.

2. Appearance

As previously indicated, the first major factor to be discussed following final impression is appearance. In this meeting, the staff man aims to learn what is considered to be appropriate or inappropriate in appearance from the viewpoint of the service man on his job. He may start the discussion meeting by asking, "What things about the service man's appearance create the best or worst impression on the customers?" "Which does the customer observe more closely, appearance of the person or of the clothing?" "Just exactly what kind of clothing is appropriate for the service man to wear on the job?" "What are the minimum requirements as to attention to personal appearance by the service man?" "What defects in personal appearance should the service man be most careful to avoid?" "What personal habits which the customers can observe are most likely to annoy them?"

From the answers to these and many other associated questions the staff man should obtain a comprehensive description of what the appearance of the service man should be. This will probably range from a cleanly-shaven face to the wearing of a necktie. In discussing this subject, just as in all the others, the staff man must be careful not to include anything in the list simply because it "sounds well," but which, experience has shown, will not be adhered to. It should be borne in mind that the company cannot run entirely counter to the community or current fads or fashions with regard to clothing. He must include only those qualifications and characteristics to which there is essential agreement.

In discussing habits, while still thinking of the service man's appearance, the question of politeness will undoubtedly arise. This can form a natural transition to the following subject, which will be politeness.

3. Politeness

In the next group of meetings the aim of the staff man is to learn exactly what polite acts and phrases the service men and their supervisors feel are desirable. Perhaps the first and most obvious question for discussion is, "How do you greet the customer, and what do you do and say on leaving the customer?" Other questions which should prompt discussion and lead to definite conclusions include: "What are the most obvious ways a service man can show that he is polite?" "What are some of the polite expressions commonly used?" "How will the customer judge whether or not the service man is polite?" "Must the service man always smile in order to be polite?"

So far, all of the questions have dealt with formal politeness. Distinction must be made between formal politeness and genuine courtesy, which involves a mental attitude in addition to the simply formal polite act or expression. Questions which emphasize this difference might be, "What is the difference between tact and politeness?" and "Can a person be polite without being courteous?" Discussion of these and related questions will bring out definitely the need for much more than formal politeness. This added factor, called for convenience "Interest in the Customer," will be discussed later. In the discussion of politeness, the use of certain words and phrases is dealt with at length. This makes an easy transition to the following subject, which is speech.

4. Speech

In dealing with the effect of speech in creating a lasting favorable impression on the part of the customer, many concrete situations can be developed. An obvious subject, too, with which to begin the discussion, is tone of voice, as the tone used by the service man in answer to the housewife's question of "Who is there?" is likely to determine her reaction to the entire situation which follows. The question, "What is there about the tone of voice of other people that you like?" easily opens up a general discussion of voice. The question, "Why do telephone companies train their operators to develop 'The Voice with a Smile'?" ties in closely with this situation. The question, "What tone of voice should be used in speaking to an angry customer?" will force further concrete discussion. This can naturally lead to the question of distinctness in speech. A hypothetical illustration showing the misinterpretation that can come from indistinct sentences would fit in well here. The question, "How can a service man be sure that he keeps his voice distinct?" should develop the idea that he should avoid mumbling, should speak slowly, should avoid slurring his words and should watch the customer's expression to see whether she understands what he is talking about.

Another vital point about speech in which every service man is interested is the choice of words, including the good or bad effect of the use of slang and of technical words and phrases. The question may be asked, "Should slang ever be used?" followed by other questions such as, "Should slang be used to give the customer the impression of greater friendliness?" The question of the use of technical words could be approached by asking a service man to give, in his own words, the answer to various questions which the customers ask him. In the answers, the service men will undoubtedly use expressions with which the customers are not familiar or do not understand. Frequently it will be discovered that certain words may be called "company slang" in that they have a definite meaning within the department or the company; but mean nothing to the outsider. It will be easy for the service man to understand how the answer to the question, "What is the matter with my iron?" "Oh, your element is out of order," would probably not mean much to most housewives. Similarly, saying, "Your contacts are burned," would not be helpful in satisfying the average customer's curiosity. A request for a list of frequently used terms with which customers may not be familiar, paralleled by a simple explanation which can be understood, should be made at this time. This later discussion will lead naturally into a consideration of the general method of giving information to customers. This can follow as the subject of the next meeting.

5. Information-Giving

"Which is most important, to use correct grammar or to give correct information?" "What is the worst case of trouble you have ever known caused by a service man giving poor information?" "What is poor information?" "How do you know whether or not the customer understands your answer?" "What may be the result if the information given is not complete, or not accurate, or not clear?"

The service men should be asked to give a list of the questions they are asked most frequently and the answers which they give to the customers on these questions. A discussion of these answers and of the answers to the questions preceding, and others relating to them, should bring out clearly the extent to which the information which is given and the way in which it is given influences the customer's final impression. Throughout the meetings concerning information-giving, and, in fact, in most of those preceding, allusions to the service man's attitude toward the customer will be mentioned as important. When speaking of information, the fact that the interested service man will ask additional questions to be sure he knows exactly what the customer wishes, and the fact that the interested service man will be especially careful to give information which will satisfy the customer, will lead naturally to a discussion of this factor called "Interest in the Customer."

6. Interest in the Customer

The discussion of the ways in which interest may be shown and what is important in creating the final impression on the customer should naturally round out the general discussion of public-contact problems. "Is doing a good repair job the only evidence of interest in the customer which the service man can show?" "Does the customer expect any more than this?" "State certain ways in which the service man can show his interest in the customer, that is, his desire to satisfy the customer's needs and wishes." Presentation of a specific situation and an analysis of what should be done, as in the case of an electric fan which has ceased to work on a hot day, should develop specific ideas on this point. Questions may be asked which will indicate the importance of the initial approach to the customer, the necessity for listening to the customer's story, the desire to remain open-minded in the face of criticism, and the need for showing friendliness, without being familiar, throughout the situation. The discussion of the necessity for maintaining a friendly attitude should be carried to the extent of stressing the point that even in situations where the employe must be firm, the appearance of friendliness can be maintained.

The outcome of the consideration of interest in the customer should have shown clearly the paramount importance of this factor in creating good final impressions.

7. General Comment

The placing of the material discussed under the five factors is arbitrary. It will be found, of course, that many subjects will be discussed from almost as many angles as there are factors. This is desirable, as it serves to place additional emphasis on such points. An example is the case of choice of words to use. In this discussion, this was placed under speech, but it would obviously also be discussed from the related angle of politeness, information-giving, and interest in the customer.

The advantage claimed for this plan is that it cuts down the length of time required to inaugurate and conduct the training program by having a training expert in charge of the program in all of its details from beginning to end. A disadvantage claimed is that it takes away one of the outstanding responsibilities of the line organization, namely, the normal responsibility for training.

Standards of Personal Service

As already indicated, the underlying reason for the training program is the acceptance and establishment of improved Standards of Personal Service. As outlined, the aim of the staff man is: First, to learn the difficulties; second, the solutions to them, and, third, to secure the acceptance of those solutions which should be used as a guide. The aim of the meetings is two-fold: To arouse immediate appreciation of the problem of how to satisfy the customer best, and, to codify the accepted standards. Throughout the entire series of meetings, both with the supervisors and with the service men, careful notes must be taken as to the material which will later be set up as the Standards of Personal Service for the service men. This is the material which, after approval by the department head and after its dissemination throughout the department, will not only be the guide and reference book for existing personnel, but will also be the basis upon which new service men shall be trained.

The next step is to set up in easy, usable form the training material which has been developed.

The form of the Standards of Personal Service naturally will vary. Direct statements, a narrative, or questions and answers may be used. The present trend of thought seems to favor the latter method. Although some training material is written in the second and third person, since the desire is to emphasize the service man's own contribution to the development of the personal service manual, the use of the first person, as far as possible, is preferable.

To illustrate, in the material which may be developed in the sections devoted to final impression and appearance, such items as the following will be included:

(1) **STANDARDS OF PERSONAL SERVICE**
"Service" Department
Leaving a Good Final Impression with Customers

(Selected by service men and supervisors from ideas and devices proposed and discussed by them in their group meetings.)

1. What are the five elements that cause the customer to have a friendly feeling toward the company?
   (1) "Appearance"; evidence of attention to my clothing and person.
   (2) "Politeness"; good manners expressed by my acts or language.
   (3) "Speech"; the impression given by my words and tone of voice.
   (4) "Information-giving"; explanations that will completely satisfy my customer.
   (5) "Interest in Customer"; a real cordial and sincere interest in my customer's wants.
2. How may I produce a poor Final Impression on the customer without realizing it?
   (1) By talking too much.
   (2) By ignoring customer's remarks as of little importance.
   (3) By losing interest in my customer.
   (4) By failure to give a greeting or leave-taking.
3. What is a good aim to set for myself as a representative of the Service Department?
   I will cause the customers to feel more friendly toward the company through my work, actions and speech.

(2) **STANDARDS OF PERSONAL SERVICE**
"Service" Department
Presenting a Pleasing Appearance

(Selected by service men and supervisors from ideas and devices proposed and discussed by them in their group meetings.)

1. What points in clothing must I observe to make a good appearance?
   (1) The coat, trousers and shirt should be conservative in color and kept in as neat and clean a condition as is possible.
   (2) The shoes should be in good repair and cleaned or polished.
   (3) A conservatively colored tie, knotted neatly, should be worn at all times.
   (4) The hat or cap should be clean and appropriate for the work.
2. What are the minimum requirements of one's person for making a good appearance?
   I should at least:
      (1) Keep hair cut and combed;
      (2) Keep hands and face as clean as possible;
      (3) Shave daily, if necessary;
      (4) Keep teeth and breath clean;
      (5) Stand up straight and look alive.
3. What things should I avoid doing to make a good appearance?
   (1) Chewing anything while with a customer.
   (2) Using tobacco on customer's premises.
   (3) Wearing jewelry prominently or badges which have no relation to the work.
   (4) Indulging in any annoying habits, such as humming or whistling.

The above examples of typical Standards of Personal Service might not apply in every detail to every organization. They should serve as an illustration of the finished material which is used for reference by present service men and for training new service men.

Follow-Up

General experience indicates that much of the advantage gained by an initial series of meetings for public-contact training disappears in a short time unless some uniform follow-up procedure is maintained. The purposes of the follow-up meetings are to maintain the interest of the service men and their supervisors in customer-relations problems, and, further, to arrive at solutions to new problems as they arise. Such problems may be the result of changes in policy, changes in rates, changes in procedure, or from a variety of other factors.

In the follow-up meetings, which, as in the case of the initial meetings, are held both with supervisors and with service men, current reports of service, complaints, letters of commendation, and other items of information should be drawn upon extensively to keep the discussion up to the minute. If the report of a professional service sampler, either on the payroll of the company or retained by the company, indicates that the actual performance of the service man was not in accordance with the agreed Standards of Personal Service, this should be discussed in the meeting, to determine whether the standards need revision or whether the service man was simply not doing what had been agreed to. As new situations arise, changes in and additions to the Standards of Personal Service should be made. Representatives of departments with which the "Service" Department has most frequent dealings should be asked to attend follow-up meetings in order to minimize such difficulties as may be due to misunderstandings as to procedure or departmental policies.

DEPARTMENTAL SUPERVISORS AND EXECUTIVES CONDUCT TRAINING

Under this plan the training program, from the original analysis of the work through the follow-up meetings, is carried on by the executives and supervisors of the department concerned, with the cooperation of the Training Department or staff training man who functionally directs the training activities. Rather than outlining this entire procedure in the same minute detail as was done in the plan just described where the Training Department conducts the training, that plan will be used as a basis of comparison, and the second plan will be described by outlining the points in which it differs from the first plan.

The same list of general questions, covering nature of responsibility, nature of contact, location of contact, classification of contacts and personal requirements, must be prepared and applied. The preparation would probably be by the training man, but the application of the questions to the service man's job would be made by the department itself.

In classifying the nature of the contact job, the line organization can readily determine, from the information it collects, which of the fundamentals should be stressed. These factors, suggested by the training staff man—appearance, politeness, speech, information-giving and personal interest—will, of course, be the same as those in the first plan.

In this plan, as in the first, discussion outlines must be set up, beginning with the one on the subject of how to make a satisfactory final impression on the customer, and going on through the list. The staff training man should work closely with the department in the preparation of these outlines. He should consider them particularly from the standpoint of organization set-up, as related to their usableness as training materials. Since he is interested in the technique of training more than in the subject matter, under this plan he must know first what the general objectives of the departmental training program are, and, with those in mind, aid in framing the material so that it will lead to that result.

In the preparation of this material the training man would, of course, work chiefly with the departmental executive responsible for the training in the "Service" Department. He would also advise him materially in the techniques involved in handling training meetings with the supervisors. He would, further, similarly coach the supervisors, who, under the second plan, would be the ones to hold the training meetings with the service men. All of this would apply both to the original training and follow-up training.

The outstanding advantage claimed for this plan is that it keeps the responsibility for training in the hands of the line organization and emphasizes the fact that training is an important phase of supervisory responsibility. A disadvantage claimed is that it takes much longer than the first plan because of the length of time required to properly train line executives and supervisors to hold effective training discussion meetings. There are some who feel that the supervisors never can be expected to train effectively.

INITIAL TRAINING BY TRAINING MAN AND FOLLOW-UP BY SUPERVISORS

Under this plan exactly the same procedure as outlined under the first plan is followed through the entire initial series of meetings, covering the preparation of the training material, the conduct of the training program, and preparation of the Standards of Personal Service. The training man, knowing that he is to turn over the follow-up training to the line organization, would, however, be discussing training methods and techniques with the department executives and supervisors as he proceeds. After the initial training program is completed and the Standards of Personal Service have been compiled, the training man would then devote his attention to meetings with the supervisors to prepare them for the follow-up training. Before the first and several following meetings, which any supervisor was to hold with his service men, the training man would outline in detail the material to be discussed in the meetings. He would add such supplementary suggestions as were advisable to aid the supervisor in knowing when to do various things during the course of the meetings. He would also coach the supervisor as thoroughly as possible in the various techniques of conference leading.

The training man would sit in at the first few meetings, acting chiefly as an observer, but also to be in readiness to add tactfully a question now and then if necessary to aid the supervisor in getting himself established in this new type of work. After each meeting he would also discuss the results with the supervisor, in order to point out ways in which difficulties which arose could be avoided in future meetings.

As the training programs proceed, the training man will turn over more and more of the work to the supervisor, until finally the supervisor should be preparing the material and conducting the meetings with only occasional consulting service from the training man. As outlined under the discussion of follow-up under the first plan, the training man should continue, however, to furnish the supervisor with such material as may be obtained from current reports of service, complaints, letters of commendation and other items of information.

The first advantage claimed for this plan is that it cuts down the length of time required to inaugurate and conduct the initial training program by having the training expert in charge of the program in all of its details. The second advantage claimed is that it provides for the eventual return of responsibility for training to the line organization. It does this, however, after the line organization executives and supervisors have had an opportunity to become acquainted with the training methods involved and are, therefore, in a better position to conduct the training program effectively.

CONFERENCE MANAGEMENT AND TECHNIQUES

Most of the following material is that which the trainer would give to the supervisor who holds the meetings. It is assumed that the trainer himself would be familiar with these techniques and methods. Some of it applies to all three methods and is, therefore, included under one heading so as to avoid repetition.

Number of Meetings

The first thing to be determined is the number of meetings required for the initial training program. Experience has indicated that from eight to twelve meetings are required, depending on the group involved and the relative amount of emphasis required on particular factors. In the case of the service men ten meetings should be sufficient to cover the initial program.

A single discussion meeting should probably be sufficient to introduce the whole program, and while probably one meeting should be sufficient to develop the fundamental ideas on appearance, it may be necessary to devote two meetings to this and then save sufficient time in the following meetings, so that ample attention can be given to the item of information-giving, which, in the case of the service man, covers such a broad field that more time will probably be necessary in order to develop all of the ideas.

The conference leader must develop at an early stage the ability to determine when the members of the discussion group have come to an agreement and are ready to accept the ideas which have been developed. In order to accomplish this, he must be able to get all members of the group to participate, so that he can judge whether or not they have assimilated the results of the discussion.

Time of Meetings

Since the purpose of these meetings is to improve the service to customers, and since the personal service element is a definite part of the service man's job, this is a phase of job training and is a part of management's responsibility and, therefore, the meetings should be conducted on company time if it is possible to do so. In situations where the service men cannot be called together during the regular working hours, evening meetings would be necessary. All service men should be required to attend the meetings, and attendance should be considered the same as any duty performed after regular working hours.

Length of Meetings

The length of the discussion meeting is another important point. Experience has indicated that people who are not accustomed in their regular work to participate in creative discussion are not able to maintain enthusiastic interest for a period of much more than one hour and certainly not in excess of one and one-half hours. Since the success of this method of training depends upon the enthusiasm of those participating, it has been considered good practice to limit the meetings to one hour, and to arrange the outline sufficiently in detail to keep the discussion active during this period.

Number of Men in the Groups

Since it is essential that every service man in the group participate in the meeting, it is necessary that the number be small enough so that this will be facilitated, both from the standpoint of time involved and the standpoint of close relationship between the leader and the small group, which is not possible in a larger group. Fifteen men is probably the maximum number where general participation is desired, and groups as small as six can operate successfully. However, ten to twelve probably is the best-sized group for discussion meetings.

Physical Situation and Materials

Since the group members are not accustomed to concentrating on discussion of this sort, it is necessary to reduce artificial interference to a minimum and to make the physical situation as conducive as possible to quiet, uninterrupted discussion. The room chosen should be sufficiently isolated so that the meeting will not be interrupted by people coming in and out, or by the telephone ringing, or by the roar of machinery. Sufficient chairs, a table upon which papers can be placed and around which all of the members can sit, scratch paper and pencils, a blackboard on which the leader can make notes and draw diagrams, and such special tools as are necessary should always be on hand before the meeting opens. The room should also be well ventilated and well lighted.

Since the purpose of the meeting is to arrive at accepted Standards of Personal Service, a recording secretary should be appointed. The secretary should keep a careful record of the ideas developed, and especially of those points upon which agreement is reached, and also those points upon which it is felt further discussion should be had at a later date after more time and thought have been given and more information has been developed.

There are some disadvantages in appointing a secretary, in that it may make some members of the group hesitant to enter into the discussion for fear that their statements may be taken verbatim. This can readily be dispelled by a statement that reference to source of ideas will not be made in deciding on the standards to be followed. However, if the leader is proficient in taking abbreviated notes which are sufficient for him to sum up and bring the discussion to a decision, and to compile the Standards of Personal Service, it will not be necessary to appoint a secretary. Some leaders feel that this is preferable.

Conduct of Meeting

The first thing in the first meeting in which the supervisor acts as the conference leader is for him immediately to get the group and himself in a comfortable state of mind. Since the usual working relation is that of supervisor and subordinate, this feeling must be overcome by the attitude which the supervisor assumes from the start. Some such statement as "We are beginning today a series of meetings in which we are going to discuss many of our common problems in order to decide on the best solutions to them, and we cannot be sure that we get the best solutions unless each of us contributes from the ideas gained by experience with these problems. Then when we have collected all of the ideas, we can readily select those which we agree are the best and most workable." He should follow this immediately by a question which will provoke thought and arouse immediate discussion. In the case of the service men, the question, "Is the quality of the repair which you make the only thing which goes to produce a good or bad impression on the customer?" might be asked. The immediate answer will be "No." This will be followed then by the question, "What other things influence the customer?" From this point on the supervisor's function is to follow his outline, which includes many questions previously prepared, and to insert such additional questions as are necessary to stimulate further discussion; or, when the discussion seems to have gone far enough, to lead to a final decision as to what the best practice should be in the various factors that should be considered in the discussion of final impression.

The supervisor must develop, at an early stage, the ability to distinguish between a thought-provoking question and one that will terminate a discussion by a "yes" or "no" answer. The first question used was answered by "no," but the following question immediately opened the field of discussion. By further thought-provoking questions, the supervisor can complete the discussion in line with the outline. He should learn that at the proper time, when agreement seems to be reached, appropriate deciding questions should be asked to which "yes" and "no" answers will be obtained.

Devices

Many devices may be used to stimulate interest by illustrating actual situations or by demonstrating through contact the necessity for establishing standardized ideas and methods. Among those devices may be included a set of a number of suggested methods from which each member of the group is to select the most desirable. This device is especially useful in arriving at a decision as to the best method to be selected from those which have been suggested.

Dialogues illustrating concrete situations in the service man's daily work can be prepared preceding the meeting and handed out to certain men who will simulate respectively the customer and the service man. If one dialogue illustrates the wrong way of meeting the situation and the other the right way, they can form an excellent basis of comparison and for discussion.

In order to crystallize the conclusions during the progress of the meeting, and particularly near its close, in order to indicate the progress which has been made, the leader must summarize from time to time. In addition to this, the leader should give a definite indication of the subject which will be discussed in the following meeting. It has generally been found advisable, at the conclusion of each meeting, to hand out a definite assignment which requires a certain amount of thought and activity preceding the next meeting. This not only assures continuity, but furnishes additional material available for immediate discussion in the subsequent meeting. An example in discussing information-giving would be to ask for a list of the questions which are asked most frequently, and the answers to them which the service man has been in the habit of giving.

Cautions

Certain outstanding cautions should be given to every supervisor who acts as a group leader:

> As outlined under the opening of the first meeting, the supervisor should never refer to the fact that he is dealing with subordinates.
>
> The leader should not talk at any time any more than is absolutely necessary, either to promote discussion or to crystallize conclusions.
>
> He should not make arbitrary statements and should never say, "You are wrong," or "That's not so."
>
> The conference leader must know his subject so that he will be in a position to anticipate questions that may be raised or statements that may be made. Although he knows the material well, he must avoid posing as an instructor, but must ask such questions as will lead the discussion to logical conclusions.
>
> He should not permit members to become personal in their arguments.
>
> He should not allow the members to "pan" the company or other departments in defending their own positions, but must be in a position to explain company and departmental policies which prescribe the methods which may be criticized.
>
> He should not allow a few members to dominate the major portion of the discussion, nor should he allow other members to sit idly by, taking no part in the meeting.
>
> He should not be afraid to allow a certain element of humor to enter now and then in order to liven up the meeting and to avoid the development of a strained situation.

There are available a considerable number of excellent textbooks dealing with conference-leading techniques, and although the training man should avoid forcing this material onto the supervisors, he should compile, in advance, a bibliography which he can supply them as they realize the necessity for such material. In his contacts with the supervisors, he can gradually encourage them to interest themselves in such text material.

Training on General Company Information

The observation of the representatives of many companies indicates the need for training of public-contact employes to give them a wider acquaintance with the activities and problems of other departments than their own. While in a small company the close contact of the employes doing different kinds of work, and the frequent conversations between them results in an interchange of information, in the large companies this situation does not exist to the same extent. For this reason various plans have been suggested to aid employes in increasing their knowledge of other departments, so that if they do not know all of the details in answer to a customer's question involving another department, they may at least know the proper department to which to refer the customer for the information desired.

Because of the close interrelation between various departments, it is necessary that complementary improvements in methods be effected if the maximum benefit is to result from a training program. In order to secure a sympathetic understanding of the methods and problems of the related departments, it is frequently desirable for representatives of such groups to attend meetings of other departments. In this way, as the result of an interchange of opinions, improved interdepartmental procedures can often be outlined, better information can be given to a customer asking a question involving the activity of another department, duplication of effort can be curtailed, and a closer understanding and a more friendly relation created between related departments.

Many companies provide for the holding of combined meetings of the members of two or more departments where the problems and activities of each department are discussed. If this plan is followed, the schedule of meetings should be so arranged that each person comes in contact with all of the departments in the company, or at least with those departments about which it is necessary for him to have considerable information. This plan is especially suited to the smaller companies, where the individual departments are correspondingly small. In very small companies meetings may be arranged where all employes may attend at the same time.

Another means of promoting interdepartmental understanding is the provision for trips of inspection and study by members of one department to other departments. Here the observation of what is done and how it is done is first-hand.

Another method of disseminating information about other departments is the preparation of printed material about them, which can be handed out and to which reference can readily be made when the occasion demands.

TRAINING BY THE INSTRUCTION METHOD

If the instructional method is to be used in the training program, the work of analyzing the service man's job from the standpoint of its personal service elements might be conducted in very much the same manner as outlined under the first plan. After the training man, however, has satisfied himself that the analysis is complete and that all necessary information is at hand, he will prepare the training material for presentation.

In companies where the lecture method of presentation has been used, it has been found that the material can be presented in a series of six well-planned lectures. In at least one case the lectures have been supplemented by personal conferences between the training man and the contact employe. Other methods which might be used are bulletins, pamphlets or other printed text material. This material might be used as text material, and the instruction could take on the form similar to classroom recitations.

The chief advantage claimed for the instruction method of training is that the material is prepared and the training program is handled by the training man who is an expert and experienced teacher, and that considerable time is saved in presenting the material to the employes. Others maintain, however, that the material cannot be made effective by the lecture method because the lectures must necessarily be general, while to be effective the training material must be specific. "Be polite" is not sufficient, but all that goes into politeness must be developed, if the idea is to be conveyed to the contact employes effectively. This same principle applies to the other factors which have a bearing on the training problem. For this reason it is contended by many that, if the instructional method is used, the material must be developed and presented separately for each specific line of work, and not for the company as a whole. The disadvantage which is pointed out by advocates of the conference method is that this method is primarily one in which the contact employe acts as the recipient of information that has been prepared and compiled by an expert, who usually cannot be as intimately acquainted with many phases of the contact employe's job as is the contact employe himself. Another difficulty pointed out in this method is that the only logical follow-up for such training is more lectures or more instruction.

Regardless of the criticisms of the instructional method of training, however, it must be admitted that it is the only method that can be applied in the case of the new employe or in the case of an employe who is transferred from non-contact to public-contact work. It must also be admitted that in public-contact training, as in other phases of training, the instructional method must be resorted to in that portion of the training that deals with the purely technical phases of the problem.

TRAINING FOR IMPROVED TELEPHONE CONTACT

A general analysis of all telephone-contact jobs will disclose the fact that all of the factors which were found to enter into the making of a satisfactory final impression on the customer, except personal appearance, must be considered in the case of the telephone-contact employe. Further analysis will disclose the fact that some of the items entering into the various factors are common to all telephone-contact jobs. The study will also emphasize the fact that since the telephone-contact employe cannot influence the customer by facial expression, gesture, or an otherwise satisfactory appearance, it will be necessary to lay especial emphasis on voice inflection, selection of words, salutation, and the general manner of speaking. Since many persons have been continuously negligent on enunciation, pronunciation and voice inflections, experience has indicated that training in these matters in this field by actual instructional procedures, including necessary practice, is a very beneficial adjunct to other training of telephone-contact employes. One method that might be used, therefore, is to train intensively all telephone-contact employes by the instructional method in the technique of telephone conversation, and then group the telephone-contact employes departmentally in small discussion groups for the analysis and discussion of the problems peculiar to the telephone-contact employe's job in each departmental unit of the company. The methods prescribed for the service man would apply in the case of the discussion portion of the training program for the telephone-contact employes.

The results of the discussion meetings in the several groups can then be summarized into a Standard-Telephone-Practice Manual for the company as a whole, which will include all of the instructions and cautions which are applicable to all telephone-contact jobs, regardless of department. This, together with other material that will be developed for the individual departments, can be used as training material for the new employes as they come into the picture.

TRAINING FOR IMPROVED STANDARDS OF CORRESPONDENCE

Analysis of the possible contacts with the public through correspondence will develop the fact that, as in the case of the telephone-contact employe, personal appearance does not enter as a factor. It also develops the fact that vocal speech can play no part in creating a good final impression on the recipient of the letter. All of the other factors, however, do apply, and since they can be expressed only through the written word, it is apparent that too much care cannot be exercised in the proper selection of words and phrases, and even in the mechanical way in which they are set down on the page. Similarly, the element of politeness in letters must be especially stressed, as there is no opportunity for facial expression or pleasant tone of voice to overcome a poorly selected phrase. Therefore, the special instruction which is required covering training for improved correspondence will be concentrated on proper vocabulary and on the construction of the letter, so that they will be complete, although brief, clear, accurate and simple in construction.

As in the case of personal contact and telephone contact, conferences with the members of the departments handling the bulk of company correspondence should be conducted by the person responsible for the promotion of this phase of the training program. However, standards for the company as a whole should be set up and promulgated for the guidance of all employes who are required to conduct correspondence in the name of the company.

RELATION OF PUBLIC-CONTACT TRAINING TO OTHER TRAINING PROGRAMS

In many public-contact jobs, such as, for instance, the job of the collector, or the cashier, or receiving teller, the training which has to do with the personal elements of the job practically completes the training necessary for that particular job, except, of course, for a few rules and regulations in which the customer would not be interested. However, in the case of the service man's job which has been analyzed, it is found that the service man must be a good mechanic. The personal service element in the service man's job is an important part of his activities on the customer's premises and is, therefore, a part of his job, so that training in this phase of the work is, in the last analysis, job training that has to do with that particular part of his job. The only advantage to be gained by separating this training from other phases of job training would be in the emphasis that can be placed on the importance of the personal service elements of the job. When, however, the Standards of Personal Service have been established, and when they have been accepted by the existing personnel, there is no reason why the training program for new employes cannot cover the mechanical and personal elements of the job simultaneously. Industry does not separate accident prevention training from the training in methods; that is, the training in methods includes such safety precautions as are necessary to instruct the employes in the correct methods of doing the work. Therefore, in the training program for the new employe, all elements entering into the work of the job should be included in the training program. If this is done, the personal service elements of the service man's job will be given as much emphasis from the standpoint of importance as is given to the mechanical phases of the work.

It, therefore, should be the aim of the training staff to build the public-contact training program in such a way that eventually it can be made a part of the over-all job training program for the departments.

DAY-BY-DAY SUPERVISION AND TRAINING

The supervisor cannot depend entirely upon the meetings for results. Particularly in the case of new people and when new proposals have been made, the supervisor must personally observe how the work is being done on the job. The experienced workman frequently assists in the training of the new workman. He also makes suggestions which the supervisor or the staff man may use in conducting training meetings. The supervisor must ask questions and make notes for discussion in later meetings. In this way the group members will see that the training is a continuous process, and not something confined to the discussion meetings.

TRANSITION

Frequent reference has been made in this report to the use of material obtained by service sampling or otherwise in the follow-up or re-training which is always necessary to keep the adopted standards alive and in use. The results of the survey reported in Publication No. 278-52—Training for Better Public Contact—Its Necessity and Importance—indicated that a number of companies are utilizing various methods of measuring the results of their public-contact training. Management cannot be sure that the standards which have been established are being carried out unless some definite and effective method of measurement is established.

One of the most effective means of carrying on follow-up or re-training is to discuss the results of failures to follow out the standards that have been adopted. Such results in the personal elements of the job cannot be obtained unless effective methods of measurement are established. The next and final report of this series will, therefore, deal with the measurement of results obtained by public-contact-training programs.

TRAINING FOR BETTER PUBLIC CONTACT—IV MEASUREMENT OF RESULTS OBTAINED BY A PUBLIC CONTACT TRAINING PROGRAM

INTRODUCTION

The preceding report of this series (Training for Better Public Contact—Building and Conducting the Training Program, Publication No. 289-83), outlined the various steps involved in the training program from the time it is proposed to the time it is actually inaugurated. Frequent reference has been made to the fact that materials obtained from the various sources which test or check the performance of employes may be used in the training program. Similarly, these tests and checks may be used to determine the improvements resulting from the establishment and continuance of the training program.

Electrical utilities for many years have tested the various materials, such as coal and water, which they use in producing electricity. They have also established laboratories for testing the various types of machinery and equipment before they are placed on the company's system. Electrical appliances sold to customers are similarly tested. No factory manager would think of discontinuing the inspection of the product in each step of his manufacturing process. This inspection is for two purposes: To determine, first, the quality, and, second, the quantity of the machine, and employe output or accomplishment. Knowledge of both of these items is necessary to train the new employe properly in the methods to be followed in producing quality product, and in training him how to come up to normal quantity production. The principle of testing or measurement of the personal service which employes give to customers is entirely consistent with the well-established practice of testing physical equipment, and measuring service and production.

Better Customer Attitude

The product obtained by the company from personal service to the customer is the impression such personal service makes on the customer. Since the training program is carried on to improve the personal service rendered, the results of public-contact training should be, in the last analysis, better customer attitude toward the company. Any measurement of employe knowledge of what should be done that does not include a measurement of the employe's ability to put the knowledge into effective use, can lead to but little indication of the effectiveness of the training program. The most effective method of measuring the mechanic's ability is the inspection of his product as to quality and quantity. No one would think of rating a mechanic for promotion or compensation only on tests of his ability to pass an examination which would determine how much of the training instructions he has assimilated, without also checking him in some way on how well he can apply that knowledge. In the case of the public-contact employe a test of how much he knows about what should be done and on how to do it, will not be indicative of his ability to apply that knowledge unless the actual product—customer attitude or customer impression—is measured.

This report will outline various methods of measuring the results of public-contact training based on answers to the questionnaire described in the first report of this series (Training for Better Public Contact—Its Necessity and Importance—Publication No. 278-52).

Checking Results

Perhaps the first reason for measuring the results of public-contact training is the desire to know what improvement, if any, has resulted from the training work. Regardless of the method of training chosen, it will be successful chiefly in proportion to the interest which is aroused in it on the part of the executives, supervisors, and employes. Further, if this interest is translated into an active effort to improve results with customers on the part of those who are being trained, the results should be tangible. The best way of determining whether the interest in keeping public-contact work at a high point, and whether the actual quality of the work has been maintained, is to carry on some kind of measurement of the customer's impression created by the personal service rendered.

THE METHODS OF MEASURING RESULTS

1. In the first report of this series the methods of measurement used by the companies answering "yes" to the question, "Do you use any method of measuring the results of your public-contact work?" were stated to include:

    Investigation and record of customer's complaints;

    Review checks on information in training material;

    Continuous service sampling of performance on job;

    Follow-up with customers to see whether such items as work orders have been satisfactorily carried out;

    Direct inquiry to community leaders as to the standing of the company.

    Details of these methods were submitted by the companies which later furnished supplementary material on the subject of measurement. While an analysis of the various methods in use indicates a great variety of devices, certain trends may be noted. The methods in use, although varying in detail, will be classified according to the elements they have in common.

Publication No. 289-108, Serial Report, Industrial Relations Committee.

2. Classification of Methods of Measurement in Use

a. Methods of measurement may be classified as direct or indirect.

The direct methods include all methods in which an attempt is made to obtain directly from the customers or from others familiar with their attitude, an indication of what their reaction has been to the personal service which has been rendered. The indirect methods include those procedures in which no attempt is made to obtain a direct statement from the customer. Under the indirect method, the employe's knowledge of prescribed methods and his ability to apply this knowledge is judged by carefully noting his performance while he is making contacts with the public, or with someone posing as a customer.

b. Methods of measurement in use may be classified as formal or informal.

Formal methods are those in which a definite time schedule is adhered to in conducting the measurement, and in which definite procedures for carrying on the measurement are used. An informal method is one in which the person seeking information uses an analysis of the general attitude as expressed by the customer, rather than hard and fast formal questions.

c. The methods of measurement may also be classified as specific or general.

Where the specific method of measurement is used, information is sought regarding a definite situation in which a particular class of work is being measured. In the general method, the purpose is to secure an over-all impression of the customer's attitude toward the company as a whole.

DIRECT AND INDIRECT METHODS OF MEASUREMENT

In the previous report the methods of training the service man were discussed. In this report the measurement of the results of that training will be discussed where applicable. It is assumed that similar means would be used in surveying the results of training in other lines of work. In many cases the survey would be company-wide, covering all public-contact positions.

1. Direct Methods

a. Professional interviewers

Interviewers, who may be either employes of the company or an outside concern, retained by the company, are sent to interview the customers in their homes or places of business to ascertain their attitude toward the company, based on the treatment they have received from company employes, and upon the physical service rendered. The advantage claimed for this method is that it permits the use of people who are specially trained in methods of securing information by asking questions without antagonizing those questioned. Another advantage is that the interviewers can do much to conciliate customers who have received a bad impression of the company for any reason by a frank discussion of the situation. The disadvantages are that many people are somewhat reticent to answer any questions, and if the interview occurs at a time very distant from their last contact with the company, their impressions may be extremely hazy.

b. Reply cards sent to customers

This device, as the name implies, is a follow-up of the service rendered to determine the customer's reaction to the service, while the situation is still fresh in the customer's mind. The advantage pointed out for this method is that it secures an analysis of the customer's reactions to a concrete situation while it is still fresh in her mind and while any courtesy or discourtesy shown by the employe is easy to remember. Another advantage is that this method lends itself readily to application in small communities. It is pointed out, however, that care must be taken in preparing the card so as to make the appeal as personal as possible.

c. Analysis of complaints and letters of commendation

This involves a study of these communications in an effort to learn directly from their own correspondence or oral statements the reactions of the customers to the company.

It is asserted that the advantage of this method is that it is based almost entirely on unsolicited comments by the customers about the service. An objection to placing too much importance on complaints and letters of commendation is that they represent such a small fraction of the customers and the statements are usually exaggerated in criticism or in praise, while the large middle group of customers who are either neutral or mildly friendly, seldom communicate with the company.

d. Inquiries directed to community leaders

In this method the purpose is to obtain the over-all reaction of men in prominent positions in the community. Where this method is used, it is normally a personal conversation between an executive of the utility concerned and various community leaders with whom he has either social or business relations, or both.

The advantage of this method is said to be that the opinions of these community leaders are based on wide observation of the reaction of the community to the utility's service and its treatment of its customers. The disadvantage is said to be that the statements are the result of a general conversation rather than a specific interview, and that the opinions expressed by these leaders are usually personal rather than representing any considerable number of people. Usually the leaders are themselves connected with some large commercial or industrial organizations, and so look at the problem from that position rather than from that of the average domestic customer. It must be admitted, however, that an opinion gained by this method should not be disregarded because it can serve as an over-all check on other methods which are used. Another disadvantage is that the same subjects cannot be brought up for conversation at regular intervals with the same community leaders.

2. Indirect Methods

In the indirect method a third party either acts as a customer and, based on a study of usual customer reactions, rates the employe's performance, or, acts as a monitor to determine to what extent the employe is making an effort to do those things which will result in a favorable customer reaction.

a. Service sampling of employes

In this method, certain people selected because of their ability to analyze situations and to take an impartial view, assume the rôle of customers and carry on what appears to the employe to be a normal business transaction. Having studied the things which seem most important to the average customer, this sampler, after the interview, rates the employe according to the extent to which he has done the things normally expected to produce a favorable impression. As indicated in the preceding serial report, Appearance, Politeness, Speech, Information-giving, and Interest in the Customer constitute these points on which the Service Sampler will rate the employe. The advantage claimed for this method is that it permits the taking of samples of personal service on any phase of the company's business where the employes have contact with the public which, by most other methods, might otherwise be very infrequently sampled. Further, it permits a numerical measurement of employe performance based on definite standards. This measurement, based on definite standards, would be difficult to make on information obtained from the customers. By the use of this or any indirect method the customer is not required to participate in the company's effort to improve its personal service. The possibility of irritating an otherwise friendly customer is thus eliminated. A disadvantage claimed is that unless the employes understand that this is a strictly sampling proposition and not a disciplinary device to detect offenders, they are likely to look upon it with suspicion.

b. Monitoring and spot checking

As in the case of the Service Sampler, the Monitor or Spot Checker, knowing what has been agreed upon as carrying the most weight with the customer in producing a satisfactory impression, can rate the employe during the progress of the employe's contact with the customer. An advantage claimed for use of the monitor or spot checker is the ease with which his work can be accomplished. This is especially true in the case of telephone and correspondence contacts where the tying-in of an extra telephone permits ready monitoring of conversations, and where the reading of correspondence after it has been written may be readily accomplished. The same disadvantage, as sometimes claimed against the use of service sampling, applies here unless the purpose of the plan, as understood by the employes, is to improve service rather than to collect information to be used for disciplinary purposes. Another disadvantage is that there are many contact jobs to which this method cannot be applied.

FORMAL AND INFORMAL METHODS OF MEASUREMENT

Various plans used under the direct and indirect methods of measurement may be adapted either for formal or informal use, or to measure specific or general situations. Ordinarily all of the plans listed would probably be carried on formally except inquiries directed to community leaders and, except on certain occasions, reply cards sent to customers, and analyses of complaints or letters of commendation.

In the formal method of measurement, a definite routine is established whereby a time schedule for the conduct of the survey is set up, the physical setup is carefully outlined, and formal questions are asked to which definite answers are expected.

Advantages and Disadvantages

The advantage claimed for this method is that the routinizing of the work permits it to be carried on on a regular basis, and provides for definite comparisons which will indicate the progress made.

A disadvantage of the formal method, when applied to the direct method of measurement, is said to be that many customers find it difficult, and many are unwilling, to analyze definitely their own reactions to their treatment by the company, who might, if approached informally, give some of the desired information.

Under the informal method, as the name implies, private conversations and letters between company representatives and customers are used with the idea of gaining more offhand comment than is obtained when a formal routine is adhered to.

A disadvantage claimed for this method is that it is difficult to use information gained informally as a definite measurement, as it represents only such thoughts as immediately arise in the customer's mind in the course of the conversation. Similarly, the measurement is limited, and the results of measurement cannot be used directly in providing for training to improve the work.

SPECIFIC AND GENERAL METHODS OF MEASUREMENT

The plans of measurement already classified as to direct or indirect, and formal or informal, may also be classified as to whether they are specific or general. As already indicated, the specific method is the one used where information is sought regarding the impression left in a definite situation in which a particular class of work is being measured, while in the general method the purpose is to secure the final impression of the customer's attitude toward the company.

Analyzing the methods on this basis, it would be found that ordinarily the analysis of complaints, the sending of reply cards to customers, the service sampling of employes and monitoring and spot-checking of employes, and interview with customers are specific methods. On the other hand, inquiries directed to community leaders are almost certain to be general, while some of the other devices may be used to measure the general attitude toward the company.

Advantages and Disadvantages

An advantage claimed for specific methods as applied to a company where training for improvement in public contact is being conducted, is that it allows specific measurement on the work of holders of positions who have received specific training in the public-contact responsibilities of those positions. A disadvantage of this plan is said to be that it is difficult to measure the attitude of the community toward the company by the consideration of a limited number of isolated public contacts.

The measurement of the performance of public-contact employes by the general methods can be best applied to those phases of the work in which the training has been company-wide, for example, general telephone training. Not only is this claimed to be an advantage, but also the measurement of the attitude of the customers toward the company as a whole, indicates whether the majority of the customers are friendly, unfriendly or neutral in their final impression of the employe's personal service. A disadvantage of the general method is said to be that it is very difficult to determine the extent of the success of the training program by using general methods of measurement.

APPLICATION OF METHODS OF MEASUREMENT

In the preceding serial report the method of analyzing the work of the service man, and of setting up and operating a public-contact-training program with and for him, was discussed. The various methods of measurement must be considered separately as they apply to measuring the results of training of the service man. In order to have a fair basis of comparison so as to determine what improvement has resulted from the training program, the quality of the work of the group being trained should be measured before and at intervals after the training program is inaugurated. The same measuring devices should be used in both cases. The choice of the method of measurement will probably depend chiefly on the local situation, as methods which are practical in urban communities would be impractical in scattered rural communities and vice versa.

Interviews with customers regarding the work of service men, analysis of complaints, letters of commendation with reference to service men, sending of reply cards to customers recently visited by service men, or a combination of two or all of these direct methods of measurement might be used. Similarly, situations might be arranged so that customers or service samplers can call upon the company for service and make service sampling reports based on the resulting contact. To be most effective, the measurement of the customer's impression of any of these situations should follow as soon as possible after the visit of the service man, and the whole program of measurement should be begun shortly before the starting of the training program, and be continued from that time on.

As indicated above, to be most effective, the formal plan with a definite schedule upon which the measurement would be based and the routine for handling the method agreed upon, should be arranged. In the case of the service man, a workable arrangement would be to provide for a certain minimum number of test cases or samples, reply cards or interviews, or a combination of these various tests to be made on a definite schedule.

Since it has been stated that the job of the service man is the one under consideration, obviously specific measurement of the results of his public-contact training should be considered. Under this plan, the questions to be answered and the points to be considered in setting the standard upon which the measurement is to be determined, will be based directly upon the standard of performance to which the service men and supervisors have agreed. This also furnishes an excellent check to determine whether the service men are practicing the things which they agree in their training meetings should be done.

RELATION OF MEASUREMENT TO THE TRAINING PROGRAM

As just indicated, measurement is a very important part of the training program. During the early stages of the training program it is necessary, from time to time, to give examinations, sometimes called review checks, on employes' knowledge of the standards which they have agreed are to be maintained in the future. These checks are tests of knowledge of what should be done, and not of the performance itself.

Various other methods of measurement which have been described in this report are measurements of actual performance on the basis of the standards which have been agreed to in the training program. When a comparison of the review checks on knowledge with the checks on performance indicates that the performance does not come up to the standards which the men themselves have set, any one of a number of reasons may be advanced—that possibly the employes have outlined an ideal standard rather than a practical one; possibly proper supervision is not being maintained to secure adherence to the standards; and possibly the employes do not thoroughly understand the details of the standards to which they themselves agreed.

Information Obtained Serves Other Purposes

The information obtained by measurement also serves other purposes. It helps to indicate how standards should be changed to conform with changing situations. It also forms a basis of comparison between similar situations over whatever period comparisons are considered desirable.

Still another excellent use for the results of measurement is to furnish first-hand-case illustrations based on the man's own performance to be used as training material. Training must be a continuous process and is an important part of supervision. Measurement, however, furnishes an indication of when training should be given additional attention and also what points should be emphasized in the continuing training program.

The final results of measurement form the basis of reports to the management of the departments concerned as to exactly what progress is being made in the realization of the desire to create the best possible impression on the part of the customer.

Recommendations of the Committee

The committee recommends that each executive, having recognized public-contact training as an important factor in maintaining good public relations, study his own local conditions in order that he may determine the best method or methods for him to adopt for the conduct of the training program, including the measurement of the results of the training. It is further recommended that these results be measured periodically and compared with previous results; that training be continued and that reports showing the results of training be presented to the management.

HEALTH PROMOTION IN THE PUBLIC UTILITY INDUSTRY —ITS NECESSITY AND IMPORTANCE

INTRODUCTION

In the Reports of the Accident Prevention Committee for the years 1920-21-22 and 23,* there will be found references to the problem of Health in the Public Utility Industry. In the Reports of the Industrial Relations Committee for the years 1926 and 1927* will be found further references. These references for the most part deal with the problem of sickness, absenteeism, and physical examination. Anyone interested should give this whole subject careful consideration.

As has conclusively been shown, sickness is responsible for approximately eight days' absence per employee per year. This loss is, for the most part, caused by what are called minor illnesses, such as the "common cold." The importance of these illnesses is clearly demonstrated by the investigation recently inaugurated by the Johns Hopkins University, into the cause and treatment of the common cold.

Aside, however, from absenteeism, is the recognized value to the employer of the long-lived employee. In a public utility this is even more apparent because the plant of the public utility is not in one factory, but is spread over either a city or a considerable stretch of country, and whether the employee be lineman, meter reader, bookkeeper, salesman or manager during the period of his employment, he has collected a great mass of information relative to the particular public utility with which he is connected, which, however carefully recorded, will be lost if he leaves the organization. Aside from humanitarian reasons, it is, therefore, of particular interest to the public utility to help its employees lengthen their lives.

Important as is the economic reason for health supervision, for the most part a natural interest in the well-being of the man or woman, is the real reason for the interest of companies in health matters. So much of our lives is spent at business that we are naturally pained on learning of the untimely end of an associate, or the severe illness of one working under our supervision. It is, therefore, logical that plans should be made to assist in preventing illness, and that companies should use the motto, "Work here and live longer."

The strains of modern business have greatly increased. Whether because of keener competition or as the natural result of our machine age, there is no doubt that this strain on the man is being felt. Even aside from business, the idea of competition and speed is also being carried into the various pursuits in which the average man seeks his pleasure. In other words, with the general speeding up of life, whether in business or whether in play, the physical make-up of the average man is bearing a strain to which, in a number of cases, it is unequal.

This strain, quite naturally, falls more heavily upon the man bearing the major responsibility. This man may be called boss, foreman, vice-president or executive, but irrespective of the name, the strain upon him is usually very much greater than that upon other employees. As is quite usual, the importance of his health is not receiving the attention it should receive, but certain organizations are at least trying to rectify this defect.

Although emphasis is being placed on the care of the executive's health, it is not intended that the health of the rank and file be neglected. It is felt, however, that while many executives arrange for the health supervision of employees, they seriously neglect their own health. The average employee needs assistance in health matters much more, however, than the executive. Often the financial means are not available, and only by cooperative methods can it be possible for the employee to get the advice or the attention required. In this situation, the company can be of great assistance.

DEVELOPING A MEDICAL DEPARTMENT

The matter of organized effort to care for the health of the employees of the organization, has been receiving attention for a considerable number of years in some organizations. It is rather noticeable that, although very few N. E. L. A. member companies have done anything in health matters in an organized way, those few companies which started an organized effort twenty or twenty-five years ago, have maintained this effort and have extended it, showing quite clearly that the policy decided upon has proved well worth-while.

A word of warning should be given as to the necessity of developing a medical department slowly and not attempting to embark on an extensive plan at the start. Practically all successful medical departments have been developed over a period of years, meeting and solving problems as they come up and developing the type of department necessary for the particular company in question.

Most of the companies which have become interested in the health of their employees have instituted some form of physical examination at the time of employment. These physical examinations vary from a rather cursory examination to a most complete medical and physical examination. Physical examinations to be of real value to the employee or the company should be thorough, complete and dignified. The superficial examination gives the company little information, and does much to discredit health activities and the company in the eyes of the employee. Better no examination than a superficial one. In certain types of employment, a check is made for specific physical defects that would render either employee or the public subject to a considerable hazard. These special checks have particular reference to hernia, color blindness, deafness, heart lesion, etc., among specific types of employees. Certain companies have put into effect a periodic examination, the period ranging from six months to a year, at times being carried out by the medical staff of the company and at other times by an outside agency. If carried out by an outside agency, the medical staff of the company should follow up. For the most part, these examinations are to provide means whereby advice can be given to the employees on the correction or prevention of various types of development that might result in either chronic illness or death.

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*These Reports are included in the N.E.L.A. Proceedings for the years mentioned.

Publication No. 289-56, Serial Report, Industrial Relations Committee.

Entrance and Periodic Examinations

The advent of Sick Benefit Plans in the industry has no doubt had a definite influence in developing both the examination on entrance and the periodic examination. Those companies which have had experience with both the entrance examination and the periodic examination, feel that these activities have been beneficial in lowering the absenteeism due to illness and in otherwise improving the efficiency of the staff.

In the larger organizations, particularly where there is a considerable group of employees, Medical Departments have been set up, ranging from a complete department, with full-time surgeons and the necessary nursing and clerical assistance, with examination rooms, treatment rooms, X-ray apparatus and laboratory facilities, to a part-time physician, usually in a consulting capacity. It is rather marked that those companies which have carried out the idea of a Medical Department for some years have enlarged that department, and from time to time have increased its functions, showing that those with experience along this line feel that the department is of considerable value.

A considerable amount of health education among employees is done in a number of companies. Various means are used, such as lectures, pamphlets, motion pictures, etc. Some of the larger companies have made definite provision for athletics, and in a few cases, vacation clubs, etc., have been developed. There is no doubt that this organized method of health education has a very definite, beneficial effect on lowering the absenteeism and in other ways improving the efficiency of the staff.

In setting up these various Medical Departments, considerable care has apparently been exercised to gain and keep the full cooperation of the various family physicians of the employees. This is most important, in view of the difficulty that public health departments apparently have had in connection with public clinics, and the industry would do well to encourage this close cooperation with the family physician.

The prime object of a physical examination is to detect indications of disease in the incipient stages, when remedial measures can be put into effect and prevent the onset of the disease. In a group of persons, it will usually be found that those under 40 years will show a healthy constitution with no indication of disease. However, there will be a very small minority which show indications, which in certain cases can be rectified. In the group of over 40 years of age there will develop more chronic diseases, and more definite remedial measures will have to be put into effect. In general the group under examination needs but little advice along the lines of reasonable living to keep it in good health. There will be found, however, men and women who seriously object to a physical examination, feeling that it is an encroachment upon their personal liberties. This will not be found so much in an examination for employment but will develop more in the periodic examination. Careful attention to this condition should be given by the examining doctor, and every care should be exercised to break down this antagonism.

Another serious defect of physical examination is that, in many people, a physical examination creates a fear for their health. Most people worry too much about their health and do too little to keep in good health, and it has been found that a certain number of this type will be very much worried by the results of a physical examination. Careful attention by the examining doctor at the time of the examination will do a great deal to offset any difficulty of this type. In fact, the doctor should make it his duty to explain the reasons for the examination and also how the employee can obtain the greatest benefit from it.

Physical examinations are, for the most part, made either by the company doctor or by an agency employed directly by the company for this purpose. A great deal is to be said for this policy. These doctors are, or should be, more skilled in physical examination than the average practitioner. The examination report will be more completely filled out, and the examinations will be more uniform. There is certainly something to be said, however, for the policy of having a physical examination executed by the family physician. The employee looks to the family physician for advice in health matters; there are no social antagonisms to be broken down between employee and the family physician, and, furthermore, the family physician should know the condition of the employee better than anyone else. Although it has not been done extensively, the experiment of having the family physician make periodic examinations of employees and report to the employer is well worth considering. The contact set up with the family physician would be very valuable and the advice to the employee in health matters by the family physician might be better received and more likely to be carried out than advice given by a stranger.

Where examinations are to be made by the family physician, he must be acquainted with the objects of the examination and pertinent facts in connection with the employment. This information can best be given by the medical staff of the company.

In connection with the Health Department set up in various companies, the decision has always to be made as to how far to go. Certain companies, as pointed out previously, have instituted a very complete medical clinic. Such clinics are more common in the manufacturing industries in which the employees are concentrated. In a public utility, with employees scattered over a considerable stretch of country, it is much more difficult to set up a complete medical clinic. Also, the wisdom of setting up such a clinic is certainly open to question, and each company will have to decide for itself as to how much medical service it intends to give the employees and how much responsibility for the medical care it intends to assume. This is such a debatable point that the Industrial Relations Committee feels that, at present, it should be left an open question.

EDUCATING FOR HEALTH

One form of activity, however, can be carried out by the company with the greatest propriety. There is available a mass of reliable and helpful literature giving advice in health matters. This literature can be carefully selected and presented to the employees in the company's usual way of presenting information. This information may be obtained from insurance companies, public health organizations, medical organizations and certain bodies which have developed this as a specialty. In the collection and selection of this information the assistance of physicians and those thoroughly familiar with the problem is of the utmost importance. A great deal of so-called health information is published and broadcast, which is anything but healthful and is, for the most part, the product of faddists. One of the greatest difficulties in educating in health matters is to get the idea across, without leading the employee to think that he is a chronic invalid. Most people are normally healthy; in fact, very much more healthy than they realize.

In setting out to educate employees in health matters it is, of course, imperative that the company set an example. It is foolish to send out information about the need for ventilating the home, if the company's premises are not properly ventilated. As a forerunner to a campaign of health education a careful survey of the company premises by someone who is competent to give advice on sanitation, health, and ventilation, will be found to be of considerable assistance.

Contacts With Health Agencies

It will be of value to the company to become thoroughly familiar with the health agencies carrying out work in its territory. The Department of Public Health, the local medical societies, the Red Cross and other social service organizations, as well as certain departments of hospitals, will be found not only able to help but glad to do so. By setting up such contacts, a great deal of overlapping is eliminated and advice of valuable character in dealing with the company's own problems will be obtained.

The contacts with the family physicians, as above pointed out, will be valuable in carrying out any type of health education and instruction. In setting up these contacts with the family physician, the company will not only gain by the instruction that can be given by the family physician, but will also gain by instructing or educating the family physician in the requirements of employment in the company and in the company policy in connection with its employees. Such contacts may easily assist where a close relation is made with the family physician, whereas, if the family physician is not taken into the confidence of the company and his assistance solicited, detrimental effects may develop.

In Conclusion

The health of all of the staff of any industry is extremely important to the industry's success. Good health will cut down absenteeism; will make for long-lived employees and will assist in creating efficiency. To obtain the good health of the staff, the advice of those instructed in health matters, such as doctors, nurses, etc., is imperative. How far the company should go in treating illness is a debatable point. Certainly, assistance should be available in emergency and in certain other cases. There can be no doubt, however, that instruction in health matters by the company through the best means available is advised.

A certain school of thought in public health matters is developing which would advise that the employee be held responsible for his health as one of the requisites of holding his job, and that the company assist in educating him as to how to maintain good health.

APPENDIX I

HOW THE MEDICAL DEPARTMENT CAN BE A FACTOR IN THE REDUCTION OF ABSENTEEISM FROM WORK

When the average person anticipates making a purchase of any commodity he first has in mind what he desires to buy, what it is for, its quality and if it is worth the price. It is true that many times a purchase of a commodity is pure guesswork, but the average customer, after careful selection of his article, pays a fair price and gets value received. It is the careless, impulsive buyer, who selects without discrimination, who generally becomes dissatisfied with his purchase.

The same care necessary in purchasing materials should be exercised in employing men and women for work in a given industry. It is just as essential that the employer have in mind definite facts that will guide him in his selection of a person able to do efficiently the work that the vacant position calls for. If a candidate for a position is selected on external appearance only, the interior is unknown. He may meet the requirements and be capable of performing the work, but be unable to stand up physically on the job. This can be determined only by a careful physical examination of the prospective employee before he is taken into service. The examination should be made before employing, and not after the man is trained, when the discovery of hidden defects may require his discharge.

THE PHYSICAL EXAMINATION

To be of any value, the examination must be sufficiently definite and thorough to detect any defect or insidious disease. The few-minute medical inspection is valueless. The examination should be made under a standard set of physical requirements for each position in the industry and careful analysis made of each job's requirements, hazards and environments. After this examination, the employer knows to a greater degree the exact physical qualities of the new employee. The selection has not been made blindly, and he has been fitted into the position for which he is best suited, and which he can discharge efficiently and with safety to himself and those about him.

This is the Medical Department's first opportunity to reduce absence from work on account of either illness or injury. A fairly healthy employee at the start is a known quantity that will not be so apt to be absent from work due to sickness. This examination detects those conditions that make for illness and are potential factors in accident making. Defective eyesight, hearing or color sense, all predispose to illness and accident, and if these are undetected in a new employee, is it not to be expected that sooner or later these will cause him, or others about him, to be absent from work on account of illness or some injury in which either he is the victim or those about him suffer from his defect?

An employee who has a rupture, defective heart, defective limb, due to crippling, or such defects as flat feet or varicose veins, is a great offender in absenteeism. Defective teeth and tonsils, by causing complications productive of more serious diseases, play their share. It is better that these conditions be detected and remedied before employment, as otherwise they are often put off after employment and go on undetected until their owner becomes a chronic offender. It is the undetected, trivial physical condition which, if given time in which to progress, will at a later date after employment bring the employee's name on the daily list of those absent on account of illness.

Undetected physical deformities may be productive of injury. In many cases, the defect is such that when a certain work is performed, the man fails and an accident is at hand. This is best evidenced by the workman with a hernia who, while lifting heavy objects, drops his end on account of sudden pain, and his feet or his fellow-worker's feet, suffer. Careful physical examination reduces absenteeism from work in proportion to the thoroughness with which the examination is made.

KEEPING EMPLOYEES IN HEALTH

After a healthy man of known physical make-up has been employed, it is essential that he be maintained in that condition, as far as possible, either by compulsory examination, by his own initiative, or, better still, by the company, as the individual is prone to neglect trivial symptoms and put off examination and treatment. This physical examination detects those conditions that may arise after employment.

Many industries examine all new employees carefully, but end their health work after the man is employed. This must be considered a mistake, for after the employee has been trained and is functioning as a part of the organization, any illness or injury will bring greater loss economically to both worker and employer. It costs money to educate a new employee, and then, too, absence from his work on account of either injury or illness will, in many cases, disrupt the orderly routine of work. Machinery and tools are maintained in a safe and efficient condition. It is even more important to maintain in a healthy state the man who uses the machinery and tools. These thorough, periodical, medical examinations of employees have proved a definite factor in the reduction of absence. If the employee is in good health, he is not prone to respiratory infections, which are the greatest cause of absence from the job. If he is in good health at the time of injury he will be returned to his bench in a shorter time and with fewer disabling complications. For example, the man with a mouth filled with diseased tonsils and teeth is off frequently with rheumatism, lumbago, indigestion, etc., from local infection, and when he is so unfortunate as to suffer some slight injury, complications develop and his disability extends over a long period of time. This is so often seen in the back injury developing from a trivial accident, and, on account of preexisting disease elements, the condition is aggravated, the deformity made more serious and convalescence delayed. Proper periodical and thorough physical examinations will reduce the absenteeism caused by illness and injury.

These two procedures are known as industrial prophylaxis of disease and come under the heading of prevention of absenteeism on account of illness and injury in industry.

There is another group of conditions in industry that makes for a reduction of absence on account of illness and injury, by the establishment of a well-organized medical department. Such a staff or department can render great service and save a vast amount of money by providing systematic methods of handling injuries and illnesses that are prevalent in its particular locality or industry. Where a large group of like medical and surgical conditions are taken care of by an organized group of doctors, greater experience and education in the most efficient manner of treatment is to be had. Without the services of such an experienced medical staff, injured employees may be kept away from the job by reason of prolonged and ineffective treatment by doctors who may not be familiar with such cases because of lack of experience with these traumatic cases. Experience has shown that injured men will, in many cases, return to work earlier when treated in the industrial medical department, where the necessary experience in this field is available, than when they are treated elsewhere. Many times they are fitted in the organization in a capacity where they can have an income and at the same time perform work that their injuries will permit without harmful effect. A man whose mind is occupied with engaging work will recover more quickly than the chap who is idle and allowed to be alone with his thoughts. A little patience on the part of the industrial medical man and cooperation from the department heads will fit this worker in and will reduce the absenteeism from the job on account of illness.

Value of Immediate Medical Aid

How much verbiage has been expended by both the medical man and the layman in industry toward remedying the absenteeism from work on account of illness, but how little real action has been inaugurated? By trying out a definite medical policy in an orderly and systematic manner, results will be produced. In illness, especially in common colds, a great reduction can be made if medical supervision is had at once when the first sneeze is heard or the first drop appears on the nose. A day at home away from the job will prevent contaminating others in close proximity to the afflicted one, and the day's rest under therapy will return him to his bench sooner than if he is left to follow his own dictates and drag his cold out three or more days, with poor work output and inferior grade of work, only later to stay at home with a more defined respiratory case. What is needed in industry is courage to follow out experimentally some of the real established health factors for a definite time and compare cases of neglect, where no treatment is given, and it will soon be seen that there is a definite value returned in proportion to the medical effort put forth. Sanity is essential in this medical work, and one must not by this policy disrupt the orderly functioning of a given industry. Where the medical authority bewails absenteeism from work and his helplessness to check it without disrupting the practical processes of his industry, he is found lacking, and has not started at the bottom of the absenteeism-defect ladder, but is at the top trying to remedy conditions which can only be reached by treatment upon each individual step of the ladder from the ground up. Many times one hears medical department chiefs say that, when an employee presents himself at their office complaining of feeling ill, their duty consists of signing a card for a department head that the employee is sick and should be excused from work. What a sad spectacle it is of a doctor doing this simple, clerical procedure instead of using those professional qualities he possesses, making a careful examination of the patient and giving a written statement of the treatment that he is to follow out while at home; for the greater proportion will go home, try home remedies and get advice from other sources instead of seeking their medical advisor, until the disease has a full hold on them and they are scared, and only then will they seek competent treatment. But if the medical chief interests himself in the individual enough to examine and supervise treatment and then check up the case, he will soon show his value to the executives of his company by a lowered absenteeism rate.

One of the causes of frequent absence from work on account of illness is the sick and health benefits that are in some cases so large that it pays an employee to be sick, as he will derive more money away from the job than at work. Benefits are so often derived from one or more companies that the employee stays at home on trivial injuries and illnesses and many times for no bona-fide cause, when he should be at work. Many ailments are subjective and it is difficult for a doctor to determine by a single examination of the employee whether he is justified in absenting himself from regular duty. This makes it necessary for the company medical department to follow closely each case of absence, so as to insure proper care of real cases of disability, and, equally important, so as to detect those cases in which there is a reasonable doubt as to whether the employee is really disabled. Such a procedure will result in a great reduction in absenteeism and many dollars will be saved to the companies and to the employees' mutual benefit associations. Not all employees are given to this practice, but in any organization employing large numbers of men there are enough malingerers of this type to bring up the absenteeism rate. In so many of the benefit companies the doctor is so submerged under the red tape of the so-called welfare department that his value is lost and his efforts become clerical.

The medical department has a very definite work of sanitation in every industry. A healthful working environment is conducive to a healthful personnel and assures a minimum of absenteeism. Proper illumination of a plant forestalls nervous and mental trouble, as eyestrain is conducive to these defects. Ventilation and heating are essential necessities in every plant if the absenteeism rate is to be kept at the lowest ebb, as underheated or overheated rooms are the direct cause of many disabling diseases. Lack of fresh air, gases, smoke and fumes are the handmaidens of disease germs, and absenteeism mounts with the neglect of these essential features of good health. The medical department, by supervision of the sanitation of any industry is able to lend important aid in health conservation. The analyzing of the greases, compounds, solutions, paints, chemicals, etc., used is a necessary duty of the medical department if it is to prevent industrial diseases. Distribution of published articles, and talks on health subjects, to the employees of an industry, at not too frequent intervals and in common sense language, are important factors in the control of absenteeism.

FIRST AID INSTRUCTION

Instruction of the lay personnel in first aid work in the absence of medical attention in time of illness or accident, has not only conserved human life by immediate assistance, but has been the stimulus of directing the attention of the employee to his own personal self and of inciting him to look after his own health and well-being. First aid has reduced the absenteeism from work, as timely attention to trivial injuries has prevented prolonged disability. Proper first aid reduces complications such as infections, following simple injuries. To be of service, this must be taught correctly and closely followed up afterward. A visiting nurse service has its advantages in helping to reduce absenteeism because the nurse calls on the ill or injured employee within a few hours after his absence is reported and is able very often to bring aid. Her ministrations in time of illness not alone save the employee expense, but also hastens his recovery. The money spent in this nursing work is returnable in a large measure in the morale of the employee body.

PREVENTION

When department or supervisory heads become aware of an employee slowing up, either in his production rate or the quality of his product, they should at once interest themselves in the cause of the letdown. Should the employee attract the attention of his fellow workers by peculiar or unusual actions, these should be looked into, and for both conditions the medical department brought into the picture. After careful examination, many times physical defects or mental crises are apparent, and attention given them at this time will often prevent a prolonged absenteeism later.

More attention should be given to research by the medical department personnel into the mental cause of accidents and its resultant absence from the job. This is a very important factor in industry today. Many employees have accidents for which there is no apparent excuse, and those in industry are at a loss to understand the cause. These occurrences always carry with them a greater period of absenteeism from work than ordinary accidents, as many times there is a mental defect to overcome besides the physical defect. Greater interest on the part of plant executives in the study of the individual instead of mass study, and the calling in of competently endowed medical personnel to aid in the work, will make for a decided lowering of the absenteeism rate.

While on this mental side of absenteeism from work, it is necessary to say a few words relative to the women in industry who so often are the greater contributors to absenteeism. Insufficient periods of relaxation are often the causes of fatigue of the women employees. On account of the average physical makeup of the woman and the fact that many times she is called upon to perform work which is beyond her physical and mental capacity, she functions for a time on her reserve nerve and vitality, but one day this weakens and she becomes a prey to the many disabling conditions to which women are susceptible. The medical department, with its efforts rightly directed in this channel, can reduce absenteeism. Women in industry are a specific problem, but progress is being made medically toward improving this condition.

In Conclusion

In conclusion the point of greatest importance in the industry today is to have each company establish a set medical policy for its employees, and then establish a medical department with a personnel whose interest is in the company and whose ambition is to produce such a state of health in that company that it will command the attention and respect of other companies. The efforts of the medical department, rightfully directed and competently manned, will be a direct agency for the reduction of absence due to illness or injury. There should be more research and less talk concerning this problem. It costs money for anything of value, be it service or product, and if only the interest on the economic loss, due to absenteeism from work, were applied to real active prevention, great headway would be made. Industrial medicine is in its infancy today, but it is here to stay, and as time goes on the medical department will be considered as essential to the successful operation of the company as is any other department of the organization.

In order to start the investigation, it is imperative that the industry keep adequate records of all cases of absenteeism, cause, occupation, length of disability, curative agent, time of year absent, and this study alone will reveal astounding facts that are easy of correction. It will be found that the greatest factor in absenteeism is not the serious illnesses of humanity, but the so-called trivial ailments which are easily corrected and prevented by a little real application to the problem.

Too much indifference is shown to the so-called comforts of workers, such as the arrangement of the work in an environment which is conducive to health for the various calls of nature. Facilities are often lacking and, if present, are inaccessible or inadequate. Often it is said to be impractical to permit sufficient time away from the job to adequately care for the various bodily functions. Constipation, the curse of American manhood and womanhood, is undoubtedly due to the demand of speed in industry and life today. We are too busy to attend to this call of nature, with the result that the organs of elimination will act only under the lash of artificial means, and their poisons remain in the systems to poison other organs and disrupt their harmonious function, and predispose the individual to illness which otherwise would not occur.

Constipation alone produces more absence from work than the much abused cold, for it is generally the constipation evil that so lowers the resistance of the worker that he becomes susceptible to colds. To properly function, the human machine must be kept clean both within as well as without. The correct amount of fuel in the form of food and liquid is necessary for the nourishment of the machine. The proper elimination of the waste products of the machine is essential to its efficient performance. Rest periods, in which the machine may recuperate its energies and lay up reserve power for emergencies, are important, and protection from overheating and underheating the machine will bring about a harmonious operation of that mechanism which

Providence gave each man as his natural heritage for his battle for existence in the world. Attention directed to the little things that produce conditions conducive to illness, with its enforced idleness, will bring a clearer vision to those who are concerned in this problem of absenteeism from work on account of illness or injury than if they direct their attention to the larger things, which will generally be taken care of and not slighted, as are the intangible conditions.

The most effective argument for the establishment of medical department's activity directed toward the reduction of absenteeism in industry is a comparison between the rate in an industry which has no medical policy and the rate in one which has a definite medical policy and a competently equipped medical department to carry out this work. The comparison will favor the latter, and industry is quick to see the value of such policy. The health of employees today is far better than that of a few years ago, but there is vast room for improvement.

APPENDIX II

OPPORTUNITIES WHICH ALL COMPANIES HAVE TO CONTROL ABSENTEEISM BY CARE IN VENTILATION

Introduction

Many theories have been advanced to explain the harmful effect of poor ventilation on the human body. So many factors enter into the question that a great diversity of opinion is possible. We may be certain, however, that bad ventilation does exert a profound influence on human health and comfort. The effect of ventilation on health and mental and physical aggressiveness should be as well recognized as is the effect of climate. The object of ventilation should be to maintain ideal atmospheric conditions indoors. While the food and water that we consume always receive attention, the condition of the air we breathe is too often left to uncontrolled whims of nature.

The changes in heating and ventilating necessary to keep pace with theory have been delayed by many factors. Most human beings have a natural inertia which opposes any change. In addition, we are fond of holding on to outworn ideas and discredited theories. Then, too, it is often the policy of manufacturers of apparatus to follow the line of least resistance, instead of keeping abreast of the latest developments.

Requirements of Good Ventilation

The normal chemical composition of the atmosphere is maintained with striking constancy under practically all conditions. This is made up as follows, by volume:

Nitrogen	78.10%
Oxygen	20.90%
Argon	0.90%
Carbon dioxide	0.03%
Insert gases other than argon	0.07%

While the chemical relation is maintained almost constant, atmospheric moisture and dust vary widely.

Of all the theories purporting to explain the effect of poorly ventilated air on the human body, one of the most widely held until recently was that of Pettenkofer. His theory was that the influence of bad air is due to the presence of toxic organic substances excreted into the atmosphere from the human body. It has now been proved that odor and bacteriological content are not harmful except where the air is specially polluted. However, an atmosphere laden with odors is objectionable on æsthetic grounds, if on no other. It now seems also that the influence of atmospheric dust on health depends, not on the gross amount of dust present, but on whether or not the peculiar kind of dust is harmful per se.

The problem of oxygen and carbon dioxide content need never worry us. Oxygen must fall to 16 per cent before important physiological reactions are involved. In the worst ventilated rooms, carbon dioxide rises only from 0.03 to 0.5 per cent, and this is still below the limit of physiological change.

The changes taking place in an unventilated room, as the result of human occupancy, may be summarized as follows:

1. Oxygen is reduced.
2. Carbon dioxide is increased.
3. Partially oxidized organic matter is given off.
4. Room temperature is raised by the heat liberated in the course of body oxidation.
5. Humidity is increased by the moisture given off in the breath and from the skin.

The first two changes may be dismissed from consideration, since it has been proved that they do not take place to such an extent as to affect the human organism. The harmful effects of organic matter cannot be substantiated, so we must look to the last two considerations for the illness due to bad air. Interference with the processes of body temperature regulation is the main point of discomfort.

In the human mechanism food and air are consumed and energy developed; because the body is inefficient in the delivery of energy for work, more heat is generated than is needed. Under normal conditions the human body develops over 300 B.t.u. of heat per hour. The excess heat is given off as:

1. Warm expired air.
2. Radiation from body surface.
3. Evaporation of perspiration.

In order to maintain temperature equilibrium, this heat must be eliminated. It has been found that the essential requirement of proper ventilation is the removal of this excess heat as it is developed. Therefore, the main requirement of a ventilation system is its cooling property. If the excess heat is not removed, the body temperature rises above the normal temperature of 98.6 deg., and discomfort, body disorders and even death may follow. The effect of this rise in temperature is dilation of the tiny blood vessels of the skin and pooling of the blood in these vessels. The consequent feeling of discomfort and lassitude is probably due to anemia of the brain and internal organs, due to this pooling of the blood in the capillaries.

It appears, then, that the essential criterion of an atmospheric condition is the net cooling effect which it exerts on the human body. This effect is determined by three factors: temperature of air; relative humidity, and movement of air. An ideal temperature for office work would be 66 to 68 deg., with about 50 per cent relative humidity. Small variations in humidity are unimportant. The third factor in ventilation is the extent to which radiation and evaporation are favored by the movement of air. In a still, warm atmosphere, the body is surrounded by a layer of hot and moist air. In order to promote radiation of heat from the body and evaporation of perspiration, this layer of air must be removed. However, too much air movement will produce drafts, a condition also injurious to the health.

To summarize, a good ventilating system will provide:

1. Temperature, 66 to 68 deg. fahr.
2. About 50 per cent relative humidity.
3. Air removal.

Effect of Poor Ventilation on Health

The New York State Commission on Ventilation has made an extensive laboratory study of the effect of overheating on health. These studies were conducted in two rooms especially equipped for the purpose at the College of the City of New York. One of these rooms was the observation room, which was insulated to prevent heat loss and exchange of gases through the walls. Heating and cooling coils were located within the room, and an elaborate system of ventilation made it possible to supply fresh air of any desired quality and quantity, or to recirculate the vitiated air of the room itself. The second chamber was the apparatus room and contained the fans, heaters and other apparatus necessary to control the atmosphere of the observation room and automatically record its condition. The experimenter manipulated valves and levers so as to expose the subject to various atmospheric conditions. The physiological reactions and mental and physical efficiency of the subject were constantly being studied, meanwhile, by physiologists and psychologists within the observation room itself.

These experiments were conducted almost continuously from December, 1913, to January, 1915. Squads of four subjects were usually used, and each experiment continued for as long a period as was necessary to obtain significant results. Altogether 113 persons were subjected to observation.

The chief atmospheric conditions studied were three in number:

1. 68 deg. fahr. with 50 per cent relative humidity.
2. 75 deg. fahr. with 50 per cent relative humidity.
3. 86 deg. fahr. with 80 per cent relative humidity.

The results obtained under these various conditions may be summarized, so far as physiological reactions are concerned, as follows:

First, the temperature of the body itself is slightly but definitely increased by a rise in atmospheric temperature. The average body temperature of the subject fell 0.8 deg. fahr. when exposed to the 68 deg. condition; it fell only 0.1 deg. when exposed to the 75 deg. condition; and it rose 0.2 deg. when exposed to the 86 deg. condition. The average final body temperature was 98.1 deg. at 68 deg. fahr.; 98.5 deg. at 75 deg. fahr., and 99.3 deg. at 86 deg. fahr.

The heart rate decreased markedly at 68 deg., but remained high at 75 deg. and 86 deg. The average final heart rates in the reclining position were 66 at 68 deg., 81 at 75 deg. and 74 at 86 deg.; in the standing position, 77 at 68 deg., 105 at 75 deg. and 99 at 86 deg. It is not certain whether the higher heart rate at 75 deg., as compared with 86 deg., is significant or not.

The most marked effect was that recorded by the Crampton Index, an arbitrary measure of the general efficiency of the circulation system. This measure is obtained by a comparison of blood pressure and pulse rate in the reclining and standing position. A high Crampton Index means that on standing up after lying down, the circulatory system is able to increase the blood pressure so as to meet the greater burden placed upon the system by erect posture without any marked increase in heart rate. A low index means that, on assuming an erect position, the heart beats much faster and that even then the blood pressure falls. In other words, it is a measure of the efficiency with which the circulation responds to a demand upon its power of adjustment. At 68 deg., the general average Crampton Index was 60; at 75 deg. it was 45; and 86 deg. it was 34. These results show a marked lowering of the efficiency of the circulating system with increased temperature.

The final symptom recorded was an increase in the rate of respiration, from an average of 17.9 at 68 deg. to 19.3 at 75 deg. and 19.7 at 86 deg.

The research laboratory maintained at Pittsburgh by the United States Bureau of Mines, the United States Public Health Service and the American Society of Heating and Ventilating Engineers has made a significant series of investigations in regard to the effects of more extreme overheating. The workers at this station equipped a carefully controlled experimental chamber which could be varied through a die range of temperatures, humidities and degrees of movement. Subjects in this chamber have been exposed to high temperature to the point at which a longer stay appeared definitely dangerous. The chief symptoms experienced were restlessness, irritability, headache, palpitation of the heart, soreness of the eyes, laziness and confusion. Weakness and a dragged-out feeling persisted for some time after such experiments had closed. The body temperature under prolonged heating rose several degrees. The pulse rate seemed to be the best measure of discomfort, 135 beats per minute corresponding to marked discomfort; and conditions becoming almost unbearable when the pulse rate exceeded 150 beats.

The results obtained under laboratory conditions are fully confirmed by practical experience. The unnatural conditions described above increase susceptibility to infection, and the resultant colds and respiratory diseases account for a large proportion of our absences from business.

Methods of Ventilation

The best method of ventilation or of cooling, to be employed in any particular case, can only be determined after careful analysis of accompanying circumstances and contributing factors. Each particular situation needs a separate solution.

Since the maintenance of a proper temperature, however, is the primary consideration in ventilating, no office room should be without a thermometer. This is probably the most important article of ventilating equipment, since it is impossible to consider ventilation without heating.

There are, in general, two types of ventilation, natural and artificial.

Natural ventilation operates to some extent even in closed rooms by heat loss through walls and ceiling. In crowded offices, however, natural ventilation is not likely to prove satisfactory. In warm weather temperature differences will provide an insufficient supply of air to remove either body odors or excess heat. On the other hand, in cold weather difficulties will be encountered as a result of inequalities of distribution. In a natural ventilating system, an outlet for warm air must be provided above and an inlet for cool air below. To properly use this system, continual watchfulness must be maintained over the outlet and inlet.

In offices special provision must usually be made for the removal of heated air and the supply of fresh cool air. Two methods are in general use:

1. Gravity Ventilation—Inlet and outlet openings are provided, but reliance for the movement of air is placed on the temperature difference between inside and outside air or chimney action.
2. Fan Ventilation—Inlet and outlet passage of air is forced by fan movement.

As a rough standard of ventilation requirements, 30 cu. ft. per person per minute may be set up. However, as heat conditions vary so much, any such standard is of necessity somewhat meaningless and must be changed to meet conditions. If the number of occupants of a room is not available, ventilating calculations may be carried out on the basis of the number of changes of air per hour over the whole room, which for the average office should be about six.

In using the method of gravity ventilation, choice in practice lies between fan supply with gravity exhaust and window supply with gravity exhaust. It has been found that a lower temperature is usually maintained in a window-ventilated room, but this room will be less perfectly aerated and will have less air movement. Fan ventilated rooms are apt to be drafty since the current of air moves more rapidly. The temperature in window-ventilated rooms is characterized by slight fluctuations and varies from 66 to 68 deg. fahr., while that in fan ventilated rooms varies from 68 to 70 deg. fahr.

Preference has been expressed for the window-ventilated room. It would appear then that coolness due to low temperature and relatively slight air movement is preferable to coolness produced by air motion in the presence of higher temperature.

If the window-supply gravity exhaust system is to be used, the following provisions should be made:

1. Radiators, equipped with automatic control, should be located beneath the window and extended for the full length of the window.
2. Deflecting boards should be placed at the bottom of the window.
3. Windows should open easily at the bottom.
4. Exhaust ducts should be placed on the wall opposite the windows, dampered so that the area may be adjusted to varying weather conditions. These exhaust ducts should be carried up through the middle of the building to avoid chilling. The tendency to back drafts may be further reduced by an aspirating cowl placed on the opening at the roof.

The choice between window and fan intake rests in general on two considerations:

1. Relative desirability of surrounding the body with a rapidly moving current of warmer air or a more moderate current of cooler air.
2. Relative cost of construction and operation of the two types.

In large crowded spaces, where little opportunity may be afforded for ventilation through the walls and ceiling, we must sometimes resort to fan ventilation. Two types of fan are in general use in forced ventilation:

1. Propeller
2. Centrifugal

The propeller fan operates on the principle of an ordinary desk fan, having curved vanes which drive the air at right angles to the general plane in which the fan itself revolves. This type will move considerable volumes of air, but only against low pressure. It is well adapted to supplement natural ventilation. However, this type is not suitable where air must be moved against considerable pressure, as in duct systems of ventilations.

For duct ventilation the centrifugal type of blower fan should be used. In this fan air is drawn in by lateral openings at the center of the plane of revolution and forced out through a tangential duct by the action of a series of parallel blades. This type may be used as either a plenum or an exhaust fan. It is used as a pressure or plenum fan when it delivers to the ventilating duct and draws in the supply freely from an air chamber. The centrifugal type may also be used as an exhaust fan, and the central opening is connected to the ventilating duct and the delivery is to the outer air.

The essential parts of a system of forced ventilation are the fan chamber, fans and ducts. From the fan chamber the air is delivered to the various parts of the building by a system of ducts carried up, through, or along the walls. These ducts must be so proportioned as to distribute the air evenly between the different parts of the building. Many systems of fan ventilation fail to give satisfactory results because the ducts are imperfectly proportioned. Also, even where the work is properly done, the system must be intelligently operated to secure the right results. Individual duct dampers should be provided so that the air supply to each room can be independently governed. It is important to secure equable distribution of air within the different parts of the room itself. Air velocity at room inlets should not be excessive, probably not over 300 ft. per minute. If it is desired to provide an air supply of 80 cu. ft. per person per minute, the inlet registers in any room should have a total area .of 0.1 cu. ft. per person.

Air conditioning is not completed by bringing in, distributing and removing an adequate supply of fresh outdoor air. However, this may improve previous conditions tremendously at a small cost, and that may be all that is practical. In almost all offices the expense of equipment to control air supply absolutely will not be justified. Variability is a recognized essential of an invigorating atmosphere. It might also be said that artificial humidification, while necessary to some manufacturing processes, does not seem to have an appreciable effect on human health and efficiency. Avoidance of overheating is the primary essential of good ventilation.

There are many schemes of ventilation on the market which embody slightly different principles. One of these is the recirculation system. This system may be used independently or as an adjunct of open-window ventilation. Recirculation requires a double system of ducts, which is somewhat of a disadvantage. The hot, odorous air is taken off the top of the room, while at the same time vent openings at the floor remove the cold air and recirculate it.

It is claimed that this method produces the required motion of the air without overheating. An automatic control must be installed on the surplus heat outlet, to determine the volume of air moved.

Unit ventilating is another special application of ventilation principles. Under this system the air comes directly from outdoors, is cleaned by air filter, heated and distributed. Each room is provided with a complete unit, making it unnecessary to run the entire ventilating system, if only a few rooms are in use. Each unit is provided with automatic temperature regulation. Then, if quick heating is desired, the fresh air damper may be closed, allowing the air of the room to circulate by gravity through the radiator. This system has been found satisfactory and economical in many cases.

In Conclusion

In conclusion, it might be said that "eternal vigilance" is the price of good ventilation. No system will work under all conditions without regulation. Its effectiveness will be influenced by wind velocity and direction, outside temperature, relative humidity and number of occupants of the rooms ventilated. A change in conditions will necessitate a change in area of duct or window opening, a different rate of heat supply, or attention to some other mechanical factor.

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PUBLIC SPEAKING COMMITTEE

If a company is serving a public that is FRIENDLY and INFORMED, it is reasonable to assume that that company is enjoying good public relations.

The only ways ever devised by man by means of which these results can be secured is through Performance, The Spoken Word and The Written Word.

Of the eight committees comprising the Public Relations National Section of the National Electric Light Association, one is known as the Public Speaking Committee.

The Public Speaking Committee deals primarily in The Spoken Word, although, to a considerable extent, it deals in Performance and The Written Word.

If we think this matter through, we are forced to the conclusion that any company will achieve good public relations if it develops a well balanced program which includes the three factors mentioned above, namely Performance, The Spoken Word and The Written Word. Likewise any company will fall short of achieving good public relations if it omits or fails to take advantage of these factors in its program. Therefore, public speaking becomes a very important activity in our industry.

It is important from two points of view. Our business is a public service business, and we are public servants. Therefore, we are obligated to acquaint the public about the economic value of our services to them; of how they can use our service to the greatest advantage. Some of our leaders have gone so far as to claim that our service is incomplete to the extent that we fail to take advantage of our opportunities to inform. In any event, it is self-evident that we will never have an informed public unless we inform, and public speaking offers that opportunity.

The other great value to the industry from organized public speaking is the value that comes to the individual employee who participates in that activity. While many employees may be unable to qualify as effective public speakers, still it is a matter of great importance and of great value to the industry to have every employee take public speaking training. Briefly the value is this: As the employee takes the training, gradually over a period of time he learns to stand on his feet and think constructively. He can effectively tell what he knows about the subject under discussion. It means that the employee learns more about his business, becomes more efficient, has a larger vision of his opportunities and his possibilities and his responsibilities, and this is reflected in his every contact with customers and friends. Public speaking training with this object in view will do as much to achieve good public relations as any activity any company can engage in.

In studies that have been made, it has been proved beyond any question of doubt that the impression the employee makes on the mind of the customer is twice as strong as all factors combined in determining the customer's estimate of the service. In other words, the impression left by contact with meter readers, collectors, telephone clerks, cashiers, sales people, complaint clerks, and so on, was twice as important as the promptness, dependability, efficiency and all around physical quality of the service itself.

Because public speaking activities are of such great importance, both to our customers and to our employees, it has been the purpose of this committee to encourage these activities, not only persistently and continuously, but to encourage our companies to carry on this work in a systematic, business-like way.

Two meetings of the committee were held last year, one in New York with an attendance of nineteen, and the other in Chicago with an attendance of twenty-six. At these meetings two important phases of work were engaged in. The first was the revision of our Handbook. This has since been published in two forms. The loose-leaf form intended for the use of executives and all who are active in public speaking. The other is a paper coveed book known as "The Electric Light and Power Industry in the United States."

While these books have not received as large a circulation as we could wish, it has been fairly generous. Thousands of copies have been placed with member companies, libraries, newspaper offices and the like. This book, with which many members are familiar and all should be, contains a total of twenty-three chapters. They cover:

History
The Electrical Industry and Research
Finances of the Electric Light and Power Industry
Customer Ownership
Regulation
Electric Rates
Cost of Manufacture and Ultimate Delivery
Steam Power
Water Power
Electricity in Industry
Electricity in the Home
Lighting
Meters
Rural Electrification
The Romantic History of Local Transportation
Advertising
National Statistical Survey
The Gas Industry
Radio Broadcasting
Public Speaking
Visual Education
Outline of Supplementary Facts on the Industry
Bibliography

In addition, the talks given at the Public Utility Conference at Grand Beach, Mich., in August, were included, as follows:

"Public Utility Information Bureaus" by H. M. Lytle, Vice-President, Chicago Rapid Transit Company.
"The Gas Industry," by B. J. Mullaney, Vice-President, The Peoples Gas Light & Coke Company.
"Street Railways," by A. W. Robertson, President, Pittsburgh Railways Company.
"Financing the Utilities," by Martin J. Insull, President, Middle West Utilities Company.
"Fallacies with Regard to the Utilities," by Howard T. Sands, Vice-President, Electric Bond & Share Co.
"Holding and Management Companies," by Halford Erickson, Vice-President, Byllesby Engineering & Management Corporation.
"State Regulations of Public Utilities," by William J. Hagenah, Vice-President and Special Counsel, Byllesby Engineering & Management Corporation.

Publication No. 289-77, Serial Report.

"Interconnection," by George N. Tidd, President, American Gas & Electric Company.

The Handbook is a real encyclopedia and can be used advantageously as a source of information for talks. In addition to that it can be used to great advantage as a text book in employee educational meetings.

To indicate what some thought of it, the committee wishes to quote what Mr. P. S. Arkwright, President of our Association and President of the Georgia Power Company, wrote us about it:

> "The Georgia Power Company has thought well enough of this book to purchase sufficient copies to place them in the hands of all of our officials and department heads. We have also made them available to interested employees. Copies also have been supplied to a number of our larger customers, libraries and similar organizations outside the company. We consider this worthwhile as a means toward educating our own employees and the public generally as to the true facts about the industry."

Another letter from Mr. E. G. Green, Educational Director, Oklahoma Gas & Electric Company, Oklahoma City Okla., the company of which Mr. J. F. Owens, Chairman of the Public Relations Section and Vice-President of N. E. L A., is Vice-President and General Manager, indicates their reaction:

> "We are finding the new N. E. L. A. HANDBOOK so valuable as a text and reference book in our public speaking classes in the Oklahoma Gas & Electric Company, that I feel prompted to write to you a word of appreciation, as chairman of the Public Speaking Committee of the National Electric Light Association, under whose direction the book was compiled.
>
> "In our advanced public speaking class, which we call the Public Speaking Forum, we have adopted the Handbook as a study text and an outline for the course of thirteen sessions. The chapters have been distributed over the period, and the student-members of the class secure their material from the chapter assigned for each meeting. Results have been excellent. We feel that this method not only informs the students regarding the electrical industry, but it also furnished them with good subjects for talks before the class and in other places.
>
> "Our work is not designed to train actors and Chautauqua orators, but rather to afford practice to the members of this company in straight business talking, such as may be used in committees, conferences, civic clubs, and the like.
>
> "And I feel that the chief element in the success of the course is the consistent use of the Handbook. Every public utility man should study it as the young men and women of the class to which I have referred are doing. It is a valuable contribution to the business."

These are but two of numerous letters that were received.

The other work engaged in by the committee this year was to develop a statement of Policies and Plans covering the purposes and scope of the public speaking committee and to work out a system of report. This statement follows:

Statement of Policies and Plans of the N. E. L. A. Public Speaking Committee

1. PURPOSE AND SCOPE—The purpose of the Public Speaking Committee is to assist in the dissemination of facts regarding the electric light and power industry primarily to employees and to qualify employees to address other groups when requested. It is axiomatic that employees well informed regarding the industry for which they work render better service to their employees and the public than those who are not, and that public speaking is an effective means of self-development. It is felt that much misunderstanding is caused by lack of understanding of facts, or by misinformation. A duty devolves upon those in the industry because of its quasi public character to provide and make available reliable, accurate and timely information.

   The scope of the committee, therefore, is to organize through the Geographic Divisions a bureau of public speakers, dealing with subjects pertaining to the electric light and power industry, and to assist in the training of employees of the industry so that they may present facts regarding the industry through the spoken word.

2. ORGANIZATION—The Public Speaking Committee recommends that a thorough plan of organization be perfected throughout each Geographic Division.

3. COMMITTEE ORGANIZATION—The Chairman of each Geographic Division automatically becomes a member of the National Committee. In addition there are several members-at-large. We recommend that the Chairmen of the Geographic Divisions perfect a similar committee whereby the chairman of each state would automatically become a member of his committee in addition to the appointment of several members-at-large; and that the state chairmen in turn organize the state in whatever manner is deemed most practicable.

4. EXECUTIVE RESPONSIBILITY—The executive of each operating company is directly responsible for public speaking activities within his territory, and in order to make any plan a success it should be understood that the individual operating company executive must be thoroughly informed of and interested in the plan before he will give it his unqualified cooperation and support to the extent of instructing his organization that this work is vitally important in rendering complete service to the public.

5. COOPERATION—In order that there be no duplication in organization set-up, there should be a very close cooperation with all public speaking organizations functioning at this time, such as those fostered by State Committees on Public Utility Information. Every possible effort should be made to make these public speaking organizations sufficiently broad to include the gas, electric railway and telephone industries.

6. SUGGESTIONS—After such an organization is perfected, any or all of the following may be undertaken:

   (a) *Lists of Speakers*

   Compile lists of experienced speakers now available, accompanied by detailed information concerning their experience, abilities, availability, etc.

   (b) *Lists of Organizations*

   Compile lists giving detailed information of all business organizations, clubs, schools and other organized groups throughout each Division, as it is helpful to know what organizations are liable to want speakers for regular programs.

   (c) *Development of Speakers*

   In order that an adequate number of speakers be developed, this committee recommends that executives, in cooperation with public speaking committee representatives, establish training classes in charge of competent instructors, wherever practicable to do so. In the larger centers this can be accomplished through employee educational meetings and regular classes; in the more scattered districts by means of employee meetings and two-day schools, which usually are held at some central point where operating companies adjacent to that point may send employees selected because of their possible public speaking abilities, the instructor giving an intensive two days' instruction. Such schools may be repeated from time to time. As rapidly as speakers develop proper ability they are given assignments.

   (d) *The Value of Public Speaking Training to the Individual*

   Undoubtedly the greatest benefit in training employee personnel in public speaking is the effect of such training on the individual employee.

   When the average employee is approached with a view to his training in public speaking, the immediate reaction is that he cannot do it, but after he has been tried out in a typical employee educational meeting, the possible benefits begin to appear.

There is created a desire to know not only about his individual job, but all jobs. He wants to know about the history and operation of his industry, about the laws under which it is operated and his responsibility to the public served.

In response to this desire to know, one sees the individual employee beginning to read and to study and to think as never before. His thinking is constructive and his thoughts crystallized.

Over a period of time he becomes conscious of additional knowledge and this additional knowledge gives him additional power, confidence and poise. He applies his increased knowledge to his daily tasks. He becomes more efficient. He exercises greater care in his personal appearance. He produces more and as a result the public receives a better and more satisfactory service.

As he is called upon to express his ideas and thoughts, either informally before individuals or formally before groups, he expresses himself accurately, correctly, courteously and effectively. Such contacts result in satisfied, pleased customers.

All of this, then, means that the relationship between the company, as represented by its employees, and the public, whom we serve, will be more pleasant and satisfactory, and to the individual employee it means a larger, more useful and happier life.

(e) *Filling Assignments*

Great care should be used in filling assignments. Only those should be sent who are really qualified and have a message for the particular group. Likewise, care should be exercised that repetition of messages be reduced to a minimum.

It is a matter of importance to the industry to know whether or not those who fill assignments are satisfactory to their audiences. A speaker is not necessarily a good judge. Comments received from the audience or from the secretary of the organization are liable to be only courteous expressions. It is well for executives in the community where the talk is made to attend the meeting, study the audience and the speaker in order to estimate the character and value of the address and to make an official report. This procedure is recommended wherever practicable.

When a speaker appears before an audience, it should be made clear under whose auspices he appears, and whom he represents. Any printed copies of the talk, or newspaper releases, should give the same information, and likewise the issuing source of copies or releases should be stated.

(f) *Subject Matter*

It is recommended that all speakers carefully observe the "Outline of Points and Facts which the Utility Industry wishes placed before the Public," as published by the association in August, 1927. All speakers not familiar with this outline should secure a copy directly from the N. E. L. A. Headquarters. Generally speaking, subjects of facts should be discussed and controversial subjects avoided. Subjects falling within the classification of civic and industrial development, economics, history, manufacture and distribution, rural electrification, safety and service can be made instructive and intensely interesting. Visual helps, such as motion picture films, slides and charts, can often be used advantageously.

The responsibility of speakers for accuracy of statement is emphasized. The information used by them should be from authentic sources.

While the use of skits and sketches, musical numbers, films (Unaccompanied by lectures) or other entertainment features, demonstrations and cooking schools cannot be classed as public talks, still they have value. All such activities should be encouraged.

(g) *Records*

To systematize our work, it is recommended that the following records be kept:

First: The Speakers' Record Card
Second: The Organization Record Card

The Speakers' Record Card would indicate the groups before whom a particular speaker appeared, subjects he discussed and the approximate audience in each case. The Organization Card would indicate what speakers have appeared before that organization, their subjects and the approximate audience in each case.

With such a record, the one responsible for making the assignments can always determine when a utility speaker appeared last before a particular group, what his subject and earlier subjects were, who the speakers were and thus be able to avoid duplication.

(h) *Publicity*

It is always a courteous thing for a speaker to prepare, well in advance, several paragraphs covering the high spots of his talk. These should be sent to the utility executive in the particular community several days in advance in order that it may be available if newspaper men wish to print articles regarding the meeting.

(i) *Reports*

A system of reports is recommended so that every talk before a public group will be reported by the local company in the particular town, through organization channels, to State, Division and National Committees.

These reports should be made monthly to the State and Geographic Division Organizations and annually to the National Organization. (See Fig. 1 and 2.)

(j) *Plant Visitation*

It is recommended that, where it meets with the wishes of the operating company, the speaker, or the utility executive, who presumably introduces him, use the opportunity to invite the public groups to visit local utility plants.

7. N. E. L. A. HANDBOOK—The Handbook is ready for distribution. It is recommended that this Handbook, which is in reality a text book for the industry and which is larger and more complete than ever before, can be used effectively by member companies, not only for public speaking purposes, but for employee educational meetings as well. We furthermore recommend that it be made available to anyone interested.

With such a statement every member company, knowing what the National Association desires in the way of information, can make provision in its organization for the keeping of these records, so that as requests are made from time to time through organization channels, it will be able to send to those who are appointed to carry on this work complete, accurate information.

The actual reports for this year are gratifying. A total of 36,887 talks to a total audience of 4,629,926, or 5603 talks to 764,456 more people than were reported in the last previous report.

A comparison of these activities for 1928 and 1927 by geographic divisions and States is shown in Table I.

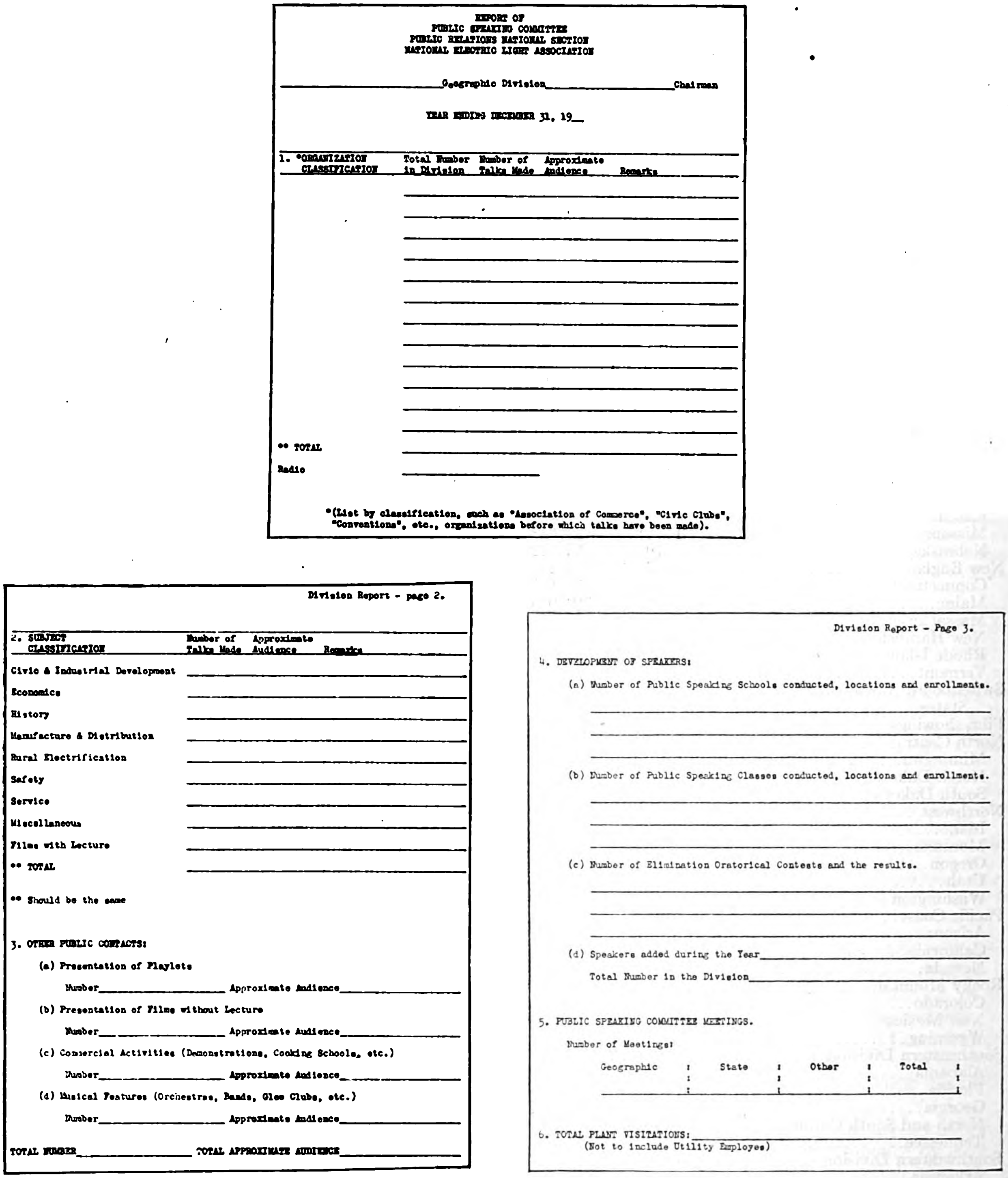
CONCLUSION

In conclusion the committee chairman wishes to express his appreciation for the splendid support and assistance he has received from the committee.

TABLE I

COMPARISON, PUBLIC SPEAKING REPORT, 1928-1927

Division	1928		1927		Increase		Decrease	
	No. of Talks	Audience	No. of Talks	Audience	No. of Talks	Audience	No. of Talks	Audience
Eastern	15,695	948,705	10,492	583,191	5,203	365,514	......	....
New York	13,064	669,136	9,720	456,364	3,344	212,772	......	....
New Jersey	2,217	203,668	65	13,900	2,152	189,768	......	....
Pennsylvania	414	75,901	707	112,927	......	....	293	37,026
East Central	439	41,235	348	40,292	91	943	......	....
Kentucky	99	11,735	145	17,717	......	....	46	5,982
Ohio	300	26,000	83	6,975	217	19,025	......	....
West Virginia	40	3,500	120	15,600	......	....	80	12,100
Great Lakes	7,691	1,335,208	7,147	1,309,762	544	25,446	......	....
Illinois	5,594	1,071,391	5,317	929,259	277	142,132	......	....
Indiana	474	62,161	416	89,937	58	....	......	27,776
Michigan	604	84,344	558	130,862	46	....	......	46,518
Wisconsin	1,019	117,312	856	159,704	163	....	......	42,392
Middle West	1,885	347,330	2,243	262,618	......	84,712	358	....
Iowa	246	10,000	196	8,850	50	1,150	......	....
Kansas	34	3,150	296	22,660	......	....	262	19,510
Missouri	1,411	318,658	1,285	206,086	126	112,572	......	....
Nebraska	194	15,522	466	25,022	......	....	272	9,500
New England	2,472	646,222	2,487	739,800	......	....	15	93,578
Connecticut	74	52,877	4	160	70	52,717	......	....
Maine	422	110,044	113	13,900	309	96,144	......	....
Massachusetts	1,502	425,059	553	52,942	949	372,117	......	....
New Hampshire	237	28,750	124	14,214	113	14,536	......	....
Rhode Island	115	12,577	113	12,496	2	81	......	....
Vermont	122	16,915	41	3,224	81	13,691	......	....
Switchboard demonstrations in 5 States	......	....	19	....	......	....	......	....
Film showings	......	....	1,520	626,603	......	....	......	....
North Central	414	24,050	405	24,985	9	....	......	935
Minnesota	......	....	227	15,570	......	....	......	....
North Dakota	......	....	86	4,181	......	....	......	....
South Dakota	......	....	92	5,234	......	....	......	....
Northwest	217	27,865	461	46,144	......	....	244	18,279
Idaho	......	....	......	....	......	....	......	....
Montana	......	....	......	....	......	....	......	....
Oregon	......	....	342	38,000	......	....	......	....
Utah	......	....	119	8,144	......	....	......	....
Washington	......	....	......	....	......	....	......	....
Pacific Coast	782	84,521	657	66,137	125	18,384	......	....
Arizona	7	492	......	....	......	....	......	....
California	775	84,029	......	....	......	....	......	....
Nevada	......	....	......	....	......	....	......	....
Rocky Mountain	86	4,840	168	44,892	......	....	82	40,052
Colorado	......	....	113	33,483	......	....	......	....
New Mexico	......	....	23	4,269	......	....	......	....
Wyoming	......	....	32	5,140	......	....	......	....
Southeastern Division	1,056	112,667	2,371	316,649	......	....	1,315	203,982
Alabama	15	....	344	90,130	......	....	329	90,130
Florida	35	1,175	82	12,300	......	....	47	11,135
Georgia	35	....	319	21,395	......	....	284	21,395
North and South Carolina	100	....	150	15,000	......	....	50	15,000
Tennessee	871	111,492	1,476	177,824	......	....	605	66,332
Southwestern Division	6,150	1,057,283	4,505	431,000	1,645	626,283	......	....
Arkansas	57	8,270	65	6,000	......	2,270	8	....
Louisiana	175	21,930	410	45,000	......	....	235	23,070
Mississippi	14	1,910	55	5,000	......	....	41	3,090
Oklahoma	3,804	774,173	2,450	250,000	1,354	524,173	......	....
Texas	2,100	251,000	1,525	125,000	575	126,000	......	....
Grand total	36,887	4,629,926	31,284	3,865,470	5,603	764,456	......	....



REPORT OF
PUBLIC SPEAKING COMMITTEE
PUBLIC RELATIONS NATIONAL SECTION
NATIONAL ELECTRIC LIGHT ASSOCIATION

__________ Geographic Division __________ Chairman

YEAR ENDING DECEMBER 31, 19__

1. *ORGANIZATION CLASSIFICATION	Total Number in Division	Number of Talks Made	Approximate Audience	Remarks
** TOTAL				
Radio				

*(List by classification, such as "Association of Commerce", "Civic Clubs", "Conventions", etc., organizations before which talks have been made).

Division Report - page 2.

2. SUBJECT CLASSIFICATION	Number of Talks Made	Approximate Audience	Remarks
Civic & Industrial Development			
Economics			
History			
Manufacture & Distribution			
Rural Electrification			
Safety			
Service			
Miscellaneous			
Films with Lecture			
** TOTAL			

** Should be the same

3. OTHER PUBLIC CONTACTS:

(a) Presentation of Playlets

Number__________ Approximate Audience__________

(b) Presentation of Films without Lecture

Number__________ Approximate Audience__________

(c) Commercial Activities (Demonstrations, Cooking Schools, etc.)

Number__________ Approximate Audience__________

(d) Musical Features (Orchestras, Bands, Glee Clubs, etc.)

Number__________ Approximate Audience__________

TOTAL NUMBER__________ TOTAL APPROXIMATE AUDIENCE__________

Division Report - Page 3.

4. DEVELOPMENT OF SPEAKERS:

(a) Number of Public Speaking Schools conducted, locations and enrollments.

(b) Number of Public Speaking Classes conducted, locations and enrollments.

(c) Number of Elimination Oratorical Contests and the results.

(d) Speakers added during the Year__________

Total Number in the Division__________

5. PUBLIC SPEAKING COMMITTEE MEETINGS.

Number of Meetings:

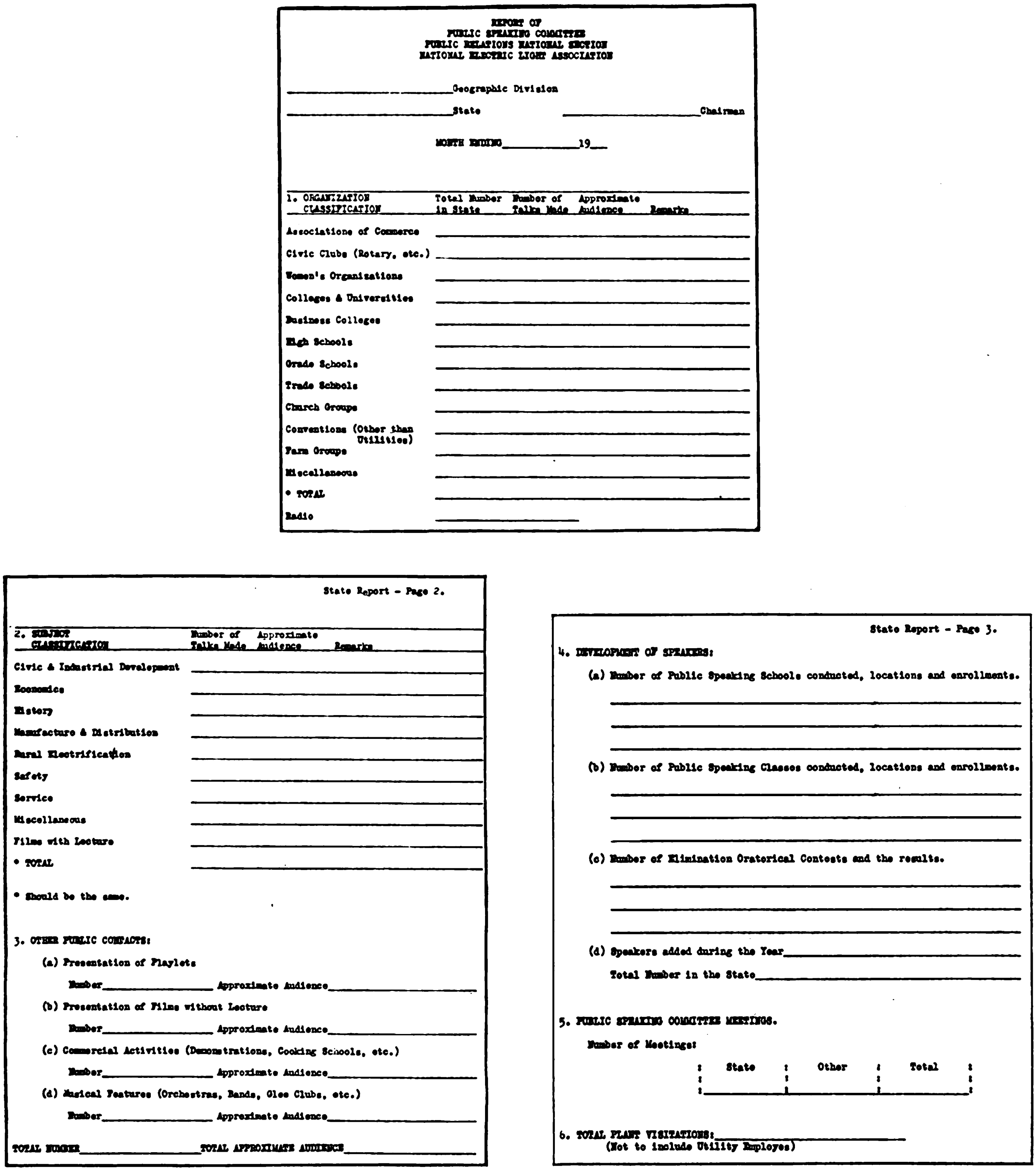
Geographic	State	Other	Total

6. TOTAL PLANT VISITATIONS:__________
(Not to include Utility Employes)

FIG. 1—ANNUAL REPORT FORM.

As committee meetings have been called, the members have generously responded and have given of their time, money and effort in helping to make this work successful.

As in previous years the officers and members of the staff at headquarters have been of great help, for all the members of the committee, like its chairman, are engaged in specific activities in the field, and as publications or reports are undertaken by the committee, the burden of editing and publishing falls upon headquarters. Our committee has nothing but praise for Mr. George F. Oxley, the Director of the Department of Public Information, who never fails us. The Geographic Division officers, even more than in former years, have generously supported the program recommended by the Committee.



REPORT OF
PUBLIC SPEAKING COMMITTEE
PUBLIC RELATIONS NATIONAL SECTION
NATIONAL ELECTRIC LIGHT ASSOCIATION

______________________Geographic Division

______________________State ______________________Chairman

MONTH ENDING__________19__

1. ORGANIZATION CLASSIFICATION	Total Number in State	Number of Talks Made	Approximate Audience	Remarks
Associations of Commerce				
Civic Clubs (Rotary, etc.)				
Women's Organizations				
Colleges & Universities				
Business Colleges				
High Schools				
Grade Schools				
Trade Schools				
Church Groups				
Conventions (Other than Utilities)				
Farm Groups				
Miscellaneous				
• TOTAL				
Radio				

State Report - Page 2.

2. SUBJECT CLASSIFICATION	Number of Talks Made	Approximate Audience	Remarks
Civic & Industrial Development			
Economics			
History			
Manufacture & Distribution			
Rural Electrification			
Safety			
Service			
Miscellaneous			
Films with Lecture			
• TOTAL			

• Should be the same.

3. OTHER PUBLIC CONTACTS:

(a) Presentation of Playlets

Number__________ Approximate Audience__________

(b) Presentation of Films without Lecture

Number__________ Approximate Audience__________

(c) Commercial Activities (Demonstrations, Cooking Schools, etc.)

Number__________ Approximate Audience__________

(d) Musical Features (Orchestras, Bands, Glee Clubs, etc.)

Number__________ Approximate Audience__________

TOTAL NUMBER__________TOTAL APPROXIMATE AUDIENCE__________

State Report - Page 3.

4. DEVELOPMENT OF SPEAKERS:

(a) Number of Public Speaking Schools conducted, locations and enrollments.

(b) Number of Public Speaking Classes conducted, locations and enrollments.

(c) Number of Elimination Oratorical Contests and the results.

(d) Speakers added during the Year__________

Total Number in the State__________

5. PUBLIC SPEAKING COMMITTEE MEETINGS.

Number of Meetings:

State	Other	Total

6. TOTAL PLANT VISITATIONS:__________
(Not to include Utility Employes)

FIG. 2—MONTHLY REPORT FORM.

While there are still a few who do not appreciate the importance of this activity, their numbers are growing fewer, and as our executives are becoming better acquainted with the possibilities of this work, of its value in their respective organizations and its value to the public, and as they realize that the more both customers and employees are informed, the more harmonious and satisfactory their relations are going to be, just naturally the more this work is going to be done, so for next year we predict that there will be more and better talks throughout the entire country.

ADDENDUM

ELECTRIFICATION OF STEAM RAILROADS

Program of the Committee

The Committee on Electrification of Steam Railroads adopted a definite program in 1926 which it was foreseen would require several years to complete. During this period the program should be repeated each year as the keynote of the Committee's activity:

1. To study railroad electrification in a general way, avoiding technical details.
2. To analyze railroad electrifications already made and to develop the fundamental reasons for, and the results of, these electrifications.
3. To promote cooperation between the executives of railway and power companies in order to develop a clearer understanding of each other's problems and requirements in connection with railroad electrification.

An understanding of this program will make clear the viewpoint of the Committee and the object of its studies.

Work of the Year

The Committee continued to maintain an office in Chicago as described in the 1928 report. The membership has been slightly increased to better represent the different interests involved, until there are at the end of the year 27 members. They represent four general divisions as follows: eleven from railroad companies, eleven from power companies, three from manufacturing companies and two consulting engineers.

Several members of the Committee are members of similar committees of other technical associations, thus providing a certain amount of cooperation and interchange of information. It is hoped that some time a plan may be worked out for greater correlation of the work of these various committees whereby overlapping of activities may be decreased. One of the good reasons for such an arrangement is to lessen the calls made upon the railroads for information and statistics.

The Committee maintains a large file of descriptive data and statistics for the preparation of its annual reports and statistical summaries. It also furnishes general information on steam railroad electrification to persons and companies who are interested in such research.

Exhibit at Chicago

On Nov. 15, 1928, the Electric Association of Chicago held its annual dinner meeting at which cooperation with the railroads was the keynote. President Crowley of the New York Central Lines made the address, and extracts from his remarks are given herewith in Appendix C.

This meeting was largely attended by railroad and central station executives from all over the country. Many members of this Committee attended in a group. The Committee prepared a special edition of its 1928 Report for distribution at the meeting, and an exhibit of the progress of electrification which is illustrated in Fig. 1. On the left of the exhibit was a panoramic view of the Virginian Railway, which was described in the report being distributed. On the right of the exhibit was depicted the present ex-

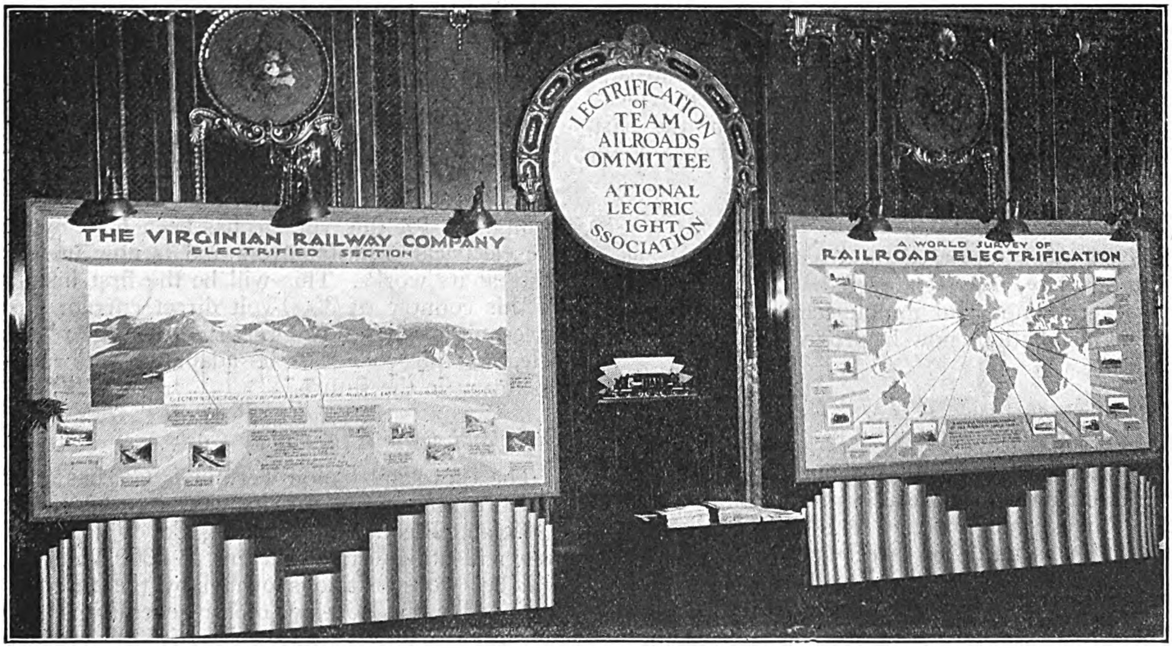

THE VIRGINIAN RAILWAY COMPANY
ELECTRIFIED SECTION
LECTRIFICATION OF TEAM AILROADS OMMITTEE
ATIONAL LECTRIC IGHT SSOCIATION
A WORLD SURVEY OF
RAILROAD ELECTRIFICATION

FIG. 1—Exhibit at Electric Association Dinner.

Publication No. 289-118, Serial Report, Electrification of Steam Railroads Committee.

tent of electrification. All the electrified sections were shown on a large paneled map of the world, with photographs inserted to illustrate the types of motive power used in the United States.

Subcommittees

This year for the first time two subcommittees were appointed on "Electrification in Europe" and "Standard Form of Contract." The Subcommittee on Electrification in Europe made a trip through the principal countries of western Europe and submitted a report which is appended hereto. The Subcommittee on Standard Form of Contract made a study of the contracts now used in this country for the sale of energy to electrified railroads. From this study they have outlined the desirable features to include in such a contract. The report of this subcommittee is also appended.

Statistical Tables

Statistics of electrical installations by steam railroads in the United States and all other countries are given in Table I, "Condensed Analysis of Installations of Electrical Operation on Steam Railroad Lines." This table is practically complete for the end of the calendar year 1928 and summarizes all the installations made since the beginning of electrification in 1895. Table II, "Physical Characteristics of Operation on Electrified Sections of Steam Railroads," presents summaries of the electrical equipment, traffic and energy for the United States, Canada and Mexico, and for all other countries and railroads from which the statistics have been received.

Recent Progress of Electrification

The past year has seen the extension of many electrifications and the purchase of considerable additional equipment, in the way of locomotives and motor cars. Several sections which had been in process of construction for some time previous were turned over to electric operation. Several railroads are known to have taken bids on initial electrifications, but the new projects announced in the past year were mostly by roads that had already some electrification.

United States

Since the last report of the Committee three electrifications have been completed. There have also been several important announcements with regard to other installations now in progress or planned for the future.

Boston, Revere Beach & Lynn R. R.

The Boston, Revere Beach & Lynn Railroad has completed the electrification of its narrow-gage system. Electric operation was commenced in October, 1928. An overhead contact line of simple-catenary construction is used for direct current at 650 volts.

Great Northern Railway

The Great Northern Railway has finished the installation work in its new Cascade Tunnel so that complete electric operation began on Jan. 12, 1929. This electrification has been described in previous reports. As one result of the new tunnel, the previous electrification, which was restricted to an older and shorter tunnel, has been replaced by an 8-mile tunnel and an electric division about 75 miles in length. Electric locomotives haul the regular freight and passenger trains by means of single-phase power from an overhead contact line energized at approximately 11,000 volts.

Pennsylvania Railroad

The Pennsylvania Railroad has completed the electrification of additional suburban routes in its Philadelphia district. The new services are from Philadelphia to Chester and Wilmington, and from Philadelphia to Media and West Chester. On Oct. 31, 1928, this company announced the authorization of a very large new project which covers the passenger and freight service on 325 miles of line and 1300 miles of track. When this improvement is completed, about 1937, the Pennsylvania Railroad and subsidiaries will have a total of nearly 2300 miles of track operated entirely with electricity. The full text of the announcement is copied in Appendix C of this report.

Reading Company

The Reading Company, on Nov. 12, 1928, made formal announcement of its plans for electrification in the vicinity of Philadelphia. The first stage of electrification will embrace only the suburban service, but it is intimated that probably extensions will be made to New York, Bethlehem and Reading. The length already authorized is 49.5 miles of route with 110 miles of track. Multiple-unit trains will be run from a single-phase 11,000-volt contact line (similar to the Pennsylvania Railroad's system in the same territory). The complete announcement is repeated here in Appendix C.

Delaware, Lackawanna & Western R. R.

The Delaware, Lackawanna & Western Railroad has selected for its suburban electrification near New York 3000-volt direct current with overhead contact line. Multiple-unit cars will be used. Some new equipment for this voltage has been built by one of the electrical manufacturers and is now undergoing tests at its works. This will be the first installation in this country of 3000-volt direct current on multiple-unit coaches. It is reported that one reason for selecting this voltage is its adaptability to main-line operation in the future.

Cleveland Union Terminals Co.

The Cleveland Union Terminals Co. has arranged to purchase power for its electric zone from the Cleveland Electric Illuminating Co. This electrification will utilize direct current at 3000 volts. There will be two substations owned by the railroad and equipped with 3000-kw. motor-generator sets. One substation will have a capacity of 6000 kw. and the other 9000 kw. The substations will be automatic, unattended, and operated by synchronous supervisory control. It is planned to have this new development in service by the early part of 1930.

Lehigh Valley Railroad

The Lehigh Valley Railroad is reported to be making estimates on the cost of electrifying its main line between Mauch Chunk and Wilkes-Barre, Pa. About 75 miles of double track is involved.

Illinois Central Railroad

The Illinois Central Railroad, which has been operating its suburban passenger service by electricity since 1926, has ordered 4 electric locomotives for freight switching in the Chicago Terminal division. These locomotives will be delivered in 1929. They will weigh 100 tons each, with a one-hour rating of 1465 h.p. The power supply will be 1500-volt direct current from overhead contact line, the same as the suburban service.

The Illinois Central is also using for freight switching an oil-electric locomotive weighing 100 tons, and will make service tests of a combination locomotive weighing 85 tons. The latter is a self-charging storage-battery unit that can be run either with or without a contact line. It is of the type called "general purpose locomotive," with all weight on drivers, and intended primarily for switching service. It can operate directly from a contact line at 750 or 1500 volts, or can run on power from the battery. The battery may be charged in two ways, either from the contact line through a motor-generator set, or by means of two small oil-engine generating sets.

Foreign Countries

The principal countries of Europe are covered by the report of the Subcommittee on Electrification in Europe. Progress in other countries of the world is described in the following paragraphs.

Argentina

The Central Argentine Railway was authorized, in January, 1929, to proceed with the extension of its suburban electrification which now extends from Buenos Aires to Tigre via Victoria. The new project includes the line from Buenos Aires to Tigre via Coghlan and the line from Coghlan to Villa Ballester, a total of 26 miles. The project also involves doubling the power station capacity, and the addition of automatic substations with supervisory control.

The Central Terminal Railway of Buenos Aires is constructing 5½ miles of double-track subway penetrating the main business district of Buenos Aires. This construction contemplates that the passenger trains of the Buenos Aires Central Railway will operate through the subway from the present terminal to a new passenger terminal to be constructed within the business district.

Australia

The New South Wales Government Railways are engaged in converting to electric traction the remainder of their large suburban services at Sydney. Electrification of two principal lines to the north and the south suburban districts was completed in 1927. Electrification in the western suburbs has been carried as far as Homebush during 1928. It is expected that the change-over will be all finished in 1930, comprising about 400 track miles.

Belgium

It is reported that the Brussels-Antwerp line of the Belgian State Railways is to be electrified. The distance is 30 miles. This will be the first electrification of main-line railways in Belgium.

Brazil

Since 1921 the Paulista Railway has been steadily engaged in the extension of its electrified zone. In September, 1928, the road inaugurated electrified service from Rio Claro to Rincao, 95 miles in length, making a total of 179 route miles operated by electricity. Plans now in hand call for the electrification, and widening to their normal gage of 63 in., of the sections from Rincao to Porto Cemiterio, 145 miles in length, and the branch from Ityrapina to Jahu, a distance of 108 miles.

Egypt

The Egyptian State Railways have had under consideration for some time the electrification of a suburban line from Cairo Terminus to Helwan, a distance of 16 miles. Tenders for the conversion were opened in February, 1929, and it is expected that the work will be completed in about eighteen months. The objects are to improve and speed up the service and to cause development of the territory. Economy is also expected from better ability to accommodate the service to the needs of traffic.

Hungary

The Hungarian Government is reported to have negotiated arrangements for construction of a large power development in the brown coal district. One of the objects is to make available electric power for electrification of the principal trunk railway between Budapest and the Austrian frontier near Vienna.

India

The Great Indian Peninsula Railway has been progressively electrifying a considerable part of its system since 1925. From Bombay to Kurla and Bandra was completed in 1925 and early 1926. The main line from Bombay to Thana was completed in 1926, and from Thana to Kalyan in 1928.[1] Work is now in progress on two divisions from Kalyan to Poona and from Kalyan to Igatpuri respectively. The whole project covers some 180 miles of route, with 1500-volt direct current, and using both locomotives and motor cars.

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[1] Latest extension not yet included in Table I.

TABLE

CONDENSED ANALYSIS OF INSTALLATIONS OF EL

Name of Railroad	Location	Electric Mileage			System of Electrification Installed			
		Route	Main Track	All Track	Volts	Phases	Cycles	Contact Line
UNITED STATES:								
Baltimore & Ohio Railroad (A)	Baltimore Tunnel	3.60	7.20	9.06	675	......	D.C.	3R.
	Staten Island Rapid Transit Lines	28.00	43.20	50.00	600	......	D.C.	3R.
Boston & Maine Railroad	Hoosac Tunnel, Massachusetts	7.92	15.83	21.38	11,000	1	25	O.H.
Boston Revere Beach & Lynn Railroad	East Boston, Lynn and Winthrop, Mass	13.80	27.60	31.00	650	......	D.C.	O.H.
Butte, Anaconda and Pacific Railway	Butte, Anaconda, Rocker; Montana	37.38	37.38	122.75	2,400	......	D.C.	O.H.
Chic., Milwaukee, St. Paul & Pac. R.R.	Harlowton, Mont.—Avery, Idaho	440.10	441.69	578.02	3,000	......	D.C.	O.H.
	Othello, Tacoma and Seattle, Washington	218.41	230.45	305.38	3,000	......	D.C.	O.H.
	Great Falls Yard	0.00	0.00	6.20	1,500	......	D.C.	O.H.
Delaware, Lack. & Western R. R.	Wallabout freight terminal, Brooklyn, N. Y.	0.00	0.00	1.08	600	......	D.C.	O.H.
Detroit, Toledo & Ironton R. R.	Fordson, Flat Rock; Michigan	16.58	33.16	50.05	22,000	1	25	O.H.
Erie Railroad	Rochester, Mt. Morris; New York	34.00	38.00	38.00	11,000	1	25	O.H.
Ft. Dodge, Des Moines & So. R. R.	Ft. Dodge, Des Moines, Rockwell; Iowa	146.60	146.60	195.03	1,200	......	D.C.	O.H.
Great Northern Railway (B)	Skykomish, Wenatchee; Washington	72.80	72.80	87.50	11,500	1	25	O.H.
Illinois Central Railroad	Chicago—Richton, Illinois; and branches	37.80	107.12	127.10	1,500	......	D.C.	O.H.
Long Island Railroad	New York & Brooklyn to western part of Long Island	122.82	285.22	364.95	650	......	D.C.	3R.
	Bay Ridge, Fresh Pond Junction; New York	11.93	37.93	84.43	11,000	1	25	O.H.
Michigan Central Railroad	Detroit, Michigan—Windsor, Ontario	4.51	9.02	28.55	650	......	D.C.	3R.
New York Central Railroad	New York, Croton, White Plains and branches	63.10	211.84	328.32	650	......	D.C.	3R.
N.Y., N. H. & Hartford R. R.	Nantasket Jc. to Pemberton, Mass	6.87	13.74	16.61	650	......	D.C.	3R.& O.H.
	Providence, Warren, Bristol, Fall River	23.91	40.69	48.50	650	......	D.C.	O.H.
	New York to Woodlawn (C)	11.95	48.71	48.71	650	......	D.C.	3R.
	Woodlawn, N. Y., to New Haven, Conn., including Harlem River Branch	75.22	324.04	509.88	11,000	1	25	O.H.
	Stamford to New Canaan, Connecticut	7.92	7.92	9.78	11,000	1	25	O.H.
	South Norwalk to Danbury, Connecticut	23.72	23.72	31.01	11,000	1	25	O.H.
	Port Morris to Fresh Pond and Sunnyside Yards; New York	9.00	25.80	25.80	11,000	1	25	O.H.
New York, Westchester & Boston Ry.	Bronx, Rye, White Plains; New York	23.44	62.67	67.50	11,000	1	25	O.H.
Norfolk & Western Railway	Bluefield—Iager, West Virginia; and branches	63.70	152.16	209.54	11,000	1	25	O.H.
Pennsylvania Railroad	Camden—Atlantic City; New Jersey	75.00	145.73	150.38	650	......	D.C.	3R.
	New York, N. Y.; Manhattan Transfer, N. J	13.41	50.84	110.08	675	......	D.C.	3R.
	Philadelphia, Paoli, Chestnut Hill; Pennsylvania	36.16	113.53	125.15	11,000	1	25	O.H.
	Philadelphia, West Chester, Pa.—Wilmington, Del.	52.60	140.10	150.06	11,000	1	25	O.H.
Southern Pacific Railroad	Oakland, Alameda, Berkeley; California	50.03	98.19	118.85	1,200	......	D.C.	O.H.
The Virginian Railway	Mullens, West Virginia—Roanoke, Virginia	134.00	156.00	231.00	11,000	1	25	O.H.
ARGENTINA:								
Buenos Aires & Western Railroad (E)	Buenos Aires, Moreno	25.38	68.35	78.30	800	......	D.C.	3R. & O.H.
Central Argentine Railway	Buenos Aires, Victoria, Tigre	35.17	41.76	53.77	800	......	D.C.	3R.
AUSTRALIA:								
New South Wales Government Rys.	Sydney and suburbs	63.50	167.00	197.25	1,500	......	D.C.	O.H.
Victorian Railways	Melbourne and suburbs	163.98	338.31	406.47	1,500	......	D.C.	O.H.
AUSTRIA:								
Austrian Federal Railways	St. Polten, Mariazell, Gusswerk	56.78	....	....	5,000	3	25	O.H.
	Innsbruck, Scharnitz	19.49	....	....	15,000	1	16⅔	O.H.
	Reutte, Schober	19.22	....	....	15,000	1	16⅔	O.H.
	Vienna, Hainburg (to border near) (L)	37.76	....	....	15,000	1	16⅔	O.H.
	Stainach-Irdning, Attnang-Puchheim	66.74	....	....	15,000	1	16⅔	O.H.
	Innsbruck, Feldkirch, Bregenz (also Buchs, Switzerland)	132.05	....	138.42	15,000	1	16⅔	O.H.
	Innsbruck, Worgl, Kufstein	45.30	....	82.34	15,000	1	16⅔	O.H.
	Worgl, Saalfelden	49.30	....	....	15,000	1	16⅔	O.H.
Vienna City Railway	Vienna	16.70	32.23	37.21	800	......	D.C.	O.H.
BOLIVIA:								
Guaqui to La Paz Railway	La Paz—Alto	5.28	6 52	8.70	575	......	D.C.	O.H.
BRAZIL:								
Paulista Railway	Jundiahy, Campinas, Tatu, Rio Claro	83.90	....	111.90	3,000	......	D.C.	O.H.
	Rio Claro, Rincao	95.00	....	....	3,000	......	D.C.	O.H.
Western Minas Railway	Barra-Mansa, Augusto-Pestana	45.00	....	....	1,500	......	D.C.	O.H.

GENERAL NOTES

D.C.—Direct Current.
O.H.—Overhead
3R—Third Rail.
4R—Four Rails.

The dates in column entitled "Year Electrified" are for the placing in operation of the original electrification and of the most recent important addition thereto.

UNITED STATES
A—Originally overhead; changed to third rail in 1901.
B—Old Cascade Tunnel electrified with 3-phase in 1909; changed to 1-phase and extended in 1927; new tunnel with extension opened in 1929, and old tunnel abandoned.
C—Operates on tracks of New York Central.
ARGENTINA
E—Overhead contact line in Port Zone for locomotive operation.
AUSTRIA
L—550 volts, direct current, in city of Vienna.

: I

ECTRICAL OPERATION ON STEAM RAILROAD LINES

Year Electrified	Traffic Affected	Reasons for Electrification	Results of Electrification
1895	Freight and Passenger	Eliminate smoke in tunnel	Capacity increased; operating costs lowered; smoke eliminated.
1925	Suburban Passenger	Legislation; tunnel operation; terminal switching	Facilities increased; operating economies.
1911	Freight and Passenger	Increase capacity; eliminate smoke in tunnel	Tunnel operation facilitated; capacity increased.
1928	Suburban Passenger	Reduce operating costs; increase efficiency of service	Reduction of headway; use of fewer scheduled cars.
1913	Freight and Passenger	Increase capacity; general economy	Fewer trains, fewer delays; increased tons per train, annual saving.
1915–1916	Freight and Passenger	General economy; increase capacity; heavy grades; tunnels	Capacity increased; traffic increased; operating econ's.
1919–1920	Freight and Passenger	General economy; increase capacity; heavy grades; tunnels	Capy. increased; traffic increased; operating economies.
1915	Freight Switching		
1926	Freight Switching	City ordinance; eliminate smoke	Smoke eliminated.
1926	Freight	Increase facilities; eliminate smoke; Detroit city ordinance	Smoke eliminated; efficiency increased.
1907	Passenger	Increase capacity	Capacity and facilities increased; economy.
1906–1912	Freight and Passenger	Increase facilities; reduce operating costs	Operating costs reduced; facilities increased.
1927–1929	Freight and Passenger	Decrease operating costs; eliminate smoke in tunnel; increase speed of trains	
1926	Suburban Passenger	Increase facilities; eliminate smoke; agreement with Chicago	Higher speed; more trains accommodated; increased patronage.
1905–1926	Freight and Passenger	Improve suburban service; facilitate terminal operation; tunnels; legislation	Smoke eliminated; facilities increased; faster service.
1927	Freight	To facilitate through freight operation with N.Y., N.H. & H.R.R.; also legislative requirement	Smoke eliminated; economies in handling through traffic
1910	Freight and Passenger	Eliminate smoke in tunnel	Capacity and speed improved; operating economies.
1906–1926	Passenger	Operation through tunnel; improve service; increase facilities	Smoke eliminated; capacity increased; air rights developed.
1895	Passenger	Increase traffic by improved service	Service improved and traffic increased.
1901	Passenger	Increase traffic by improved service	Service improved.
1907	Passenger	Legislation prohibiting steam operation in tunnel; terminal operation; increase facilities	Facilities increased.
1907–1914	Freight and Passenger	Increase facilities; general economy	Facilities increased.
1908	Freight and Passenger	Increase facilities; general economy	Facilities increased.
1925	Freight and Passenger	Increase facilities; general economy	Facilities increased.
1918–1927	Freight and Passenger	Increase facilities; general economy	Facilities increased.
1912	Suburban Passenger	Increase facilities	
1915–1925	Heavy Freight	Grades; tunnels; increase capacity	Capacity increased; operating economies.
1906	Passenger	Increase traffic by improved service and facilities	Revenue increased by increased traffic; oper'g economies.
1910	Passenger	Legislation; tunnel; new terminal in New York	
1915–1924	Freight and Passenger	Suburban traffic; congested terminal	Terminal capacity increased.
1928	Suburban Passenger	Suburban traffic; congested terminal	Terminal capacity increased.
1911	Passenger	Increase facilities; eliminate smoke	
1925	Heavy Freight	Increase capacity; heavy grades; tunnels	Increased capacity; reduced fuel and operating costs.
1923	Suburban and Freight	Improve service; increase capacity; tunnel operation	Traffic increased by improved service and capacity increased.
1916	Suburban Passenger	Better service with faster schedules	Capacity increased; faster schedules; general economy; increase in traffic.
1926–1928	Suburban Passenger	Increase capacity	
1919–1923	Suburban Passenger	Increase facilities; general economy	
1907	Freight and Passenger	Increase capacity; grades; tunnels; conserve fuel; use water power	Operating economies; increased facilities.
1912	Freight and Passenger		
1912	Freight and Passenger		
1914	Freight and Passenger	Increase traffic	Traffic increased.
1924	Freight and Passenger	Tunnels and heavy grades; utilize water power	
1925–1927	Freight and Passenger	Increase capacity; tunnels and heavy grades; conserve fuel	Smoke eliminated; capacity increased.
1927	Freight and Passenger	Increase capacity; tunnels and heavy grades; conserve fuel	Smoke eliminated; capacity increased.
1928	Freight and Passenger	National policy; conserve fuel	
1925	Passenger	Agreement in lease-contract with city	Smoke eliminated.
1905	Freight and Passenger	To shorten ascent and use average grade of 6.5 percent	Reduction in running time; fuel economy.
1921–1926	Freight and Passenger	Coal scarcity; heavy grades; increase capacity	Capacity increased; operating economies.
1928	Freight and Passenger	Coal scarcity; heavy grades; increase capacity	
1927	Freight and Passenger	Heavy grades; conserve fuel	

TABLE I—

CONDENSED ANALYSIS OF INSTALLATIONS OF EL

Name of Railroad	Location	Electric Mileage			System of Electrification Installed			
		Route	Main Track	All Track	Volts	Phases	Cycles	Contact Line
CANADA:								
Canadian National Railways	St. Clair Tunnel; Port Huron, Michigan; Sarnia, Ontario	3.67	7.34	12.19	3,300	1	25	O.H.
	Montreal, Cartierville, St. Eustache	17.20	25.40	32.20	2,400		D.C.	O.H.
Montreal Harbour Commissioners	Montreal Harbour Lines	19.00	38.00	63.00	2,400		D.C.	O.H.
CHILE:								
Anglo-Chilean Cons. Nitrate Corp.	Tocopilla, Tigre	24.92	24.92	31.57	1,500		D.C.	O.H.
Bethlehem Chile Railway	Tofo, Cruz Grande	15.00	15.00	24.00	2,400		D.C.	O.H.
Chile Exploration Co.	Chuquicamata	16.26	16.26	21.66	660		D.C.	3R. & O.H.
Chilean State Railways	Valparaiso, Los Andes, Santiago	144.00		233.00	3,000		D.C.	O.H.
Chilean Transandine Railway (D)	Rio Blanco, Chile—Argentine Border	22.37	22.37	23.71	3,000		D.C.	O.H.
CHINA:								
South Manchuria Railway	Fushun, Colliery	25.00		43.00	1,200		D.C.	O.H.
CUBA:								
Hershey Cuban Railway	Havana—Matanzas	54.37	83.58	110.92	1,200		D.C.	O.H.
United Railways of Havana	Havana and Suburbs	101.28	127.37	167.76	650		D.C.	O.H.
CZECHOSLOVAKIA:								
State Railways	Tabor, Bechyn	14.50			700		D.C.	O.H.
	Prague and vicinity	16.00		40.00	1,500		D.C.	O.H.
FRANCE:								
Midi Railway (F)	Bordeaux, Dax, Toulouse and branches	541.24	883.63		1,500		D.C.	O.H.
Paris, Lyons and Mediterranean	Chambery, St. Pierre d'Albigny	15.50	31.00	35.00	1,500		D.C.	3R.
Paris-Orleans Railway (G)	Paris, Vierzon and branches	148.20	395.83	585.36	1,500		D.C.	O.H.
State Railway of France	Paris (St. Lazare), Versailles and St. Germain	27.09	54.18		650		D.C.	3R.
	Paris (Invalides), Versailles	11.97	23.94	28.10	650		D.C.	3R
GERMANY:								
German Government Railways	Silesia near Breslau and Gorlitz	215.00			15,000	1	16⅔	O.H.
	Brown Coal District near Leipzig and Magdeburg	114.34			15,000	1	16⅔	O.H.
	Bavaria near Munich	422.56			15,000	1	16⅔	O.H.
	Bavaria near Munich	11.18			1,000		D.C.	O.H.
	Baden near Basel	29.83			15,000	1	15	O.H.
	Saxony near Plauen	3.11			650		D.C.	O.H.
	Hamburg Harbor	1.24			3,000	1	25	O.H.
	Hamburg Suburban	20.51			6,000	1	25	O.H.
	Berlin Suburban	139.82			800		D.C.	3R.
	Berlin Suburban	5.59			550		D.C.	3R.
HUNGARY:								
Hungarian State Railways	Budapest, Alag	9.50		25.00	15,000	1	50	O.H.
INDIA:								
Bombay, Baroda & Cen. India Ry.	Borivli, Bombay, Colaba	23.00		67.70	1,500		D.C.	O.H.
Great Indian Peninsula Railway	Harbor Line: Bombay, Bandra, Kurla	10.50		23.00	1,500		D.C.	O.H.
	Main Line Sub.: Bombay, Kurla, Thana	33.00		73.00	1,500		D.C.	O.H.
ITALY:								
Italian State Railways (R)	Milan, Varese, Porto Ceresio	45.11			650		D.C.	3R.
	Lecco, Sondrio & Colico, Chiavenna	65.62			3,000	3	15	O.H.
	Monzo, Lecco	23.18			3,700	3	16⅔	O.H.
	Genoa to Ceva, Ronco, Leghorn, etc.	270.99			3,700	3	16⅔	O.H.
	Turin to Modane, Ronco, etc.	264.47			3,700	3	16⅔	O.H.
	Naples, Pozzuoli, Villa Literno	22.06			650		D.C.	3R.
	Florence, Poretta, Bologna	81.90			3,700	3	16⅔	O.H.
	Benevento, Foggia	63.01			3,000		D.C.	O.H.
	Rome, Avezzano	67.11			10,000	3	45	O.H.
	Bolzano, Brennero	55.49			3,700	3	16⅔	O.H.
	Trento, Male	37.04			800		D.C.	O.H.
	Brunico, Campo Tures	9.51			800		D.C.	O.H.
North Milan Railway	Milan, Bovisa, Saronno & Bovisa, Meda	31.00	62.00		3,000		D.C.	O.H.
Valli di Lanzo Railway	Turin, Ceres	26.10			4,000		D.C.	O.H.
JAPAN:								
Chichibu Railway	Kumagya, Kagemori	35.00			1,200		D.C.	O.H.
Japanese Government Railways	Tokio Suburban: Yamate line (H)	17.70	35.40	40.40	1,200 & 1,500		D.C.	O.H.
	Tokio Suburban: Keihin line (H)	27.90	55.80	65.40	1,500		D.C.	O.H.
	Tokio Suburban: Chuo line (H)	19.50	39.00	45.90	1,200		D.C.	O.H.
	Usui Line: Yokogawa, Karuizawa (I)	6.90	6.90	13.40	650		D.C.	3R.
	Tokio, Ofuna, Kozu, Atami & Ofuna, Yokozuka	101.28	222.15	299.51	1,500		D.C.	O.H.
Yoshino Railway	Yoshino, Yoshinoguchi	7.20			1,500		D.C.	O.H.

CHILE

D—Will operate in unison with electric traction of Argentine Transandine when the latter road has completed its electrification. Combined rack and adhesion on electrified section.

FRANCE

F—Electrification started in 1910 with 12,000 volts, 1 phase, 16 2/3 cycles. Approximately 70 miles were electrified but have since been changed to 1500 volts d-c.

G—First electrification made in 1900-1904 from Paris to Juvisy with 600 volts d-c. Changed to 1500 volts in 1924.

ITALY

Mileages electrified by Italian State Railways in Table I are for end of 1928, but in Table II are for year 1927.

JAPAN

H—Part of Tokio city, circle and suburban system.

I—Combined rack and adhesion on electrified section.

(*Continued*)

ECTRICAL OPERATION ON STEAM RAILROAD LINES

Year Electrified	Traffic Affected	Reasons for Electrification	Results of Electrification
1908	Freight and Passenger	Grades; smoke in tunnel; increase capacity	Capacity increased 100%; tunnel operation improved.
1918–1927	Freight and Passenger	Operation in tunnel and residence section	Tunnel operation facilitated; capacity increased.
1922	Freight	Increase capacity	Capacity increased; smoke eliminated; better efficiency in winter.
1927	Freight and Mixed	Heavy grades; difficult to obtain water; high cost of fuel	Increased speed and tonnage; lower costs.
1916	Freight	Heavy grades; scarcity of water	
1926	Freight	Reduce operating costs	Cost per ton-mile greatly reduced.
1924	Freight and Passenger	Increase capacity; heavy grades; scarce coal	Capacity increased; operating economies.
1927	Freight and Passenger	Heavy grades; tunnel operation; expensive fuel	Capacity increased; smoke eliminated.
1914	Freight and Passenger		
1920	Freight and Passenger	Grades; high cost of fuel	
....	Freight and Passenger	High cost of fuel	
1903	Freight and Passenger	Increase capacity; conserve fuel	
1928	Freight and Passenger	Tunnel operation; eliminate smoke	
1910–1928	Freight and Passenger	Increase capacity and speed on heavy grades	Capacity increased; fuel saved.
1925	Freight and Passenger	Heavy grades; long tunnels; plenty of water power	Capacity increased; fuel saved.
1900–1924	Freight and Passenger	Increase capacity and facilities; reduce consumption imported coal	Capacity increased; annual coal consumption reduced.
1900–1928	Passenger	Improve service; increase capacity.	Traffic increased by improved service and increased capacity.
1900	Passenger	Long grade; tunnel about 2 miles long	Satisfactory.
1914–1928	Freight and Passenger	Grades; congestion; use local coal	
1922–1927	Freight and Passenger	Use brown coal not suitable for steam locomotives	
1912–1928	Freight and Passenger	Utilize water power	
1908–1909	Freight and Passenger	Utilize water power	
1913	Freight and Passenger		
1916	Passenger	Heavy grades	
1911	Freight		
1908–1924	Suburban Passenger	Increase capacity; eliminate smoke; general economy	
1924–1928	Suburban Passenger	Increase capacity; eliminate smoke; general economy	
1903	Suburban Passenger	Increase capacity; eliminate smoke; general economy	
1924	Freight and Passenger	Experiment with electric traction	
1928	Suburban Passenger		
1925–1926	Suburban Passenger	Heavy suburban passenger traffic	
1926	Suburban Passenger	Heavy suburban passenger traffic	
1901–1902	Suburban Passenger	Heavy suburban passenger traffic	Excellent.
1902	Freight and Passenger	Tunnels; grades; conserve coal; use water power	Excellent.
1914	Freight and Passenger	Tunnels; grades; conserve coal; use water power	Excellent.
1911–1928	Freight and Passenger	Tunnels; grades; conserve coal; use water power	Very satisfactory; capacity and traffic increased; operating economy.
1912–1924	Freight and Passenger	Tunnels; grades; conserve coal; use water power	Very satisfactory; capacity and traffic increased; operating economy.
1925–1927	Freight and Passenger	Improve service; long new tunnel under city	
1927	Freight and Passenger	National policy; conserve coal; use water power	
1927	Freight and Passenger	National policy; conserve coal; use water power	
1928	Freight and Passenger	National policy; conserve coal; use water power	
1929	Freight and Passenger	National policy; conserve coal; use water power	
	Freight and Passenger		
	Freight and Passenger		
1929	Suburban Passenger	Increase capacity; improve service; bus competition	
1921	Freight and Passenger		
1922	Freight and Passenger	Heavy grades	
1908	Passenger	Increase capacity	Capacity increased.
1909–1928	Passenger	Increase capacity	Capacity increased.
1904–1922	Passenger	Increase capacity	Capacity increased.
1912	Freight and Passenger	Increase capacity; tunnels; heavy grades	Capacity increased; tunnel operation facilitated.
1925–1928	Freight and Passenger	Increase capacity	Capacity increased.
1922–1923	Freight and Passenger	Heavy grades	

TABLE I—

CONDENSED ANALYSIS OF INSTALLATIONS OF EL

Name of Railroad	Location	Electric Mileage			System of Electrification Installed			
		Route	Main Track	All Track	Volts	Phases	Cycles	Contact Line
MEXICO:								
El Potosi Railway	El Potosi Mine, Morse Smelter	14.91	17.39	18.64	600	.....	D.C.	O.H.
Mexican Railway	Esperanza, Orizaba, Paso del Macho	64.00	64.00	70.23	3,000	.....	D.C.	O.H.
MOROCCO:								
Moroccan Railway	Sale, Casablanca, Kourigha	158.46	158.46	....	3,000	.....	D.C.	O.H.
NETHERLAND EAST INDIES:								
Java State Railway	Tandjong Priok, Batavia, Meester Cornelis	24.85	56.00	75.00	1,500	.....	D.C.	O.H.
NETHERLANDS:								
Netherlands Railways (U)	Amsterdam, The Hague, Rotterdam and branches	83.89	167.78	217.49	1,500	.....	D.C.	O.H.
NEW ZEALAND:								
New Zealand Government Railways	Otira, Arthurs Pass	8.40	....	13.40	1,500	.....	D.C.	O.H.
	Christchurch, Lyttleton	6.33	....	....	1,500	.....	D.C.	O.H.
NORWAY:								
Norwegian State Railways	Narvik, Riksgrensen (J)	26.10	26.10	40.39	16,000	1	15	O.H.
	Oslo, Drammen	31.69	39.77	62.14	15,000	1	15	O.H.
	Oslo, Lillestrom	13.05	26.10	50.95	15,000	1	15	O.H.
	Notodden, Tinnoset	18.64	18.64	22.37	10,000	1	16⅔	O.H.
Rjukan Railway	Rjukan, Moel	9.94	9.94	12.99	10,000	1	16⅔	O.H.
Thamshavn Railway	Thamshavn, Lokken	15.00	....	....	6,000	1	25	O.H.
SPAIN:								
Spanish Northern Railway	Ujo, Busdongo	38.53	38.53	49.72	3,000	.....	D.C.	O.H.
	Barcelona, Moncada, Manresa	39.77	79.54	93.21	1,500	.....	D.C.	O.H.
	(Barcelona), Moncada, San Juan de las Abadesas	65.90	65.90	73.90	1,500	.....	D.C.	O.H.
Catalan Railway	Barcelona, San Baudilio	7.46	13.67	14.60	1,500	.....	D.C.	O.H.
Spanish Southern Railway	Nacimineto, Gador	18.64	....	....	5,500	3	.....	O.H.
SWEDEN:								
Swedish State Railways	Riksgrensen, Kiruna, Lulea (J)	287.00	....	....	16,000	1	15	O.H.
	Stockholm, Gothenburg	286.00	....	....	16,000	1	16⅔	O.H.
Mellersta Ostergotland Railway	Linkoping, Vadstena, Motala	44.70	....	....	10,000	1	25	O.H.
Nordmark Klaralvens Railway	Filipstad, Karlstadt and branches	101.37	101.37	123.32	16,000	1	25	O.H.
Lund Bjarred Railway	Lund, Bjarred, Malmo	6.80	....	....	16,000	1	16⅔	O.H.
SWITZERLAND:								
Bernese Alps Railway	Bonigen, Spiez, Brig, Simplon	73.40	....	....	15,000	1	16⅔	O.H.
	Schwarzenburg, Bern, Thun, Spiez, Zweisimmen	83.80	....	....	15,000	1	16⅔	O.H.
Burgdorf-Thun Railway	Burgdorf, Thun	25.50	....	....	750	3	40	O.H.
Emmenthal Railway	Burgdorf, Langnau	13.70	....	....	750	3	40	O.H.
Freiburg Railway	Freiburg, Murten, Ins	20.50	....	....	840	.....	D.C.	......
Martigny-Orsieres Railway	Martigny, Orsieres	12.40	....	....	8,000	1	15	O.H.
Montreux-Oberland Railway	Montreux, Zweisimmen, Lenk	53.45	....	59.66	1,000	.....	D.C.	O.H.
Rhaetian Railway	Chur, Filisur, St. Moritz; Chur, Davos, Filisur; and branches	171.57	171.57	198.59	11,000	1	16⅔	O.H.
Sihlthal Railway	Zurich, Sihlbrugg	11.80	....	....	15,000	1	16⅔	O.H.
Swiss Federal Railways	Simplon Tunnel (K)	13.70	....	....	3,300	3	16⅔	O.H.
	Lucerne, Emmenbrucke, Wildegg (K)	34.20	1,598.24	2,338.32	5,500	1	25	O.H.
	General System	979.90	....	....	15,000	1	16⅔	O.H.
UNION OF SOUTH AFRICA:								
South African Railways	Pietermaritzburg, Glencoe	171.00	....	287.00	3,000	.....	D.C.	O.H.
	Cape Town, Sea Point and Simonstown	26.65	....	67.00	1,500	.....	D.C.	O.H.
UNITED KINGDOM:								
Great Western Railway	Bishop's Road, Westbourne Park, Hammersmith (O)	4.02	8.24	9.88	600	.....	D.C.	4R.
	Ealing, Wood Lane (O)	4.19	8.37	8.74	600	.....	D.C.	3R.
London, Midland & Scottish Ry.	London and suburbs: General System (Q)	39.10	77.00	88.10	630	.....	D.C.	4R.
	London and suburbs: Campbell Rd. Jct., Barking (N)	5.00	10.40	14.30	600	.....	D.C.	4R.
	Liverpool, Southport, Crossens, Omskirk	37.00	87.10	93.90	600	.....	D.C.	3R.
	Manchester, Bury, Holcombe Brook	13.90	25.67	28.85	1,200	.....	D.C.	3R.
	Lancaster, Morecambe, Heysham	9.50	18.80	19.50	6,600	1	25	O.H.
London & North Eastern Railway	Newcastle, Tynemouth	31.75	68.25	80.50	600	.....	D.C.	3R.
	Shildon, Newport	18.50	42.25	48.25	1,500	.....	D.C.	O.H.
Mersey Railway	Liverpool, Birkenhead	4.78	9.55	11.86	650	.....	D.C.	4R.
Southern Railway	London Suburbs: Western section	89.00	....	250.00	650	.....	D.C.	3R.
	London Suburbs: East-central section	175.00	....	489.00	650	.....	D.C.	3R.
	London Suburbs: Central section (P)	30.00	....	108.00	6,600	1	25	O.H.
VENEZUELA:								
LaGuaira & Caracas Railway	LaGuaira, Caracas	22.68	22.68	24.85	1,600	.....	D.C.	O.H.

NETHERLANDS

U—The line Rotterdam—The Hague—Scheveningen was electrified in 1908 with 6600 volts, single-phase, 25-cycles, changed in 1926 to 1500 volts d-c.

NORWAY AND SWEDEN

J—The line Narvik—Riksgrensen, in Norway with the line Riksgrensen—Kiruna—Lulea, in Sweden, form a unified system from the Atlantic to the Gulf of Bothnia.

SWITZERLAND

K—Transformation to 15,000 volts. 16 2/3 cycles, has been prepared.

UNITED KINGDOM

M—First electrification made in 1913 from Bury to Holcombe Brook with 3000-volt d-c. Changed to 1200 volts in 1916.

N—On London, Tilbury & Southend Line and operated jointly with the District Railway. No figures for the District Railway's operations are included in the Tables.

O—Operated jointly with the Metropolitan Railway.

P—The former London, Brighton & South Coast Railway electrification with 6600-volt a-c. is being gradually changed to 650-volt d-c., like the Southern Railway, of which it is now a part.

Q—Also operated over with jointly owned stock between Queens Park and Watford. No figures for this operation included in Table.

(*Concluded*)

ECTRICAL OPERATION ON STEAM RAILROAD LINES

Year Electrified	Traffic Affected	Reasons for Electrification	Results of Electrification
1925	Freight............	Capacity; grades; regeneration; economy........................	Capacity increased; operating economies; greater safety and reliability.
1924–1927	Freight and Passenger	Heavy grades; conserve fuel....................................	Operating economies; service more satisfactory.
1927	Freight and Passenger	Scarcity of coal and of good water for steam; plenty of water power; benefit of regeneration....................................	Higher speed; increased capacity; economy.
1925–1926	Suburban Passenger..	Conserve fuel by using water power..........................	Faster schedules.
1908–1927	Passenger...........	Increase capacity of road and stations........................	Capacity and traffic increased.
1924	Freight and Passenger	Heavy grades; five-mile tunnel................................	Capacity increased; smoke in tunnel eliminated.
1929	Freight and Passenger	Tunnel operation..	
1923	Freight and Passenger	To provide unified operation with Swedish line Lulea-Riksgrensen	Capacity increased
1922	Freight and Passenger	National policy; save coal; use water power......................	
1927	Freight and Passenger	National policy; save coal; use water power.....................	
1911	Freight and Passenger	Use water power..	
1912	Freight and Passenger	Cheap water power from associated industries..................	Favorable.
1908	Freight............	Heavy grades; high cost of fuel................................	
1924	Freight and Passenger	Heavy grades; sixteen miles of tunnels; increase capacity..........	Capacity multiplied about three times.
1929	Freight and Passenger	Increase traffic by improved service............................	Satisfactory.
1929	Freight and Passenger	Increase capacity and speed..................................	
1926	Freight and Passenger	Eliminate smoke in tunnel and subway terminal station...........	Smoke eliminated; faster service.
....	....	....	....
1915–1923	Freight and Passenger	Save fuel; use water power....................................	
1925–1926	Freight and Passenger	Save fuel; use water power....................................	
1908–1915	Freight and Passenger		
1921	Freight and Passenger	Reduce transportation charges.................................	Most favorable; operating costs reduced; capacity increased.
1916	Passenger...........		
1910–1927	Freight and Passenger	Utilize available water power; long heavy grade; tunnel 9 miles long.	
1920–1923			
1899	Freight and Passenger	Increase capacity; conserve fuel..............................	
1919			
1903			
1910	Passenger...........		
1901	Freight and Passenger		
1913–1922	Freight and Passenger	Save coal; heavy grades; increase capacity......................	Operating costs reduced.
1924			
1906	Freight and Passenger	Heavy grades; tunnel; save coal; use water power...............	
1910			
1918–1928	Freight and Passenger	National policy; save coal; use water power; increase capacity......	Coal conserved; operating economies; better service work provided for industries during post war depression.
1926	Freight and Passenger	Increase capacity over heavy grades...........................	Reduction in running time; better service.
1927–1928	Suburban Passenger..	Increase capacity..	Capacity increased; service improved.
1906	Suburban Passenger..	Increase capacity..	Capacity increased.
1920	Suburban Passenger..	To provide for working in tubes; increase capacity................	Capacity increased.
1914–1927	Suburban Passenger..	Develop suburban traffic......................................	Greatly increased residential traffic.
1905–1908	Suburban Passenger..	Enable through operation of Metropolitan Ry. trains.............	Traffic increased.
1904–1913	Suburban Passenger..	Tramway competition; increase capacity.........................	Capacity, speed and service improved; traffic increased
1916	Suburban Passenger..	Tramway competition; increase capacity.........................	Traffic increased.
1908	Passenger...........	Develop traffic..	Service improved.
1904	Freight and Passenger	Improve service in effort to increase traffic.....................	Traffic increased.
1915	Freight............	Great density of traffic......................................	Capacity increased.
1903	Passenger...........	Tunnel; grades; heavy expense.................................	Business increased; operating economies.
1915–1925	Suburban Passenger..	Increase traffic; increase capacity.............................	Increase in traffic.
1925–1929	Suburban Passenger..	Increase traffic; increase capacity.............................	Increase in traffic.
1909–1925	Suburban Passenger..	Increase traffic; increase capacity.............................	Increase in traffic.
1928	Freight and Passenger	Expensive fuel; heavy maintenance of steam locomotives..........	Economy; faster service; greater capacity.

TABLE II—PART I

PHYSICAL CHARACTERISTICS OF OPERATION ON ELECTRIFIED SECTIONS OF STEAM RAILROADS

Name of Railroad	Statistics for Year	Trackage Electrified			Tunnels		Ruling Grade			Electric Passenger Locomotives				Electric Freight Locomotives				Electric Passenger Motor Cars			Passenger Trailer Cars		Car Capacity	
											Largest Type				Largest Type				Largest Type					
		Gage	Route	All Track	Number	Aggregate Length	Against Heaviest Traffic	Length Against Heaviest Traffic	Maximum Curve on Ruling Grade	Number	Weight	Power	Tractive Effort	Number	Weight	Power	Tractive Effort	Number	Weight	Power	Number	Weight of Largest Type	Passengers Seated	Freight Tons
		Ins.	Miles	Miles	No.	Ft.	%	Ft.	Deg.	No.	Lb.	H.P.	Lb.	No.	Lb.	H.P.	Lb.	No.	Lb.	H.P.	No.	Lb.	No.	Tons
UNITED STATES:																								
Baltimore & Ohio Railroad:																								
Baltimore Tunnel (b)	1928	56.5	3.60	9.06	9	9,530	1.32	1,000	5.7	12	160,000	800	36,000	(a)	...	...	...	...	...	...	...	...	S	S
Staten Island Lines	1928	56.5	28.00	50.00	1	609	1.82	3,000	3.0	...	...	...	...	...	...	...	...	90	95,750	390	10	83,265	71	...
Boston & Maine Railroad	1928	56.5	7.92	21.38	1	25,080	0.75	9,500	4.0	(a)	...	...	...	7	265,000	1,360	18,480	...	...	...	...	...	S	S
Boston Revere Beach & Lynn R. R. (d)	1928	36.0	13.80	31.00	2	1,000	2.50	250	10.0	...	...	...	...	...	...	...	...	60	55,000	120	7	45,000	57	...
Butte, Anaconda & Pacific Railway (r)	1928	56.5	37.38	122.75	5	1,656	0.30	31,680	5.0	1	160,500	1,116	19,700	27	160,500	1,116	30,000	...	...	...	...	...	76	50
Chic., Milwaukee, St. Paul & Pacific:																								
Rocky Mountain Division	1928	56.5	440.10	578.02	35	29,515	1.70	116,160	10.0	9	620,000	3,400	49,000	27	576,000	3,000	70,700	...	...	...	...	...	S	S
Coast Division	1928	56.5	218.41	305.38	8	16,712	1.74	100,320	10.0	5	521,000	3,200	42,000	15	576,000	3,000	70,700	...	...	...	...	...	S	S
Delaware, Lack. & West. R. R. (k)	1928	56.5	...	1.08	0	...	...	...	...	...	...	...	...	1	102,840	220	25,700	...	...	...	...	...	...	S
Detroit, Toledo & Ironton Railroad	1927	56.5	16.58	50.05	...	...	0.25	1,900	...	...	...	...	...	2	372,000	...	...	...	...	...	...	...	...	S
Erie Railroad	1928	56.5	34.00	38.00	0	...	0.88	2,620	4.0	...	...	...	...	...	...	...	...	8	117,000	400	5	60,000	78	...
Fort Dodge, Des Moines & So. R. R.	1928	56.5	146.60	195.03	0	...	1.50	6,600	8.2	...	...	...	...	12	130,000	880	...	12	84,000	300	...	...	48	S
Great Northern Railway	1928	56.5	72.80	87.50	4	48,342	2.20	54,595	10.0	(a) 5	527,200	3,350	67,200	5	742,200	4,350	112,500	...	...	...	...	...	S	S
Illinois Central Railroad	1928	56.5	37.80	127.10	1	650	3.00	600	7.5	...	...	...	...	...	...	...	...	140	141,301	1,000	140	88,546	84	...
Long Island Railroad:																								
Suburban District	1928	56.5	122.82	364.95	2	9,300	1.30	5,800	4.0	7	313,000	2,130	10,200	8	313,000	2,130	10,200	742	117,200	450	250	75,000	80	S
Bay Ridge Division	1928	56.5	11.93	84.43	1	3,500	0.70	7,500	2.0	...	...	...	...	7	316,000	1,460	44,200	...	...	...	...	...	...	S
Michigan Central Railroad	1928	56.5	4.51	28.55	1	8,368	1.50	6,993	2.0	12	240,000	1,120	34,400	(a)	...	...	...	...	...	...	...	...	S	S
New York Central Railroad	1928	56.5	63.10	328.32	2	12,460	0.57	1,970	...	83	285,000	2,488	18,440	9	354,000	3,320	55,800	336	133,000	400	...	...	100	S
N.Y., N.H. & Hartford Railroad:																								
New York to Woodlawn (e)	1928	56.5	11.95	48.71	1	9,150	1.02	4,300	6.0	(f)	...	...	...	(f)	...	...	...	(f)	...	...	...	...	...	...
Woodlawn to New Haven, incl. Harlem River Branch	1928	56.5	75.22	509.88	0	...	1.00	660	1.5	71	356,000	1,680	23,300	73	282,000	1,345	24,800	65	176,000	680	103	103,600	120	S
Stamford to New Canaan	1928	56.5	7.92	9.78	0	...	1.40	528	0.0	(f)	...	...	...	(f)	...	...	...	(f)	...	...	...	...	...	...
South Norwalk to Danbury	1928	56.5	23.72	31.01	1	350	1.27	1,584	1.0	(f)	...	...	...	(f)	...	...	...	(f)	...	...	...	...	...	...
Port Morris to Fresh Pond & Sunnyside Yards	1928	56.5	9.00	25.80	0	...	0.75	1,056	0.0	(f)	...	...	...	(f)	...	...	...	(f)	...	...	...	...	...	...
Providence to Fall River	1928	56.5	23.91	48.50	1	5,080	1.29	1,056	6.0	...	...	...	...	...	...	...	...	22	102,000	...	39	...	77	...
Nantasket Jct. to Pemberton (g)	1928	56.5	6.87	16.61	0	...	1.23	1,056	9.0	...	...	...	...	...	...	...	...	8	61,800	320	17	...	56	...
New York, Westchester & Boston Ry.	1928	56.5	23.44	67.50	1	4,000	1.50	1,000	...	...	...	...	...	1	159,200	652	23,200	80	126,900	350	5	88,000	80	...
Norfolk & Western Railway	1928	56.5	63.70	209.54	17	16,800	2.00	18,480	12.0	...	...	...	...	16	828,000	4,750	108,000	...	...	...	...	...	...	100
Pennsylvania Railroad:																								
Camden to Atlantic City	1928	56.5	75.00	150.38	0	...	1.15	3,500	...	...	...	...	...	...	...	...	...	107	106,000	470	...	...	72	...
New York Terminal	1928	56.5	13.41	110.08	6	...	1.93	3,500	...	46	396,600	4,170	43,500	...	...	...	...	...	...	...	...	...	S	...
Phila., Wil'n, & W. Chester (d)	1928	56.5	52.60	150.06	0	...	1.10	3,500	...	...	...	...	...	...	...	...	...	123	118,600	450	...	...	72	...
Phila., Paoli & Chestnut Hill	1928	56.5	36.16	125.15	0	...	1.85	3,500	...	1	408,600	3,300	29,500	...	...	...	...	158	118,600	450	...	...	72	...
Southern Pacific Railroad	1928	56.5	50.03	118.85	1	467	5.25	1,940	15.0	...	...	...	...	...	...	...	...	87	117,400	560	60	67,200	116	...
The Virginian Railway	1928	56.5	134.00	231.00	19	18,480	2.07	63,360	12.0	...	...	...	...	14	1,282,380	7,125	162,000	...	...	...	...	...	...	120

ARGENTINA:																								
Buenos Aires & Western Railway	1928	66.0	25.38	78.30	2	19,685	3.80	410	7.0					2	137,812	920	19,700	76	127,900	800	97	78,300	93	50
Central Argentine Railway	1928	66.0	35.17	53.77	0		0.80	5,906	2.1									84	113,100	500	54	80,040	94	
AUSTRALIA:																								
New South Wales Govt. Railways	1928	56.5	63.50	197.25	2	1,513	2.50	13,200	6.7									307	112,500	720	295	78,750	79	
Victorian Railways	1928	63.0	163.97	406.47	3	1,075	2.50	5,280	4.3					3	123,312	760	14,160	385	116,137	560	476	61,376	92	45
AUSTRIA:																								
Austrian Federal Railways:																								
St. Polten, Mariazell, Gusswerk	1927	30.0	56.78		21	14,810	2.50		21.8	16	108,927	450		(a)										
Vienna, Hainburg	1927	56.5	37.76				3.00		7.0	15	116,865	800		(a)				7	30,000	118	9	17,200	28	
Stainach-Irdning, Attnang-Puchheim	1927	56.5	66.74		10	10,066	2.50		7.0	14	134,505	1,360		6	172,430	1,620								
Innsbruck, Feldkirch, Bregenz	1927	56.5	132.05	138.42	15	49,343	3.10		7.0	32	259,749	2,480		29	172,430	1,620								
Innsbruck, Worgl, Kufstein (z)	1927	56.5	45.30	82.34	21	24,220	2.30			(z)				(z)										
BOLIVIA:																								
Guaqui to LaPaz Railway	1928	39.4	5.28	8.70	0		7.00	1,476	17.4	2	44,100	250	7,200	3	42,997	200	6,500	3	19,845	100			32	
CANADA:																								
Canadian National Railways:																								
St. Clair Tunnel	1928	56.5	3.67	12.19	1	6,025	2.00	4,899	0.0	(a)				9	141,000	750	27,785						S	S
Montreal, Cartierville, St. Eustache	1928	56.5	17.20	32.20	1	16,632	0.60	15,840	2.0	6	166,000	1,260	20,200					2	164,000	500			86	
Montreal Harbour Commissioners	1928	56.5	19.00	63.00	0									9	200,000	1,600	65,000							S
CHILE:																								
Anglo-Chilean Cons. Nitrate Corp.	1928	42.0	24.92	31.57	0		0.00							7	132,300	980	21,785							
Bethlehem Chile Iron Mines Railway	1928	56.5	15.00	24.00	0		0.00							3	240,000	1,370	44,000							50
Chile Exploration Co.	1928	56.5	16.26	21.66					12.2					14	152,000	560	27,000							70
Chilean Transandine Railway	1928	39.4	22.37	23.71	51	21,080	8.00	5,709	8.7	3	187,866	1,920	70,560	(a)										
CUBA:																								
Hershey Cuban Railway	1928	56.5	54.37	110.92			4.00	13,124	12.2					11	120,000	820	30,000	25	65,000	220	5	47,200	50	33
United Railways of Havana	1928	56.5	101.28	167.76			1.57	7,808	2.0					13	120,000	900	22,200	64	70,000	300	7	36,000	62	
FRANCE:																								
Midi Railway	1928	56.5	541.24		35	66,417			8.7	50	149,940	1,400	22,050	60	167,580	1,400	35,280	29	121,275	700			80	50
Paris, Lyons and Mediterranean Ry.	1928	56.5	15.50	35.00						3	290,000	2,720	30,000	11	290,000	2,450	41,000							
Paris-Orleans Railway	1928	56.5	148.20	585.36	2	14,312	0.60	11,581	1.6	10	286,650	4,400	38,808	193	169,785	1,720	21,829	80	143,325	1,000	80	83,128	143	16
State Railway of France:																								
Paris (St. Lazare), Versailles, St. Germain	1928	56.5	27.09		5	4,294												107	119,070	660	103	82,687	86	
Paris (Invalides), Versailles	1928	56.5	11.97	28.10	3	11,470	1.00	39,371	3.5	12	136,710	1,200	22,050					42	185,220	660	18	110,250	90	
INDIA:																								
Great Indian Peninsula Ry.:																								
Harbor Line	1927	66.0	10.50	23.00	0		2.94	792	2.0									13	157,024	1,100	39	96,656	110	
Main Line Suburban	1927	66.0	33.00	73.00	3	4,916	0.66	8,184	0.0									23	149,716	1,100	69	73,920	110	
ITALY:																								
Italian State Railways:																								
Milan, Varese, Porto Ceresio	1927	56.5	45.09	91.45	2	1,159	2.00	6,234	5.8														80	22
Monzo, Lecco, & Lecco, Sondrio, etc.	1927	56.5	88.86	120.87	30	54,222	2.12	920	0.0														80	22
Genoa to Ceva, Ronco, Legnorn, etc.	1927	56.5	238.64	619.82	194	322,499	3.50	6,968	4.4														80	22
Turin to Modane, Ronco, etc	1927	56.5	191.79	449.27	28	72,195	3.00		2.3														80	22
Naples, Pozzuoli, Villa Literno	1927	56.5	22.93	44.98	5	37,239	0.80	12,533	1.7														80	22
Florence, Poretta, Bologna	1927	56.5	82.40	165.42	47	62,365	2.61	2,840	5.0														80	22
North Milan Railway		56.5	31.00	62.00	0									4	141,000	1,400	19,800	8	119,000	700	8	74,900	102	

GENERAL NOTES

Length of All Track electrified includes Main Track, Yard and Siding Track in electric zone (so far as equipped for electric operation).

Ruling Grade refers to grade against heaviest traffic and to curves on this grade.

Ratings of Locomotives and Cars owned, due to condensing for tabulation, are given for the largest type only of each kind. Horsepower and Tractive Effort are the one-hour ratings.

Average Number Trains Daily is number run in both directions.

Figures expressing length have been converted to (1) the English Foot, and (2) the Mile of 5280 ft.

Figures expressing weight have been converted to (1) the Pound Avoirdupois, and (2) the ton of 2000 lb. This applies likewise to the Ton-Miles and Kilowatt-hours per Ton-Mile.

TABLE II—PART I—(*Concluded*)

PHYSICAL CHARACTERISTICS OF OPERATION ON ELECTRIFIED SECTIONS OF STEAM RAILROADS

Name of Railroad	Statistics for Year	Trackage Electrified			Tunnels		Ruling Grade			Electric Passenger Locomotives				Electric Freight Locomotives				Electric Passenger Motor Cars			Passenger Trailer Cars		Car Capacity	
											Largest Type				Largest Type				Largest Type					
		Gage	Route	All Track	Number	Aggregate Length	Against Heaviest Traffic	Length Against Heaviest Traffic	Maximum Curve on Ruling Grade	Number	Weight	Power	Tractive Effort	Number	Weight	Power	Tractive Effort	Number	Weight	Power	Number	Weight of Largest Type	Passengers Seated	Freight Tons
		Ins.	Miles	Miles	No.	Ft.	%	Ft.	Deg.	No.	Lb.	H.P.	Lb.	No.	Lb.	H.P.	Lb.	No.	Lb.	H.P.	No.	Lb.	No.	Tons
JAPAN:																								
Japanese Government Railways:																								
Yamato Line	1928	42.0	17.70	40.40	0	...	1.35	...	5.8	...	...	...	...	...	...	...	...	139	87,163	536	173	54,816	64	...
Keihin Line	1928	42.0	27.90	65.40	0	...	0.55	...	5.8	...	...	...	...	...	...	...	...	165	86,744	536	171	58,454	64	...
Chuo Line	1928	42.0	19.50	45.90	2	2,304	0.62	...	5.8	...	...	...	...	...	...	...	...	170	87,163	536	145	52,214	56	...
Usui Line	1928	42.0	6.90	13.40	26	14,666	6.67	...	5.8	28	133,843	644	26,019	(a)	...	...	...	...	...	...	...	...	80	28
Tokiado Line	1928	42.0	101.28	299.51	27	62,955	1.52	...	4.3	54	238,140	1,850	20,947	15	133,182	1,287	27,562	...	...	...	...	...	80	28
MEXICO:																								
The Mexican Railway	1928	56.5	64.00	70.23	16	3,563	4.00	154,288	17.5	10	309,000	2,736	48,500	(a)	...	...	...	...	...	...	...	...	8	50
El Potosi Railway	1928	30.0	14.91	18.64	0	...	0.00	...	...	...	...	...	...	5	55,125	400	11,200	2	26,460	200	...	...	...	...
MOROCCO:																								
Moroccan Railways (j)	...	56.5	158.46	158.46	...	...	...	...	...	...	...	...	...	10	160,965	1,340	...	10	146,853	700	...	...	64	53
NETHERLAND EAST INDIES:																								
Java State Railway	1928	42.0	24.85	75.00	...	...	...	...	...	13	154,350	1,200	17,640	...	...	...	...	23	99,225	450	23	63,945	80	...
NETHERLANDS:																								
Netherlands Railways	1928	56.5	83.89	217.49	0	...	0.00	...	5.8	...	...	...	...	...	...	...	...	115	141,120	800	115	88,200	88	...
NEW ZEALAND:																								
New Zealand Government Railways	1927	42.0	8.40	13.40	1	28,050	3.00	36,960	5.8	(a)	...	...	...	5	112,000	680	...	...	...	...	...	...	...	...
NORWAY:																								
Norwegian State Railways:																								
Narvik, Riksgrensen	1928	56.5	26.10	40.39	23	15,257	0.20	...	0.0	...	...	...	...	9	299,880	2,800	44,100	...	...	...	...	...	...	...
Oslo, Drammen	1928	56.5	31.69	62.14	5	1,506	1.40	27,560	6.2	2	170,888	1,150	14,773	23	135,166	940	16,978	...	...	...	...	...	...	...
Oslo, Lillestrom	1928	56.5	13.05	50.95	0	...	2.60	9,219	2.2	(a)	...	...	...	9	147,294	1,400	19,183	...	...	...	...	...	...	...
Notodden, Tinnoset	1928	56.5	18.64	22.37	3	1,644	1.50	6,890	...	(a)	...	...	...	3	135,166	940	16,978	...	...	...	...	...	...	...
Rjukan Railway	1928	56.5	9.94	12.99	1	787	0.68	528	9.7	(a)	...	...	...	5	101,430	640	16,096	...	...	...	...	...	...	...
SPAIN:																								
Spanish Northern Railway:																								
Ujo, Busdongo	1928	66.0	38.53	49.72	70	83,665	2.00	6,086	5.8	(a)	...	...	...	12	176,400	1,620	27,562	...	...	...	...	...	92	22
Barcelona, Moncada, Manresa	...	66.0	39.77	93.21	20	6,621	1.65	17,773	6.3	(a)	...	...	...	12	225,250	2,280	42,997	14	145,971	920	14	116,203	86	22
Moncada, San Juan de las Abadesas	...	66.0	65.90	73.90	10	4,488	2.00	9,016	5.8	(a)	...	...	...	12	242,550	2,280	42,997	12	145,971	920	12	116,203	86	22
Catalan Railway	1928	39.4	7.46	14.60	1	3,937	1.20	3,609	17.5	4	81,585	400	13,230	(a)	...	...	...	...	...	...	...	...	52	18
SWEDEN:																								
Nordmark Klaralvens Railway	1928	35.1	101.37	123.32	1	163	1.20	15,027	5.8	15	89,500	485	...	(a)	...	...	...	1	60,417	120	...	...	90	20
SWITZERLAND:																								
Montreux-Oberland Ry.	1928	39.4	53.44	59.65	18	13,964	7.20	32,810	44.0	...	...	...	...	3	30,870	240	...	27	79,380	640	...	...	72	17
Rhaetian Railway	1928	39.4	171.57	198.59	77	99,480	4.50	51,259	17.5	27	145,971	1,200	21,388	(a)	...	...	...	...	...	...	185	40,792	60	28
Swiss Federal Railways	1928	56.5	1,027.80	2,338.32	229	532,788	2.70	...	6.3	286	220,500	2,000	18,301	55	288,855	2,460	41,895	45	187,425	800	...	...	72	...
UNION OF SOUTH AFRICA:																								
South African Railways (j)	...	42.0	171.00	287.00	...	...	1.50	...	...	(a)	...	...	...	95	147,840	1,200	...	...	...	...	...	...	...	...

UNITED KINGDOM:																								
Mersey Railway	1928	56.5	4.78	11.86	3	18,876	3.70	1,175	0.0	....	....	....	....	....	....	....	....	28	91,728	500	40	64,288	64	....
London & North Eastern Railway:																								
Newcastle, Tynemouth	1928	56.5	31.75	80.50	6	5,343	2.10	264	4.8	....	....	....	....	2	125,440	700	....	71	92,288	300	55	57,344	72	....
Shildon, Newport	1928	56.5	18.50	48.25	0	....	0.60	528	0.0	....	....	....	....	10	166,880	1,100	....	....	....	....	....	....	....	....
London, Midland & Scottish Ry.:																								
London and suburbs: General system	1928	56.5	39.10	88.10	10	15,948	2.00	1,254	1.7	....	....	....	....	....	....	....	....	135	125,440	1,120	218	67,200	96	....
London and suburbs: Campbell Rd. Jct., Barking	1928	56.5	5.00	14.30	0	....	1.10	759	0.0	....	....	....	....	....	....	....	....	45	66,080	450	45	41,440	48	....
Liverpool, Southport, Crossens, Omskirk	1928	56.5	37.00	93.90	3	2,268	0.97	1,650	0.0	....	....	....	....	....	....	....	....	90	150,080	1,000	115	67,200	115	....
Manchester, Bury, Holcombe Brook	1928	56.5	13.90	28.80	5	4,335	2.50	2,442	0.0	....	....	....	....	....	....	....	....	38	120,960	800	28	64,960	95	....
Lancaster, Morecambe, Heysham	1928	56.5	9.50	19.50	0	....	1.30	1,254	10.9	....	....	....	....	....	....	....	....	3	90,720	420	6	38,080	72	....
Great Western Railway:																								
Bishop's Rd., Westbourne Pk., Hammersmith	1928	56.5	4.02	9.88	2	714	1.39	2,178	6.7	....	....	....	....	....	....	....	....	46	91,840	600	92	51,520	60	....
Ealing, Wood Lane	1928	56.5	4.19	8.74	0	....	1.85	1,650	5.4	....	....	....	....	....	....	....	....	32	67,200	230	32	36,400	46	....
Southern Railway:																								
London Suburbs: Western Section	1928	56.5	89.00	250.00	3	2,830	....	....	....	....	....	....	....	....	....	....	....	220	85,800	550	184	59,400	90	....
London Suburbs: East-central section	1928	56.5	175.00	489.00	23	31,100	....	....	....	....	....	....	....	....	....	....	....	500	90,200	550	478	59,400	110	....
London Suburbs: Central section	1928	56.5	30.00	108.00	5	5,136	....	....	....	....	....	....	....	....	....	....	....	71	136,400	1,000	164	55,000	82	....
VENEZUELA:																								
La Guaira & Caracas Railway (d)	1928	36.0	22.68	24.85	8	1,312	4.25	101,711	53.0	....	....	....	....	5	71,000	456	9,922	4	61,740	264	28	24,255	78	22

SPECIAL NOTES

a—Passenger and Freight Locomotives
b—Electric service one direction only
c—Measured at Locomotive
d—Placed in service during year 1928.
e—Operates on tracks of New York Central
f—Included in Woodlawn—New Haven Section
g—Summer service only
h—Regeneration not computed
i—Power sold to other companies
j—Information from technical journals
k—Electric operation of isolated freight yard
l—Power purchased from other railroads
m—Train miles
n—Estimated for 1928
o—Per 1000 ton-miles passenger service
p—Freight and passenger service
q—Net ton-miles
r—Main line division only
t—High tension at Power **Station** or Substation
v—Approximate figure by test
x—For six months, June—November, 1927
z—Placed in service during year 1927. Equipment included in section Innsbruck, Feldkirch, Bregenz
S—Standard railroad equipment
T—At train
P.S.—At Power Station
S.S—At Substations

TABLE II—PART II

PHYSICAL CHARACTERISTICS OF OPERATION ON ELECTRIFIED SECTIONS OF STEAM RAILROADS

Name of Railroad	Average No. Trains Daily		Average Cars Per Train		Maximum Cars Per Train		Average Schedule Speed		Car-Miles in Year		Freight Service	Energy Supplied				Energy Used				
	Passenger	Freight	Passenger	Freight	Passenger	Freight	Best Passenger Trains	Best Freight Trains	Passenger Train	Freight Train	Excluding Locomotives	Generated	Purchased	Total	Delivered to Contact Line	Per Passenger Train Car-Mile	Per Freight Train Car-Mile	Per 1000 Gross Ton-Miles of Freight Service	Point of Measurement of Energy Used	% Regenerated Power of Delivered Power
	No.	No.	No.	No.	No.	No.	M.P.H.	M.P.H.	No.	No.	Gross Ton-Miles	Kw-hr.	Kw-hr.	Kw-hr.	Kw-hr.	Kw-hr.	Kw-hr.	Kw-hr.		%
UNITED STATES:																				
Baltimore & Ohio Railroad:																				
Baltimore Tunnel (b)	13	21	8	45	11	72	28.0	19.0	142,590	1,297,900	....	....	7,360,840	7,360,840	5,486,800	....	....	....	....	0.0
Staten Island Lines	466	....	2	....	5	....	22.6	....	2,843,068	....	....	....	16,495,796	16,495,796	....	3.31	....	....	T.	0.0
Boston & Maine Railroad	12	28	6	57	10	120	28.5	18.9	215,172	3,868,065	175,126,918	....	7,467,890	7,467,890	7,467,890	5.25	1.58	34.98	T	0 0
Boston Revere Beach & Lynn RR.(d)	272	....	4	....	7	....	23.7	....	2,670,000	....	....	....	1,466,800	1,466,800	1,390,000	....	....	....	S.S.	0.0
Butte, Anaconda & Pac. Railway (r)	4	6	3	60	5	75	30.0	16.4	117,457	5,079,040	248,085,908	....	19,315,384	19,315,384	....	....	(p)3.72	(p)69.90	S.S.	0.0
Chicago, Milwaukee, St. Paul & Pacific R. R.:																				
Rocky Mountain Division	4	....	10	80	16	132	32.8	14.7	6,553,898	52,190,990	1,998,972,938	....	113,436,311	113,436,311	(c)70,214,875	2.37	0.93	24.35	T.	15.3
Coast Division	4	....	10	47	15	100	29.2	12.9	3,810,520	15,810,893	594,575,842	....	48,838,098	48,838,098	(c)28,546,690	2.34	1.16	30.87	T.	18.7
Delaware, Lack. & Western R. R. (k)	....	....	....	....	....	....	....	....	....	....	....	....	56,210	56,210	....	....	....	....	....	0.0
Detroit, Toledo & Ironton Railroad	....	8	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	(h)
Erie Railroad	20	....	2	....	8	....	31.0	....	535,000	....	....	....	2,395,800	2,395,800	2,155,650	4.03	....	....	S.S.	0.0
Fort Dodge, Des Moines & So. R.R.	8	12	1	25	....	....	30.0	18.0	275,000	2,585,657	94,247,079	....	....	....	....	....	....	....	....	....
Great Northern Railway	8	4	10	80	15	137	27.0	12.9	....	....	....	....	....	....	....	....	....	....	T.	(h)
Illinois Central Railroad	552	....	4	....	8	....	38.5	....	10,814,046	....	....	....	60,607,807	60,607,807	54,019,187	5.00	....	....	S.S.	0.0
Long Island Railroad:																				
Suburban District	895	8	10	....	11	....	32.0	....	42,914,621	....	23,298,204	....	(l) 203,302,760	203,302,760	165,679,400	4.41	....	....	S.S.	0.0
Bay Ridge Division	....	30	....	60	....	100	....	25.0	....	....	....	....	9,168,775	9,168,775	9,168,775	....	....	....	....	0.0
Michigan Central Railroad	38	47	10	35	....	....	15.3	8.5	474,530	1,728,084	55,440,115	....	12,065,900	12,065,900	3,938,800	....	....	....	....	0.0
New York Central Railroad	505	45	8	50	17	115	31.5	13.5	23,391,989	....	....	186,448,185	43,555,000	230,003,185	158,049,628	....	....	....	....	0.0
N.Y., N.H. & Hartford Railroad:																				
New York to Woodlawn (e)	172	....	8	....	13	....	32.0	....	5,627,259	....	....	....	22,275,984	22,275,984	22,275,984	2.86	....	....	T.	0.0
Woodlawn to New Haven, incl. Harlem River Branch	190	44	8	54	13	100	46.5	22.0	24,523,377	53,000,000	2,301,000,000	123,192,000	75,894,000	(i)199,086,000	199,086,000	4.02	0.94	30.40	T.	0.0
Stamford to New Canaan	32	2	2	14	6	25	26.2	....	(f)	(f)	(f)	(f)	(f)	(f)	(f)	(f)	(f)	(f)	....	0.0
South Norwalk to Danbury	8	6	5	18	7	70	28.6	20.0	(f)	(f)	(f)	(f)	(f)	(f)	(f)	(f)	(f)	(f)	....	0.0
Port Morris to Fresh Pond & Sunnyside Yards	18	21	12	61	13	100	20.0	22.0	350,000	9,149,807	304,483,834	....	8,329,632	8,329,632	8,329,632	(f)	1.04	28.50	T.	0.0
Providence to Fall River	42	....	3	....	6	....	23.0	....	702,382	....	....	....	5,234,050	5,234,050	5,234,050	7.46	....	....	S.S.	0.0
Nantasket Jct. to Pemberton (g)	36	....	4	....	....	....	27.0	....	....	....	....	....	375,000	375,000	375,000	....	....	....	....	0.0
New York, Westchester & Boston Ry.	248	2	2	15	6	20	33.0	15.0	3,500,000	20,000	....	....	(l) 21,028,191	21,028,191	21,028,191	6.00	....	....	T.	0.0
Norfolk & Western Railway	....	34	....	47	....	....	....	....	....	....	782,309,882	78,714,311	....	78,714,311	70,514,201	....	....	90.00	P.S.	(h)
Pennsylvania Railroad:																				
Camden to Atlantic City	48	....	4	....	7	....	43.0	....	3,310,533	....	....	....	35,148,900	35,148,900	15,598,702	4.71	....	....	S.S.	0.0
New York Terminal	200	....	9	....	13	....	40.0	....	....	....	....	296,890,210	36,147,000	(i)333,037,210	85,090,795	....	....	....	S.S.	0.0
Philadelphia, Wilmington & West Chester (d)	75	....	4	....	10	....	40.0	....	615,580	....	....	....	5,139,670	5,139,670	....	....	....	....	S.S.	0.0
Philadelphia, Paoli & Chestnut Hill	172	....	5	....	12	....	30.0	....	4,253,055	....	....	....	49,490,591	49,490,591	....	7.30	....	....	S.S.	0.0
Southern Pacific Railroad	780	....	2	....	8	....	20.3	....	4,022,617	....	....	27,803,200	....	27,803,200	21,873,400	5.40	....	....	P.S.	0.0
The Virginian Railway	....	19	....	68	....	119	....	....	....	29,120,883	1,711,900,032	104,636,000	....	104,636,000	96,281,470	....	3.30	56.20	P.S.	8.3

ARGENTINA:																				
Buenos Aires & Western Railway	260	5	5	15	8	22	33.1	....	8,404,753	136,708	8,884,667	45,770,640	....	45,770,640	25,109,122	2.94	2.06	31.69	S.S.	0.0
Central Argentine Railway	209	....	6	....	8	....	35.4	....	7,629,675	....	....	30,099,271	....	30,099,271	25,047,542	3.28	....	....	P.S.	0.0
AUSTRALIA:																				
New South Wales Government Rys.	....	0	8	0	8	0	20.0	....	23,690,204	....	....	97,744,384	....	97,744,384	80,793,565	3.41	....	....	S.S.	0.0
Victorian Railways	2546	6	5	13	7	....	22.0	....	37,493,361	468,058	5,174,343	176,911,804	118,194	177,029,998	103,960,000	3.62	....	50.00	P.S.	0.0
AUSTRIA:																				
Austria Federal Railways:																				
St. Polten, Mariazell, Gusswerk	....	....	....	....	....	....	....	....	....	....	....	....	3,200,000	3,200,000	3,200,000	....	....	....	S.S.	0.0
Vienna, Hainburg	....	....	....	....	....	....	....	....	....	....	....	....	2,400,000	2,400,000	2,400,000	....	....	....	S.S.	0.0
Steinach-Irdning, Attnang-Puchheim	13	5	....	....	....	....	....	....	2,235,175	2,482,493	82,858,380	....	6,700,000	6,700,000	6,700,000	....	....	....	S.S.	0.0
Innsbruck, Feldkirch, Bregenz	19	9	....	....	....	....	....	....	9,010,300	13,857,220	437,587,200	38,000,000	....	38,000,000	38,000,000	....	....	....	S.S.	0.0
Innsbruck, Worgl, Kufstein (z)	....	....	....	....	....	....	....	....	....	....	....	7,500,000	1,500,000	9,000,000	9,000,000	....	....	....	S.S.	0.0
BOLIVIA:																				
Guaqui to LaPaz Railway	1	6	4	2	5	5	9.9	9.9	(p)862,878	....	....	326,160	19,200	345,360	305,328	....	....	....	....	0.0
CANADA:																				
Canadian National Railways:																				
St. Clair Tunnel	9	43	7	29	12	70	....	....	127,367	2,532,176	109,380,983	5,905	5,733,800	5,739,705	4,215,404	1.91	1.12	38.60	....	0.0
Montreal, Cartierville, St. Eustache	80	....	4	....	14	....	28.0	....	700,000	....	....	....	3,620,000	3,620,000	....	5.17	....	....	....	0.0
Montreal Harbour Commissioners	....	....	....	....	....	....	....	....	....	....	....	....	2,696,678	2,696,678	2,696,678	....	....	....	....	0.0
CHILE:																				
Anglo-Chilean Cons. Nitrate Corp.	....	22	10	13	12	21	....	14.9	17,202	1,102,411	39,230,150	433,305	5,036,075	5,469,380	3,726,264	....	4.89	....	P.S.	28.8
Bethlehem Chile Iron Mines Ry.	0	10	0	17	0	17	....	12.0	....	872,850	39,590,715	836,640	....	836,640	836,640	....	0.96	21.10	P.S.	164.0
Chile Exploration Co.	....	168	....	....	....	....	....	....	....	....	62,500,000	(t)5,277,950	....	5,277,950	4,069,672	....	....	65.10	(t)S.S.	0.0
Chilean Transandine Railway	1	2	7	6	8	10	15.0	15.0	43,900	137,061	2,230,633	....	1,267,560	1,267,560	1,204,190	....	....	....	S.S.	0.0
CUBA:																				
Hershey Cuban Railway	58	8	2	18	4	25	27.9	18.6	644,896	1,614,630	(q) 16,960,425	19,227,400	622,900	19,850,300	6,249,430	....	....	....	S.S.	0.0
United Railways of Havana	767	8	2	8	4	19	24.8	15.5	3,843,535	762,496	....	....	....	....	12,151,129	....	....	....	S.S.	0.0
FRANCE:																				
Midi Railway	....	....	....	....	24	....	61.8	28.0	4,445,082	1,304,415	761,550,955	215,506,370	....	215,506,370	73,754,660	(p)12.8	....	41.60	S.S.	0.0
Paris, Lyons and Mediterranean Ry	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Paris-Orleans Railway	330	115	11	57	24	80	56.0	25.0	47,466,700	69,562,500	(p) 2,883,847,600	....	115,012,596	115,012,596	94,780,559	1.46	0.37	21.20	S.S.	0.0
State Railways of France:																				
Paris (St. Lazare), Versailles, St. Germain	454	....	4	....	6	....	40.4	....	4,869,912	....	....	....	....	....	....	2.41	....	....	S.S.	0.0
Paris (Invalides), Versailles	220	....	8	....	12	....	49.7	....	3,293,420	....	....	....	12,800,000	12,800,000	11,100,000	3.38	....	....	S.S.	0.0
INDIA:																				
Great Indian Peninsula Ry.:																				
Harbor Line	211	....	....	....	....	....	19.0	....	7,166,092	....	....	....	31,033,826	31,033,826	26,486,126	3.70	....	....	S.S.	0.0
Main Line Suburban	104	....	....	....	....	....	22.0	....												
ITALY:																				
Italian State Railways:																				
Milan, Varese, Porto Ceresio	28	0.5	7	19	....	....	....	....	7,878,354	249,138	6,660,262	13,468,915	....	13,468,915	....	1.68	0.82	58.00	P.S.	0.0
Monza, Lecco, & Lecco, Sondrio, etc.	39	17	8	16	....	....	....	....	6,367,120	6,073,996	162,376,900	9,439,410	7,730,110	17,169,520	....	1.84	0.89	63.30	P.S.	0 0
Genoa to Ceva,Ronco,Leghorn,etc.	137	134	10	27	....	....	....	....	37,067,795	88,854,742	2,389,716,141	122,951,912	721,508	123,673,420	....	1.53	0.75	52.72	P.S.	0.0
Turin to Modane, Ronco, etc.	73	44	7	29	....	....	....	....	27,942,697	73,270,781	1,984,914,940	45,161,458	49,347,212	94,508,670	....	1.49	0.73	51.43	P.S.	0.0
Naples, Pozzuoli, Villa Literno	53	6	4	6	....	....	....	....	3,288,884	796,780	21,317,120	....	5,209,150	5,209,150	....	1.85	0.90	63.70	P.S.	0.0
Florence, Poretta, Bologna	25	20	10	16	....	....	....	....	12,374,356	15,533,430	415,257,609	8,760,200	7,016,500	15,776,700	....	1.63	0.80	56.17	P.S.	0.0
North Milan Railway	....	....	....	....	8	50	49.7	24.8	....	....	....	....	....	....	....	....	....	....	....	....

TABLE II—PART II—(*Concluded*)

PHYSICAL CHARACTERISTICS OF OPERATION ON ELECTRIFIED SECTIONS OF STEAM RAILROADS

Name of Railroad	Average No. Trains Daily		Average Cars Per Train		Maximum Cars Per Train		Average Schedule Speed		Car-Miles in Year		Freight Service	Energy Supplied				Energy Used				
	Passenger	Freight	Passenger	Freight	Passenger	Freight	Best Passenger Trains	Best Freight Trains	Passenger Train	Freight Train	Excluding Locomotives	Generated	Purchased	Total	Delivered to Contact Line	Per Passenger Train Car-Mile	Per Freight Train Car-Mile	Per 1000 Gross Ton-Miles of Freight Service	Point of Measurement of Energy Used	% Regenerated Power of Delivered Power
	No.	No.	No.	No.	No.	No.	M. P.H.	M. P.H.	No.	No.	Gross Ton-Miles	Kw-hr.	Kw-hr.	Kw-hr.	Kw-hr.	Kw-hr.	Kw-hr.	Kw-hr.		%
JAPAN:																				
Japanese Government Railways:																				
Yamate Line	398	....	4	....	5	....	18.7	....	11,714,524	....	....	18,480,840	25,919,866	44,400,706	37,461,284	3.20	....	....	S.S.	0.0
Keihin Line	432	....	4	....	8	....	24.2	....	16,013,729	....	....	10,908	60,150,484	60,161,392	51,687,207	3.22	....	....	S.S.	0.0
Chuo Line	395	....	4	....	6	....	19.3	....	8,766,217	....	....	8,650,180	25,722,893	34,373,073	28,435,490	3.24	....	....	S.S.	0.0
Usui Line	26	36	6	....	10	....	8.8	8.8	1,393,292	1,690,251	18,626,495	2,879,830	8,758,840	11,638,670	10,600,568	3.47	3.41	309.4	S.S.	0.0
Tokiado Line	116	10	11	....	16	....	41.6	26.7	75,112,640	12,393,187	136,572,359	9,228,298	36,527,241	45,755,539	37,750,703	....	....	....	S.S.	0.0
MEXICO:																				
The Mexican Railway	6	10	8	15	15	30	24.9	21.7	552,717	2,318,931	....	....	12,968,550	12,968,550	12,968,550	....	....	....	P.S.	25.0
El Potosi Railway	....	10	....	12	....	14	....	14.9	....	....	(q) 5,986,591	....	1,469,730	1,469,730	1,469,730	....	....	(q)245.50	S.S.	(v) 20.0
MOROCCO:																				
Moroccan Railways (j)	....	....	....	....	....	....	....	....	(m)246,074	(m)395,210	287,608,000	....	9,400,000	9,400,000	9,400,000	....	....	33.80	S.S.	(h)
NETHERLAND EAST INDIES:																				
Java State Railway	50	....	2	....	5	....	31.1	....	....	....	....	....	6,695,678	6,695,678	4,352,189	(o)46.73	....	....	S.S.	0.0
NETHERLANDS:																				
Netherlands Railways	....	....	6	....	10	....	59.0	....	9,818,120	....	....	....	45,100,000	45, 100,000	....	3.34	....	....	P.S.	0.0
NEW ZEALAND:																				
New Zealand Govt. Railways	1	12	....	....	....	....	18.2	15.9	30,006	693,684	6,483,330	1,382,610	....	1,382,610	1,382,610	4.56	1.81	193.70	P.S.	0.0
NORWAY:																				
Norwegian State Railways:																				
Narvik, Riksgrensen	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	(v)10.0
Oslo, Drammen	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0.0
Oslo, Lillestrom	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0.0
Notodden, Tinnoset	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0.0
Rjukan Railway	(p)28	....	3	12	5	24	24.8	24.8	88,000	372,000	6,300,000	....	1,686,380	1,686,380	840,000	....	(p)3.67	268.00	P.S.	0.0
SPAIN:																				
Spanish Northern Railway:																				
Ujo, Busdongo	12	20	12	28	24	50	24.8	18.6	....	(p)323,140	75,122,016	....	9,469,395	9,469,395	8,719,770	....	....	(q)106.40	S.S.	14.2
Barcelona, Moncada, Manresa	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Moncada, San Juan de las Abadesas	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Catalan Railway	48	8	4	....	12	40	31.1	15.5	....	....	....	....	....	....	....	....	....	....	....	....
SWEDEN:																				
Nordmark Klaralvens Railway	16	....	....	....	....	....	31.1	18.6	....	....	30,558,831	....	3,091,100	3,091,100	3,091,100	....	....	101.16	P.S.	0.0
SWITZERLAND:																				
Montreux-Oberland Ry.	20	2	3	4	12	14	17.4	12.4	807,820	142,922	20,680,356	....	4,500,000	4,500,000	3,800,000	(p)2.90	....	....	P.S.	0.0
Rhaetian Railway	14	2	....	....	17	....	22.7	13.7	....	....	(p) 32,087,090	....	13,694,760	13,694,760	13,694,760	....	....	(p)86.90	P.S.	(h)
Swiss Federal Railways	969	459	9	30	....	....	40.4	21.7	....	....	(p)5,896,913,385	382,900,000	20,470,000	403,370,000	354,000,000	....	....	(p)60.00	S.S.	0.0
UNION OF SOUTH AFRICA:																				
South African Railways (j)	8	37	....	....	....	....	21.0	21.0	....	....	....	....	(x) 60,069,918	(x) 60,069,918	....	....	....	....	....	(v)19.0

UNITED KINGDOM:																			
Mersey Railway	466		5		5		19.9		2,241,590			8,651,047		8,651,047	5,640,601	2.51			P.S.	0.0
London & No. Eastern Railway:																				0.0
Newcastle, Tynemouth	178	24	5	8	8		20.7	11.1	5,736,682	48,136	499,011		13,691,861	13,691,861	10,934,364	2.36	2.66	259.70	S.S.	0.0
Shildon, Newport		11		56		90		17.0		3,080,811	45,032,255		1,132,808	1,132,808	1,132,808		0.36	25.20	S.S.	0.0
London, Midland & Scottish Ry:																				
London and suburbs: Gen'l Sysm.	991		5		7		27.2		17,962,526			72,984,854	4,240,651	77,225,505	56,569,047	3.45			S.S.	0.0
London and suburbs: Campbell Rd. Jct., Barking	469		6		8		21.0		3,610,542				10,882,692	10,882,692	8,711,965	2.41			S.S.	0.0
Liverpool, Southport, Crossens, Omskirk	511		5		6		35.8		8,886,503			42,046,494		42,046,494	30,339,460	3.39			S.S.	0.0
Manchest'r, Bury, Holcombe Brook	217		5		5		26.6		2,650,104			13,700,339		13,700,339	9,682,250	3.65			S.S.	0.0
Lancaster, Morecambe, Heysham	106		3		7		30.0		304,234			604,557	447,885	1,082,442	390,432	1.28			P.S.	0.0
Great Western Railway:																				
Bishop's Rd., Westbourne Pk., Hammersmith	478		5		6		17.1		2,640,702			9,836,578		9,836,578	7,605,305	2.88			S.S	0.0
Ealing, Wood Lane	339		4		6		21.1		1,966,948			3,753,308		3,753,308	2,901,930	1.47			S.S.	0.0
Southern Railway:																				
London suburbs: West'n Section	590						25.0		29,968,018			78,045,350		78,045,350	59,558,598	2.06			S.S.	0.0
London suburbs: East-cent. section	2148						25.0		39,562,757				111,710,167	111,710,167	92,348,060	2.33			S.S.	0.0
London suburbs: Central section	600						24.0		12,882,533				35,561,510	35,561,610	35,335,130	2.74			S.S.	0.0
VENEZUELA:																				
La Guaira & Caracas Railway (d)	14	18	2	4	2	4	18.6	13.0	106,657	128,257	8,025,622	1,405,945		1,405,945	1,405,945	2.53	3.44	171.60	P.S.	0.0

The South Indian Railway has been authorized by the Railway Board to electrify suburban sections in the vicinity of Madras. A proposed scheme for much more extensive electrification is said to depend on the development of sufficient water power.

Japan

In 1928 the Japanese Government Railways completed electrification on the Atami line from Odawara to Atami. About 13 miles was equipped with overhead contact line at 1500 volts, direct current.

Morocco

More complete information has been received regarding the electric operation of the Moroccan Railway, inaugurated in 1927 on about 160 miles of single-track line. Electric trains now run between Casablanca and Kourigha and between Casablanca and Sale. The reasons were scarcity of coal and of good water for steam, abundance of water power, and the possibility of very advantageous use of regenerative braking on heavy mineral trains brought down grade toward the coast. The change to electricity is said to have resulted in a great expedition of traffic.

The system chosen is 3000-volt direct current, from overhead contact line, with locomotives for freight trains and multiple-unit trains for passengers. Twenty-six locomotives were purchased, of two slightly different types, each approximately 80 tons weight, 1400 h.p., 37 miles per hour. The locomotives are arranged for multiple-unit operation and for regenerative braking. The freight cars used here are of the large capacity of 53 tons.

The motor cars are 73 tons weight, 700 h.p. and 53 miles per hour. Each has four motors and seats 64 persons. The two motors on each truck are connected in series across the line voltage. The motor cars are also equipped with multiple-unit control but not for regenerative braking.

New Zealand

In February, 1929, the New Zealand Government Railways inaugurated electric operation between Christchurch and Lyttleton on the South Island. The length is 6.33 miles, which includes the Lyttleton Tunnel. An overhead contact line is energized with direct current at 1500 volts. Six 50-ton locomotives were installed and one automatic substation containing rotary converters with supervisory control. This is the second short electrification on this system within the last five years.

Union of South Africa

The South African Railways completed, in 1928, the electrification of two lines, namely, Capetown to Sea Point and Capetown to Simonstown. The length of the first is 3.65 miles and of the second 23 miles. These lines furnish principally suburban passenger service. Multiple-unit trains operate with 1500-volt direct current from an overhead line. Energy is furnished by the Electricity Supply Commission's power station which is interconnected with the Capetown Municipal power station.

From Capetown to Sea Point the line is single-track and carries 180 trains per day for express and local service. From Capetown to Simonstown it is double-track as far as Fish Hoek (18.7 miles) and carries 211 trains per day with 18 train-sets. The equipment consists of 83 motor coaches, 37 driving trailers and 95 plain trailers.

Proposed Activities

The work already planned for next year, in addition to the regular statistical studies, includes (1) a continuation of the preparation of a standard form of contract for sale of energy to electrified railroads, and (2) a special report on the electrification of steam railroads including data on the capital cost of several typical installations.

APPENDIX A

REPORT OF SUBCOMMITTEE ON ELECTRIFICATION IN EUROPE

The Subcommittee, composed of four members, sailed from New York the latter part of October and landed in England early in November. After traveling through England and around the Continent, they sailed from Southampton at the end of the year and arrived in New York the first week of January. Eight weeks were spent in Europe.

ITINERARY AND PLACES VISITED

The itinerary is shown by Fig. 1. Seven countries were visited: England, Netherlands, Sweden, Germany, Switzerland, Italy and France. In addition to visiting most of the steam railroad electrifications in these countries, the rapid-transit subways were inspected in London, Berlin and Paris. Numerous generating stations supplying energy for railroad traction were visited, both hydraulic and steam stations, also substations and converting stations for making the energy suitable for railroad purposes.

The principal cities, railroads, power companies and manufacturing plants which were visited in each country are as follows:

England

Underground Electric Railways of London.
  Lines, generating station, overhaul shop, signal school.

NOTE 1—Weights and distances have been expressed as tons and miles, the ton consisting of 2000 pounds. Horse powers have not been changed due to the slight difference between the metric and the foot-pound ratings. Electrical units are of course the same in all countries.

NOTE 2—Locomotive horsepower is intended to be expressed as the one-hour rating. Some capacities which were given orally may vary from this method, although the effort has been made to check all ratings by books and technical articles.

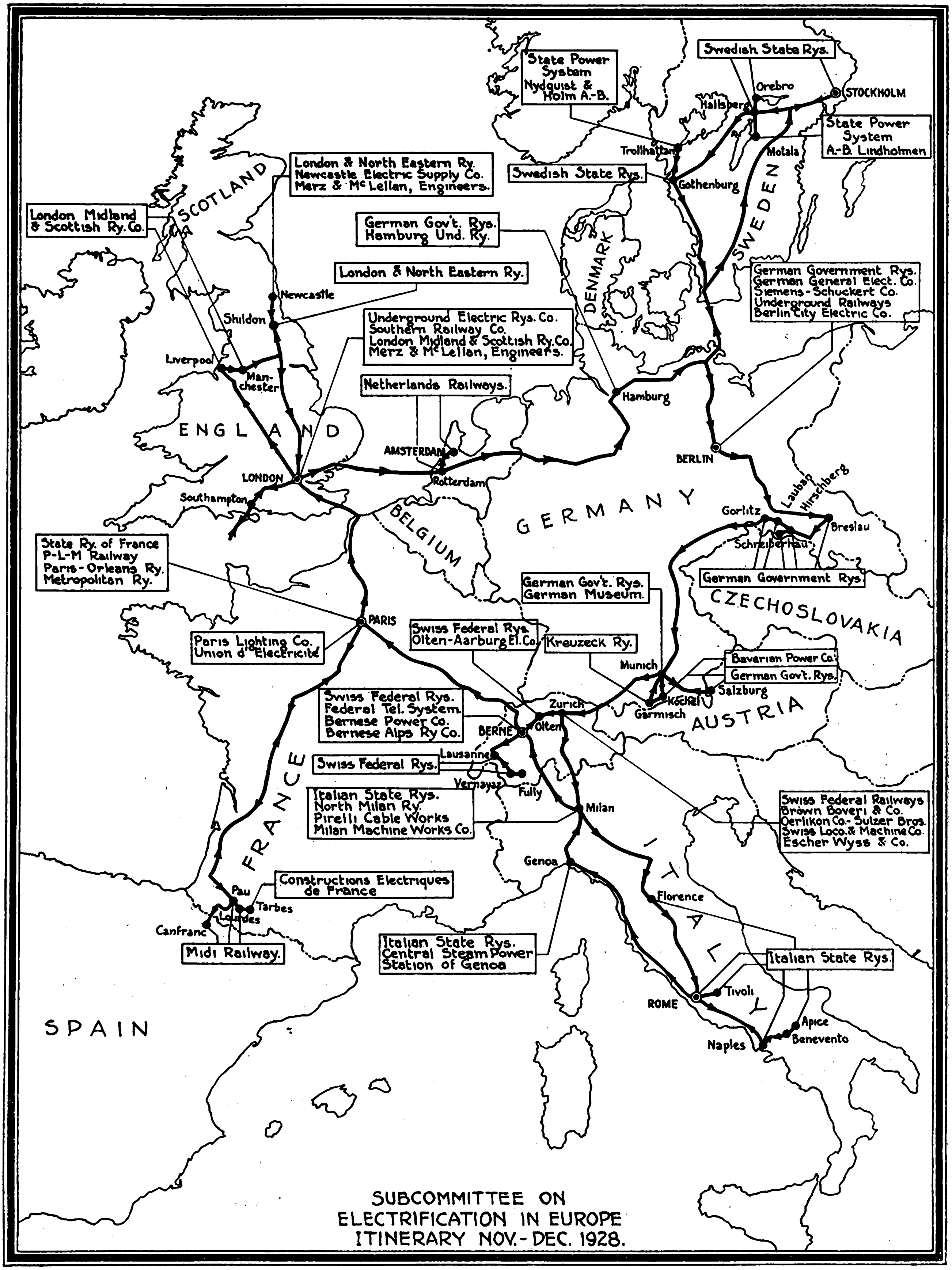
State Power System Nydquist & Holm A.-B.
Swedish State Rys.
Orebro
STOCKHOLM
Hallsberg
State Power System A.-B. Lindholmen
Trollhattan
Motala
Swedish State Rys.
Gothenburg
SWEDEN
London & North Eastern Ry. Newcastle Electric Supply Co. Merz & McLellan, Engineers.
London Midland & Scottish Ry. Co.
SCOTLAND
German Gov't. Rys. Hamburg Und. Ry.
DENMARK
London & North Eastern Ry.
German Government Rys. German General Elect. Co. Siemens-Schuckert Co. Underground Railways Berlin City Electric Co.
Newcastle
Shildon
Underground Electric Rys. Co. Southern Railway Co. London Midland & Scottish Ry. Co. Merz & McLellan, Engineers.
Liverpool
Manchester
Netherlands Railways.
Hamburg
ENGLAND
AMSTERDAM
BERLIN
LONDON
Rotterdam
Southampton
BELGIUM
GERMANY
Lauban
Hirschberg
Gorlitz
Breslau
Schreiberhau
State Ry. of France P-L-M Railway Paris-Orleans Ry. Metropolitan Ry.
German Gov't. Rys. German Museum.
German Government Rys.
CZECHOSLOVAKIA
PARIS
Swiss Federal Rys. Olten-Aarburg El. Co.
Paris Lighting Co. Union d'Electricité
Kreuzeck Ry.
Bavarian Power Co.
Munich
German Gov't. Rys.
Salzburg
Kochel
Swiss Federal Rys. Federal Tel. System. Bernese Power Co. Bernese Alps Ry Co.
Zurich
Garmisch
AUSTRIA
BERNE
Olten
Lausanne
Swiss Federal Rys.
Vernayaz
Fully
FRANCE
Italian State Rys. North Milan Ry. Pirelli Cable Works Milan Machine Works Co.
Milan
Swiss Federal Railways Brown Boveri & Co. Oerlikon Co.- Sulzer Bros. Swiss Loco. & Machine Co. Escher Wyss & Co.
Genoa
ITALY
Constructions Electriques de France
Pau
Florence
Tarbes
Lourdes
Canfranc
Midi Railway.
Italian State Rys. Central Steam Power Station of Genoa
Italian State Rys.
Tivoli
ROME
SPAIN
Apice
Benevento
Naples
SUBCOMMITTEE ON ELECTRIFICATION IN EUROPE ITINERARY NOV.-DEC. 1928.

FIG. 1—MAP OF ITINERARY.

Southern Railway Co., London district.
 Lines, generating station, signal and interlocking plants, and car shops.
London, Midland & Scottish Railway Co.
 London district: Lines, generating station, substations, signal and interlocking plants, and car shops.
 Liverpool district: Lines and generating station.
 Manchester district: Lines and substation.
London and North Eastern Railway Co.
 Newcastle district: Tyneside electrified lines.
 Shildon district: Electrified mineral line.
Newcastle-upon-Tyne Electric Supply Co., Ltd.
 Office building, power stations, low-temperature carbonization plant.

The Netherlands

Netherlands Railways, Amsterdam and Rotterdam.
 Lines and substations.

Sweden

Swedish State Railways.
 Stockholm: Offices, locomotive inspection shop, electrification Stockholm-Gothenburg.
 Hallsberg: Special cars for contact-line inspection and repairs, substation.
 Motala: Private factory of A.-B.Lindholmen-Motala, building electric locomotives for the Government Railways.
 Orebro: General overhaul shop.
 Gothenburg: Locomotive inspection shop.
 Trollhattan: Private factory of Nydquist & Holm A.-B., building electric locomotives for the Government Railways.
Swedish State Power System.
 Motala: Hydraulic generating station.
 Trollhattan: Hydraulic generating station and canal system.

Germany

German General Electric Co., Berlin.
 Locomotive factory near Berlin.
 Factory making mercury arc rectifiers and railway motors.
Siemens-Schuckert Co., Berlin.
 Departments making electrical equipment for railways and for power generation.
Berlin Elevated and Underground Railways.
 Lines and substations.
Berlin City Electric Co.
 Klingenberg generating station.
Bavarian Power Co.
 Walchensee hydroelectric generating station.
Kreuzeck Railway.
 Aerial cableway near Garmisch.
German Government Railways Co.
 Berlin district: Offices, and electrification of City, Circle and Suburban Railway including substations and overhaul shop.
 Silesian district: Electrification Breslau-Gorlitz and branches, overhaul shops at Hirschberg and Lauban, substation at Hirschberg.
 Bavarian district: Offices, overhaul shop and substation at Munich; electrified sections, Regensburg-Munich, Munich-Salzburg, Munich-Garmisch.

Switzerland

Swiss Federal Railways.
 Berne district: Mechanical and electrical departments, inspection shops, communication circuits, substations; electrified lines, including Berne - Lausanne - Martigny, Berne - Delemont, and Berne-Zurich; Vernayaz hydraulic power station.
 Zurich district: Main shops at Zurich; substations at Olten, Rupperswil and Gruze; electrified line Zurich-Chiasso, including St. Gotthard tunnel.
 Simplon Route: Electrified line from Iselle (Italy) to Brigue, including Simplon tunnel, and from Thun to Berne.
Bernese Alps Railway (Loetschberg Line).
 Electrified line from Brigue to Thun, including Loetschberg tunnel.
Manufacturers in Zurich District:
 Brown Boveri & Co.
 Oerlikon Co.
 Swiss Locomotive & Machine Works.
 Sulzer Brothers.
 Escher Wyss & Co.
Hydroelectric Generating Stations.
 Muhleberg Station of Bernese Power Co.
 Fully Station of West Swiss Power Co.
 Olten-Goesgen Station of Olten-Aarburg Electric Co.

Italy

Italian State Railways.
 Milan district: Electrification Monza-Lecco. and shops.
 Florence district: Principal locomotive depot, and electrification Florence-Pistoia.
 Rome district: General offices, locomotive shops, electrification Rome-Tivoli, and substations.
 Naples district: Electrification Naples-Villa Literno, electrification Benevento-Foggia and substation.
 Genoa district: Electrification Genoa-Ronco and substation, Genoa Harbor development, private steam generating station supplying part of railway energy.
North Milan Railway, Milan.
 Office, substation, shops and electrification in process for suburban service.
Manufacturers at Milan:
 Pirelli Cable Works.
 Societa Officine Meccaniche.

France

Metropolitan Railway of Paris (Underground).
 Lines and car shops.

Paris, Lyons & Mediterranean Railway.
  General Offices at Paris.

Paris-Orleans Railway.
  Offices, substations, locomotive shops and electrified lines for suburban service, at Paris; and electrification Paris-Orleans.

State Railways of France.
  Offices, car shops, electrified suburban lines, all in or near Paris.

Midi Railway.
  Paris: General Offices.
  Tarbes: Motive Power Department.
  Electrified Lines: Bordeaux-Tarbes and Pau-Canfranc (Spain), including substation at Lourdes.

Electrical Manufacturers.
  Constructions Electriques de France at Tarbes: Electric locomotives and power generating equipment.

Electric Power Companies.
  Two steam generating stations at Paris belonging to private companies and involved in the supply of power to railroad and underground lines: the North Station of the Cie. Parisienne de Distribution d'Electricité, and the Gennevilliers Station of the S. A. Union d'Electricité.

ELECTRIFICATION IN COUNTRIES VISITED

A short description will be given of the railroad electrification in each of the countries visited. Preceding this description is a table of general statistics for the seven countries visited and for three adjoining ones. This table indicates the size of each country and the extent of railroad development. For ease of comparison by the American readers, similar figures for the United States are also given.

A great amount of information was secured on the trip which cannot be included in this report without making it unduly long. Consequently, in accordance with the Committee's policy of studying electrification in a general way, only the most general information has been included here.

GENERAL STATISTICS FOR THE UNITED STATES AND EUROPEAN COUNTRIES

Country	Area in Square Miles	Population	Pop. per Sq. Mi.	Route Miles of All Rys.	Ry. Mi. per 1,000 Sq. Mi.	Ry. Mi. per 10,000 Pop.	Route Miles of Govt. Rys.	Motor** Vehicles Registered	Motor Vehicles per 1,000 Inhabitants
	a	b	b/a	c	c/a	c/b	d	e	e/b
Austria	32,368	6,535,363	201.91	4,128	127.53	6.32	3,608	23,673	3.62
Czechoslovakia	54,206	14,388,000	265.43	8,289	152.98	5.76	2,289	39,950	2.78
France	212,736	40,960,000	192.54	26,872	126.32	6.56	6,907	956,000	23.34
Germany	180,972	62,592,575	345.87	35,597	196.70	5.69	33,320	456,000	7.28
Italy	119,744	40,799,000	340.72	13,355	111.53	3.27	10,300	158,600	3.89
Netherlands	13,213	7,626,072	577.16	2,254	170.58	2.96	......	73,894	9.69
Spain	195,040	22,128,000	113.45	9,705	49.76	4.38	......	176,000	7.95
Sweden	158,525	6,087,923	38.40	10,110	63.77	16.61	3,877	109,522	17.99
Switzerland	15,944	3,959,000	248.31	3,492	219.02	8.82	1,828	53,000	13.39
*United Kingdom	94,278	44,170,241	468.51	21,165	224.50	4.79	......	1,194,335	27.04
United States	2,973,774	120,013,000	40.36	249,131	83.78	20.76	......	23,127,315	192.71

*Includes England, Scotland, Wales and Northern Ireland.
**Total of passenger cars, trucks and buses.

Much material of a more detailed character has been placed in the Committee's files—including notes, reports, maps, monographs, magazines and manufacturers' descriptions of equipment. Such articles, for instance, as relate to costs of installation and of operation cannot be used in this country without first receiving very careful analysis of a specific nature not justified for a general report. All the data will be retained for office reference and for consultation by other organizations properly interested in the subject of railroad electrification.

England

At the beginning of 1923 all the principal railroads in England were, for the purpose of general operating economy, consolidated by act of Parliament into 4 large systems. The new systems are the successors to 123 separate railways that formerly operated the same lines. Prior to the consolidation there had been installations of electric traction on several of the existing railways. These installations had been made principally for suburban service or for experiment. They were of various types and of both alternating and direct current. Some of the consolidated systems thus found themselves possessed of 2 or 3 different types of electrification.

Since the consolidations some of the electrified lines have been changed over to the type preferred by the present owner. There has also been a general attempt on the part of the Government to cause adoption of a standard system of electrification for the whole country. Three reports by committees functioning under the Ministry of Transport have been made in 1920, 1921 and 1928. The last report was issued while the Subcommittee was in London.

The reports of 1921 and 1928 both favor direct current. The last one recommends the "maximum standard voltages" of 750 and 1500, at the substation, for third rail and overhead contact line, respectively. A higher pressure of 3000 volts is recommended to be permitted in certain cases by spe-

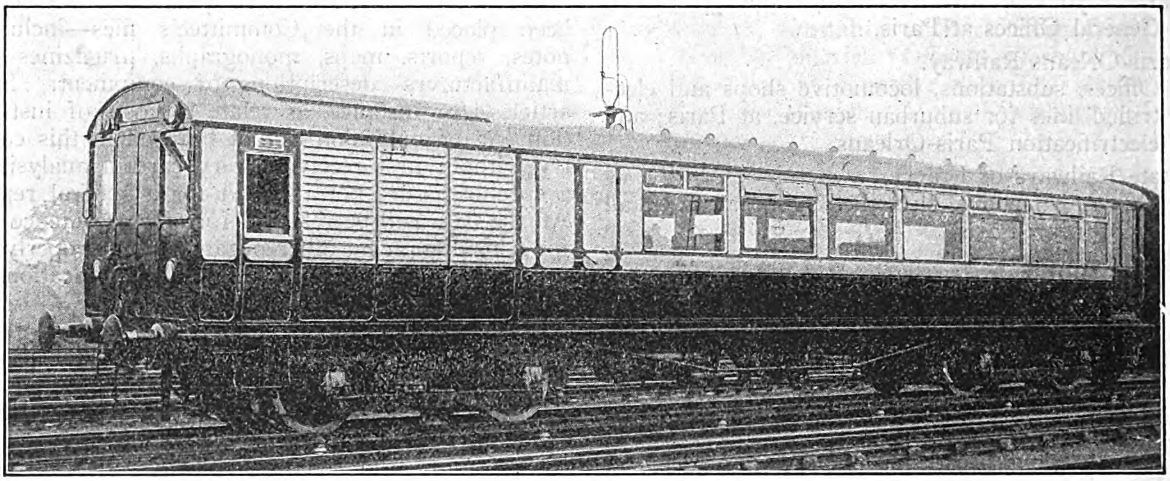

FIG. 2—LONDON, MIDLAND & SCOTTISH RAILWAY—MOTOR CAR FOR LONDON SUBURBAN SERVICE.

cial approval. There are various other recommendations relating particularly to motor voltages and to clearances, having in view the greatest facility for interrunning.*

Electrical operation at present is confined almost wholly to passenger traffic in the vicinity of some of the large cities. In the London area there is some joint running between the electrified sections of the steam railroads and the Underground Railways. The electrifications of the 4 large systems will be discussed individually.**

Great Western Railway

The Great Western has 2 short sections of line electrified in the London area. Each is about 5 miles in length. Both lines use a contact rail at pressure of about 600 volts. Electric operation is partly joint with the Underground Railways.

London, Midland & Scottish Railway

The L. M. S. has 4 sections electrified for passenger service at London, Liverpool, Manchester and Lancaster. Each will be described in turn.

This company has some very interesting electrical installations, several of which are quite new. Among the ones visited mention should be made of the large automatic substation at London, the 1200-volt substation at Manchester and of new signalling and interlocking installations at both London and Manchester.

London Electrification

The London suburban service on certain lines out of Euston Station was electrified in 4 stages between 1914 and 1922. About 42 miles of line and 90 miles of track are involved. The contact rail is supplied with direct current at 600 volts, and a fourth rail makes an insulated return circuit. Power is generated in the railway's power station at Stonebridge Park, adjacent to its car shops. There are 5 turbines with a total capacity of 30,000 kw. The energy is transmitted by cables at the generator pressure of 11,000 volts to 11 converter stations, which are also equipped with storage batteries.

The rolling stock consists of 99 motor cars and 182 trailers. First and third class accommodations are provided. The cars are compartment type with side doors for each compartment. This type of car seems to be preferred for commuting in the metropolitan area. Multiple-unit control is used, with driver's cabs on all the motor cars and on some of the trailers. The cars are large, well equipped and comfortable riding.

There is in addition to the service from Euston Station a short electrification, about 5 miles in length on the other side of London. This installation was made about 1905 and also uses third rail, but the energy is purchased from one of the electric power companies.

There is some joint running arranged for the Underground Railways on both the east and west side electrifications. There is also steam operation over the electrified tracks for other passenger and freight service.

Liverpool Electrification

Frequent electric passenger service is furnished in an extensive district north of Liverpool. There are about 38 miles of line and 93 miles of track. Electrification was done progressively between 1904 and 1913 with third rail at 600 volts. First and third class accommodations are provided. Freight is handled over the same tracks by steam locomotives, mostly at night.

The equipment includes 93 motor cars and 120 trailers. The old rolling stock has wooden bodies, but in 1927 four 6-car trains of steel cars were added.

The old cars are run in 5-car trains consisting of a motor car at each end and 3 trailers between. There is one driver's cab at each end of the train for direct control, power being cabled through the train to the motor car at the rear end. Cars have end entrances and center aisles. The motor cars weigh 54 tons and trailers 30 tons. Each motor car is equipped with four 150-horsepower motors, 600-volt. Vacuum brakes are used.

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* It is anticipated that main-line trains may run from the 1500-volt lines onto the 750-volt terminal sections.

** There is also a separate short railway at Liverpool, called the Mersey Railway, which has been electrified since 1903. This railroad crosses under the River Mersey by a long tunnel and was quite difficult to operate by steam.

The new steel cars are made up into 3-car sets, each consisting of motor car, trailer and driving trailer. Two sets are operated as a 6-car train. Each motor car is equipped with four 240-horsepower motors, 600-volt.

Power is generated in the railway's power station at Formby with capacity of 22,000 kw. Twenty-five cycle energy is transmitted at generator pressure of 7500 volts to converter stations where it is fed to the contact rail. Storage batteries are also installed in some substations. An interesting feature is the use of a fourth rail for return current placed between the running rails and bonded to them.

The patronage on this line has grown to the limit of facilities and reconstruction of substations and distribution system is being considered. The power station has recently been completely overhauled and modernized by much new equipment. The rolling stock and roadway are well maintained and in very satisfactory condition. Consequently the cars ride well and the service is an asset to the territory.

Manchester Electrification

The line from Manchester north to Bury and Holcombe Brook was electrified in 1914 with 1200-volt contact rail. It is the only high-voltage third rail used in England. A specially constructed and protected side-contact third rail is used. There are about 14 miles of line and 30 miles of track.

Energy is supplied by the railway's power station at Clifton Junction with capacity of 10,000 kw. Three-phase power at 25 cycles is fed to 2 substations at generator pressure of 6600 volts. Each substation contains 1200-volt rotary converters and a large battery of the same voltage. It is customary to give the battery a boosting charge for about 30 hours per week at night and on Sunday. The battery does 3 cycles of work per day, handling the peaks of morning, noon and evening. This is due to an intermediate peak at midday occasioned by a long nooning which permits many riders to travel home to lunch.

There are 38 motor cars and 28 trailer cars. Cars are all steel with end entrances and center aisles. They are run in trains of 3, 4 or 5 cars. Control is of multiple-unit type with 2 driver's cabs for each car, and a small room for control switches at one end of each motor car. The motor cars are equipped with four 200-horsepower motors of 1200 volts each, giving a maximum speed of 60 miles per hour.

Control and lighting are at 120 volts supplied by a rotary transformer on each motor car. Heating is done with 1200-volt electric heaters. Vacuum brakes are used. The railway built the cars and 1200-volt motors in its own shops, but purchased the control equipment. The operating officials state that they are well satisfied with the operation of this line.

Lancaster Electrification

In 1908 the first single-phase electrification in the country was accomplished on about 10 miles of line between Lancaster, Morecambe and Heysham. Power is supplied by an overhead line energized at 6600 volts, 25 cycles. The power has been generated by the railway in a station adjacent to the line near Heysham. Beginning in 1929, power will be purchased from the local power system at Lancaster.

The motor cars have 2 motors each, of either 150 or 180 horsepower. A main transformer on each motor car reduces the line voltage for the motors, and an auxiliary transformer supplies the lighting. The control is multiple-unit type. The motor cars weigh about 45 tons and the trailers 20 tons.

North Eastern Railway

The North Eastern Railway is not electrified in the London area, but has 2 electrified sections in the north of England. One in the Tyneside district adjacent to Newcastle furnishes passenger service with multiple-unit trains. The other, in a coal mining district a little south of Newcastle, uses electric locomotives for handling the mineral traffic.

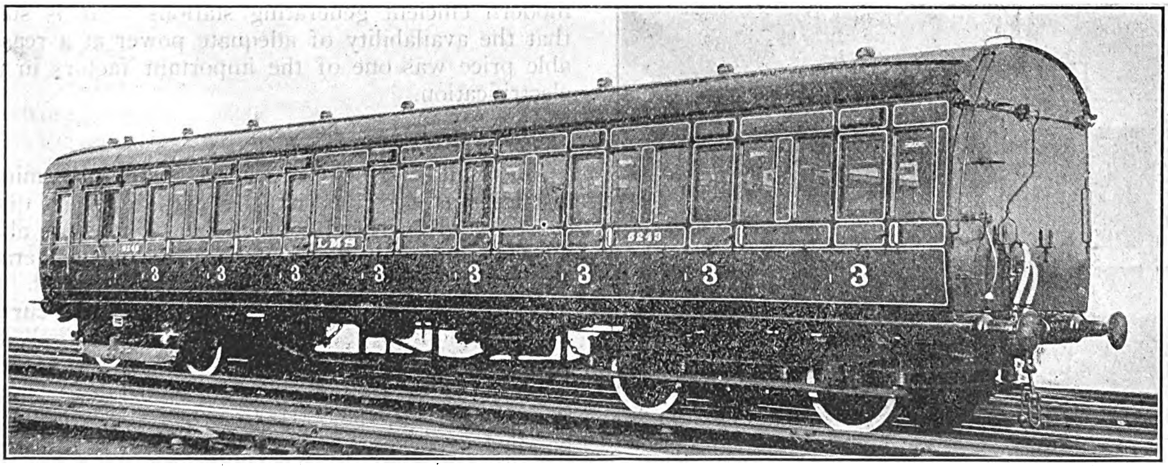

FIG. 3—LONDON, MIDLAND & SCOTTISH RAILWAY—DRIVING TRAILER FOR LONDON SUBURBAN SERVICE.

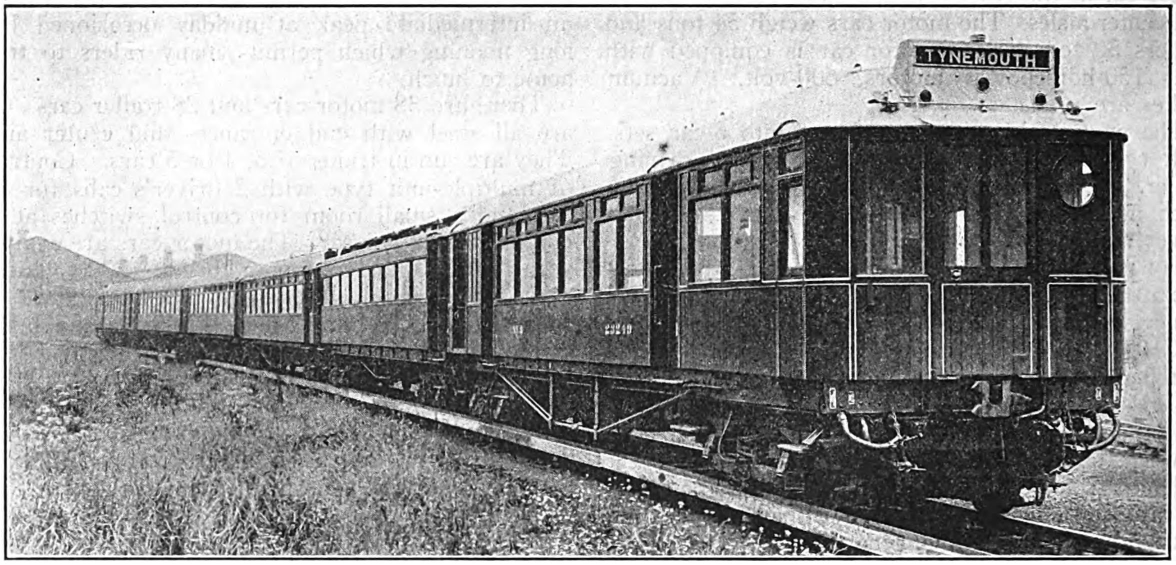

FIG. 4—LONDON & NORTH EASTERN RAILWAY—MULTIPLE-UNIT TRAIN FOR TYNESIDE ELECTRIFICATION.

Tyneside Electrification

The Tyneside electric service was inaugurated in 1904 through residential and heavy industrial districts about the River Tyne between Newcastle and the sea. There are about 32 route miles and 80 miles of track. First and third-class accommodations are provided with end-entrance center-aisle cars.

This line was electrified to meet tram and interurban competition. The results were very successful, and the growth of population, in addition, made a large increase in the passenger business. During the last few years there has been severe competition from highway buses, but this has been met by more frequent service. On the most traveled section there is now a train every 10 minutes.

The rolling stock is mostly the original equipment bought in 1904. The cars have wood bodies finished in natural teak. They are well fitted inside and have been kept in very good condition. They are grouped in 2-car units, for operation usually as 4-car or 6-car trains, although there are some 3-car units, including baggage cars. There is one motor car in each unit, and all cars are equipped for multiple-unit control, although some trailers do not have driver's cabs.

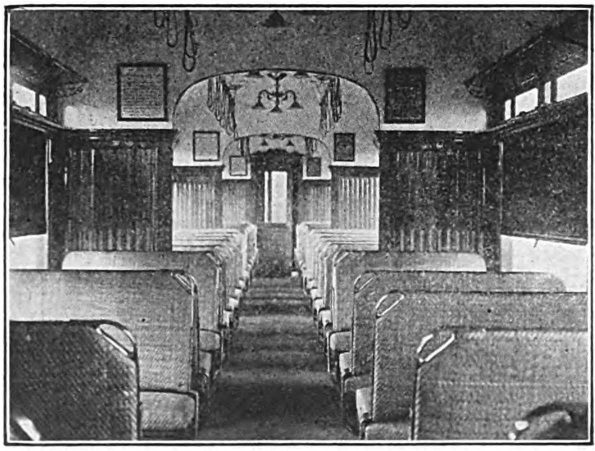

FIG. 5—LONDON & NORTH EASTERN RAILWAY—INTERIOR OF CAR FOR TYNESIDE ELECTRIFICATION.

Each motor car has one driving truck, or motor bogie, fitted with two 150-horsepower motors, each 600-volt. The motor cars weigh 34 tons and seat about 50 people in cars having both first and third-class accommodations, or 68 if entirely third class. The trailers, of somewhat varying design, weigh 22 to 25 tons and seat 68 or 72 persons, third class.

Power for the Tyneside electrification is furnished by the Newcastle-upon-Tyne Electric Supply Co., principally from its Carville generating station on the electrified line. This power company was a pioneer in the development of an interconnected network, covering a large territory and supplied by modern efficient generating stations.* It is stated that the availability of adequate power at a reasonable price was one of the important factors in this electrification.

Shildon-Newport Electrification

The Shildon-Newport section, in the coal mining district, was electrified in 1915 with 1500-volt direct current and overhead contact line. There are about 19 route miles of double track, and a considerable amount of yard trackage electrified at each end. The voltage is the highest used by any direct-current electrification in the country. It is also the only line to use electric locomotives excepting a few locomotives used for special switching purposes. During the year 1927, 53,000,000 gross ton-miles were handled.

The overhead is of the double catenary type with two contact wires, and suspended from steel latticed

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*This power company is also noted for its interconnection with iron and steel plants, including the utilization of waste heat for generating electric power.

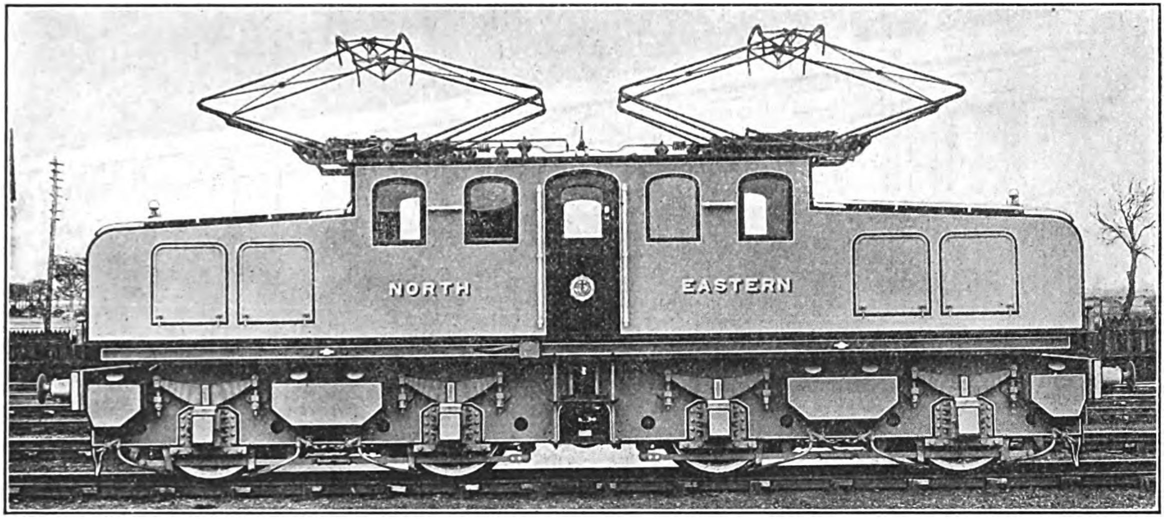

FIG. 6—LONDON & NORTH EASTERN RAILWAY—LOCOMOTIVE FOR SHILDON-NEWPORT ELECTRIFICATION.

structures. Counterweights are used for tensioning the contact wires. Pantagraph collectors are used on the locomotives. There are 10 locomotives weighing about 75 tons each and having wheel arrangement B + B. They have a free-running speed of 45 m.p.h., and were designed to haul trains of 1400 tons at an average speed of 25 m.p.h. The starting tractive effort is 28,000 lb.

The motors are nose-suspended and rated at 275 horsepower each. There are 4 motors on each locomotive, the motors being wound for 750 volts, with the 2 motors of each truck connected permanently in series. Acceleration may be manual or automatic. The locomotives were built in the railroad's locomotive shops using electrical equipment purchased outside.

Power is purchased from the local power company, which is part of a large interconnected system. Three-phase energy at 20,000 volts is taken into the railway substations and converted to direct current. There are 2 substations equipped with rotary converters connected as sets of two in series to give 1500 volts.

Southern Railway

The Southern Railway has at London the largest suburban passenger electrification in the world. While the electric traction in itself is not unusual, the traffic situation is very complicated. Added to large peak loads, originating on many lines over a wide territory, is a feature of multiple terminals with the attendant problem of providing access to each terminal for the trains to and from London over each and every route.

The reasons impelling electrification of the Southern Railway are largely related to traffic and improvement of service. In the first place, some twenty years ago, the constituent railways of the present Southern system found themselves losing much traffic to competing urban carriers. This caused them to turn to electrification as a help in retaining their patrons. Some lines were actually electrified, and others were planned but did not reach the stage of construction prior to the War.

After the Armistice, work was resumed under somewhat different conditions as the potential suburban business had spread out and extended farther from the London terminals. Other carriers, however, competed for the business, making electrification still desirable.

Finally, the latest reason for electrification of the Southern's remaining steam suburban service is that the steam trains make it impossible to work the electric suburban service to full advantage of its possible speed and capacity. This has resulted in plans for elimination of all steam suburban service and substitution of multiple-unit trains.

Other changes had to be made in order to secure the greatest improvement from the faster acceleration and quicker turn-about of the electric trains. The terminals have been rearranged, certain lines rerouted to prevent part of the cross traffic, and new switching and signalling installed in the terminal zones.

As the situation stands today, the Southern has apparently won back the lost patronage, added much new business, and is now building up its territory with a permanent riding public. The railway's analyses of its traffic indicate the futility of attempting to attract patronage within a certain radius of city terminals, say about 4 miles. Ability to run the inner 4 miles at high speed, without stops, makes the service more attractive to the residents beyond. This company expects that the greatest development of electrification in succeeding years will take place between the 4-mile and 30-mile circles, as it has found that, by pushing out farther into the country with suburban electrified lines, it is able to stimulate an increase of new business on the new sections, considerably over-balancing the loss of riders in the close-in districts and making a definite gain in the total suburban business handled.

The first experience with electric motive power by the railways constituting the present Southern

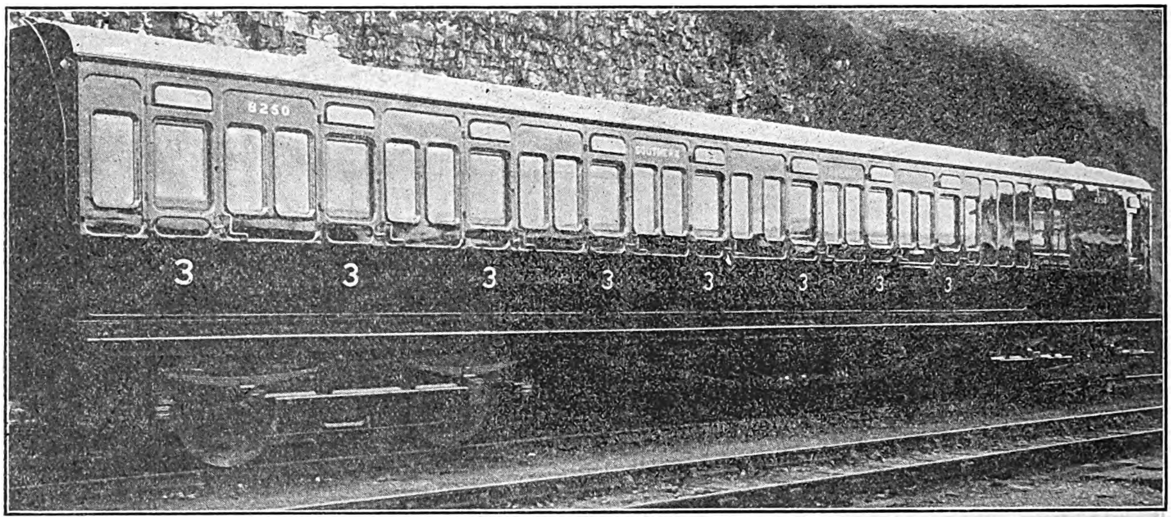

FIG. 7—SOUTHERN RAILWAY—THIRD CLASS COACH FOR LONDON SUBURBAN SERVICE.

Railway system dates back to 1898 when a short tube was built in the heart of London.

Several years later, in 1909, the London, Brighton & South Coast Railway opened the first section of a single-phase electrification using 6600 volts and 25 cycles. This was later extended several times and is now the central section of the Southern's suburban lines.

Alternating current was adopted for this service on account of the long distance to which it was intended to carry the electrification, and the possibility of extending it to the main through service of the company. At the time of consolidation the alternating-current system had grown to 24 route miles. With work then in progress, it reached its culmination in 1925 with a total of 41 route miles. All of the alternating-current lines will eventually be changed to direct current, as explained later.

Prior to the War the London and South Western Railway had started to electrify some of its service. The work was brought to completion in 1915 and 1916 on 49 route miles, and is now embraced in the western section of the Southern's suburban lines. It utilizes a third rail energized with direct current at 650 volts. At the time of consolidation the railway was committed to extend on 30 route miles. With further additions there are now 89 miles of route and 250 miles of track electrified in this western section.

The London & South Eastern Railway which now forms the eastern section of the consolidated lines had considered electrification for several years before the War but did not get started. Afterwards it completed plans for 100 route miles, but construction was not begun until after the consolidation of 1923. This section uses 650-volt direct current supplied by a third rail, like the western section.

Electrification of the eastern section was first brought into service in 1925 and continued in subsequent years. At the end of 1928, with some mileage converted from alternating current on the old Brighton lines, there is a total of 175 miles of route and 489 miles of track electrified with direct current in the eastern and central sections.

As the work progressed it was found that the full advantages of consolidation would not be attained with 2 direct-current zones separated by the intervening alternating-current zone of the old Brighton railway. Hence it was decided to change the latter to the new company's standard third-rail system. Some of the mileage has been changed to direct current and a part has been paralleled with third rail so that both kinds of trains can operate. Ultimately all of the high-tension overhead will be removed.

Taking the 3 sections together there are, at the end of 1928, 264 route miles and 739 track miles using the third rail. The central section still contains 30 route miles and 108 track miles electrified with alternating current. This gives a total of 294 route miles and 847 track miles altogether in the 3 sections, which will be increased to 875 track miles in 1929 when work in process is completed.

Multiple-unit trains are used for all this service. There are at present 488 motor cars and 452 trailers, a total of 940 cars, on the direct-current lines. There are also 71 motor cars and 164 trailers on the alternating-current lines. All of this rolling stock, except about 10 per cent, has been provided by conversion of the former steam stock. This practice will be followed in the future as far as possible in order to retain serviceable equipment.

It is now customary, on replacing steam service, to schedule about twice as many trains per day. Other improvements, such as described above, in rearranging terminals, new signalling and elimination of steam suburban trains from terminal zones, have permitted 50 per cent increase in number of trains over the schedules provided in the earlier days of electric service.

Due to faster and more frequent service the patronage has shown a very gratifying response. Although the total number of passengers carried by all railroads in England showed a decrease of nearly 75,000,000 between 1925 and 1927, the Southern Railway registered an increase of more than 7,000,000 passenger rides in this period between the same stations in its electrified area. During January, 1928, the number of passenger rides increased nearly 700,000 over January, 1927, between stations in the electrified area. As an indication of the volume of traffic carried into and out of London by this railroad, a count in February, 1928, showed nearly 524,000 passengers on a normal day, handled at 6 terminals. The heaviest hours of morning and evening accounted for 75,000 passengers each.

Two districts of the Southern Railway electrification were visited, including a trip to the steam power station at Wimbledon Park, which supplies energy for the western section. This station, adjacent to the car shops at Wimbledon, has a capacity of 25,000 kw. for 3-phase energy at 25 cycles. The power is transmitted at generator pressure of 11,000 volts to the converter stations which feed into the third rail at 650 volts.

Energy is purchased for the eastern section, also third rail, and there are altogether 49 direct-current substations. Energy is also purchased for the present alternating-current electrification in the central section.

Future Plans

It is difficult to say just what may be done about electrification. The railroads were consolidated for economy of working. Since that time, however, there have been 2 negative influences which have delayed the anticipated results and retarded development: (1) depression of the coal industry with consequent decrease of coal traffic, and, (2) large increase in road-vehicle competition for both passenger and freight business.

Due to the insularity of the country and its numerous rivers, there is no part very far from ocean transportation, which serves to move a large tonnage of heavy and slow-moving goods. At the present time much of the lighter and short-haul traffic is handled by highway carriers. These facts, together with the considerable investment required for electrification, have tended to prevent its development—except for suburban service. However, the railway electrification committees above cited have made a considerable study of the technical requirements which would be imposed by trunk-line electrification. Their recommendations are intended to embrace the best choice of system for economy, interchange of equipment, and proper clearances with the most economical use of existing structures.

There is a new development in England which may have some effect on this matter of electrifying trunk lines. That is the new extensive grid system, or transmission network, for supplying large quantities of electric power from large, efficient steam power stations. This system is being planned and carried to conclusion by a board acting under authority of the Government. The grid system aims to cure the previous lack of harmony and efficiency of power supply from many small plants of diverse frequencies. Having abundant coal resources within its own confines, there is no present indication that England will be impelled to electrify its railways as a measure of national economy like some of the other European countries. Whether the unification of electricity supply, however, will bring any important results or economies that will have a bearing on trunk-line electrification cannot be predicted.

As for suburban service, the traffic around the large cities is very heavy. Two railroads at London have considerable suburban service electrified, and state that their electric operations are very satisfactory. Other railways in the North are giving suburban service with electric trains that they say would be difficult to render with steam. The opinion of railway men interviewed in England seems to be that suburban electrification will extend gradually in the future as it has in the past.

The Netherlands

Netherlands Railways

The Netherlands Railways are operated by a corporation in which the National Government is a large shareholder. About 81 miles of line have been electrified in the district between Amsterdam and Rotterdam. Multiple-unit trains are used for local and express passenger service. International trains and freight trains are still operated over the same tracks by steam locomotives.

Electrical operation was adopted because traffic between Amsterdam and Rotterdam was so congested that more capacity had to be provided. The

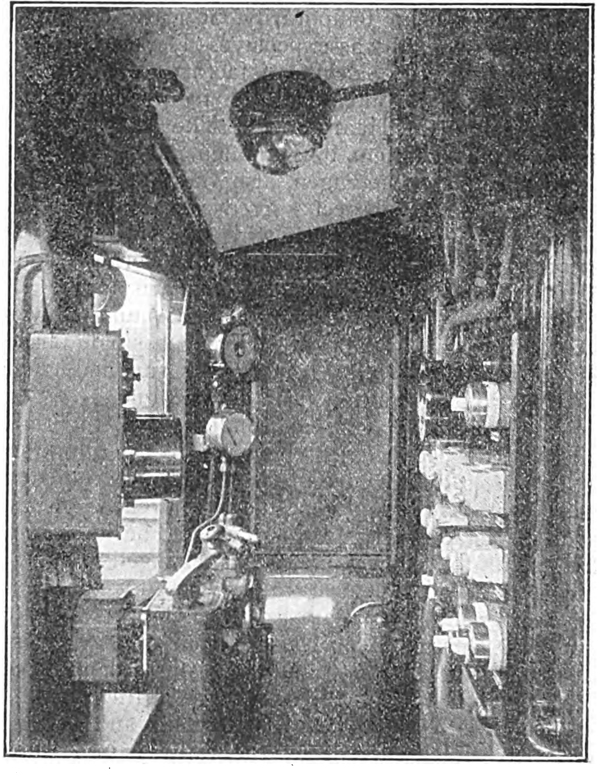
FIG. 8—NETHERLANDS RAILWAYS—DRIVER'S CAB ON ELECTRIC MOTOR CAR.

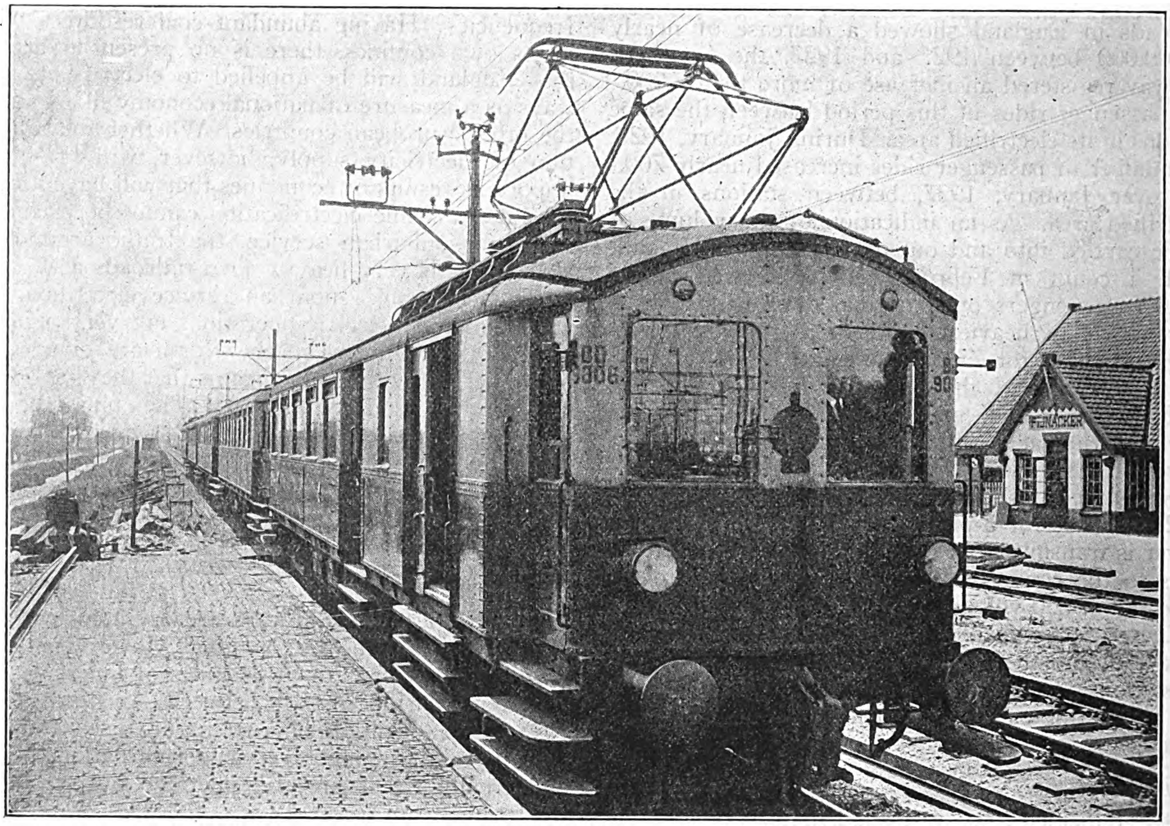

FIG. 9—NETHERLANDS RAILWAYS—MULTIPLE-UNIT TRAIN.

main line was double-track, and it was necessary to electrify or to add 2 more tracks. Electrification solved the problem temporarily, at least, during a period when capital was expensive. The electric service is reported to be very satisfactory.

The electrified routes are (1) from Amsterdam to Rotterdam via Haarlem and The Hague, with branch from Haarlem to Ijmuiden, and (2) from Rotterdam to Scheveningen, also via The Hague by a different route. Direct current at 1500 volts is supplied by a double contact wire suspended from a catenary. Several different types of overhead construction have been installed for comparison.

The line from Rotterdam to Scheveningen was built for electric traction in 1908 using single-phase current at 10,000 volts. Energy was supplied from a separate power station near The Hague.

Since 1920 investigations conducted by the railways and the Government have led to the adoption of 1500-volt direct current as a national standard for railways. It was also decided to purchase energy from the established power systems. The line from Rotterdam to Scheveningen was changed to 1500 volts in 1926, and electric trains were introduced on the Amsterdam-Rotterdam line in 1927.

Electric energy is purchased from 3 power systems operating in the vicinity of Amsterdam, Rotterdam and The Hague. This energy is furnished as 3-phase at either 6000 or 10,000 volts, and is converted to direct current by the railway in 7 substations. Three or 4 mercury arc rectifiers are installed in each substation, except at The Hague where there are 2 rectifiers and 2 motor-generator sets.

The substation visited at Amsterdam contains 3 rectifier sets, each composed of 2 bowls. Ordinarily 2 sets are used and one held in reserve. The capacity of each set is 1000 kw. continuous, and 1500 kw. for two hours. There is one transformer for each set. The rectifiers and all switching operations of the substation are actuated by remote control from a nearby switch tower. Little trouble has been experienced with flash-backs, interruptions lasting not more than 2 or 3 minutes.

Trains are composed of motor and trailer cars in like numbers. The motor cars are equipped with four 180-horsepower motors, connected two in series across 1500 volts. They also have electro-pneumatic control and air brakes. The electrical equipment is all hung underneath the body, and not placed in the car, as seen in several European countries. Current is collected by pantographs. Car heating is done by electricity at the voltage of the contact line. Lighting current is furnished by a special generator and storage battery. The control circuits have the same voltage as the lighting. Acceleration is automatic and the full speed of 59 m.p.h. is attained in 3 minutes.

The motor cars weigh about 68 tons and the trailer cars about 44 tons. The bodies are steel and trucks are 4-wheel of M.C.B. type. Cars have end entrances and center aisles, with one or two cross

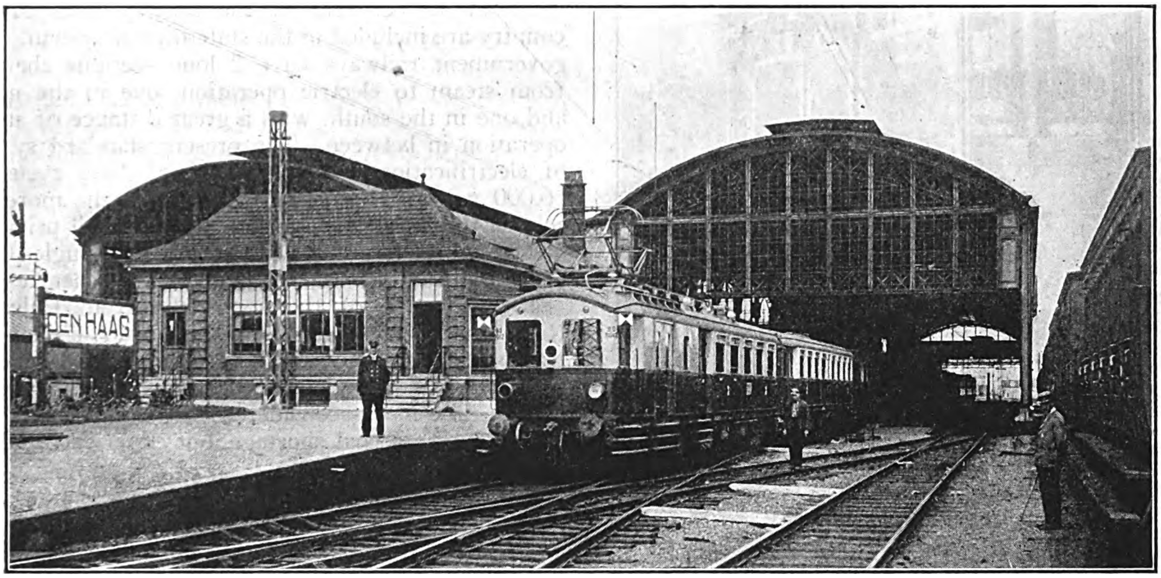

FIG. 10—NETHERLANDS RAILWAYS—ELECTRIC TRAIN AT THE HAGUE.

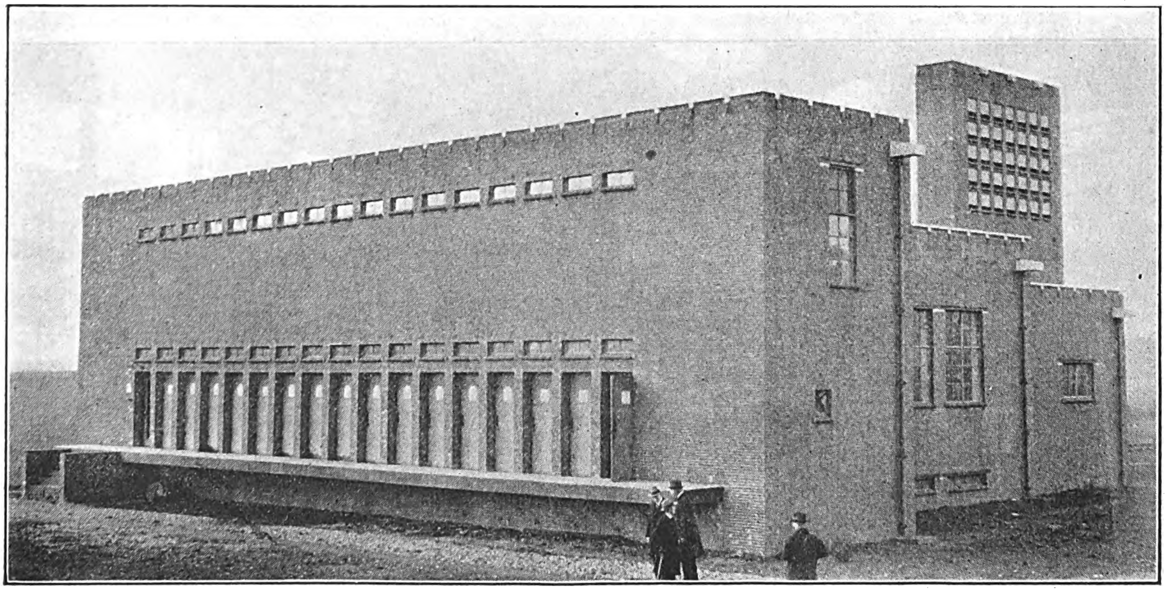

FIG. 11—NETHERLANDS RAILWAYS—REMOTE-CONTROL SUBSTATION AT AMSTERDAM.

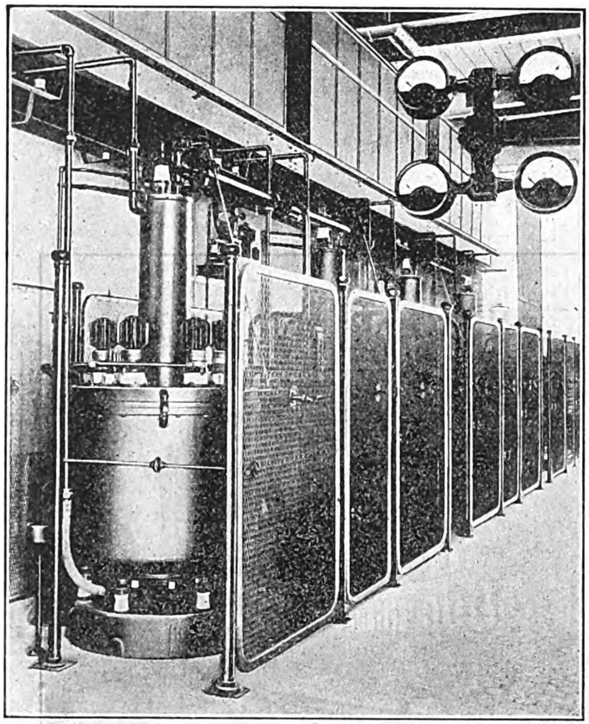

FIG. 12 — NETHERLANDS RAILWAYS — RECTIFIERS IN SCHIEBROECK SUBSTATION.

partitions making separation of the smoking and non-smoking sections. Second and third class cars are used. A trip was made over the line on an express train from Rotterdam to Amsterdam and return. The cars ride well and the service is quite commendable.

Future plans contemplate: (1) purchase of electric locomotives for hauling long-distance passenger trains and freight trains over the present electrified sections; (2) addition of more tracks to the main line between Amsterdam and Rotterdam to care for the increase of business since electric traction was installed; and, (3) the extension of electrification to other lines of which Amsterdam-Utrecht will probably be the first.

Sweden

Swedish State Railways

About 40 per cent of the railway lines of the country are included in the state-owned system. The government railways have 2 long sections changed from steam to electric operation, one in the north and one in the south, with a great distance of steam operation in between. The present standard system of electrification is single phase of 16⅔ cycles at 16,000 volts. This system is used on the more recent of the 2 electrifications. Several small privately owned railroads are electrified, all with single-phase energy but of different voltages and frequencies.

Electrification of the north line from Luleå to Riksgrensen was started before the War, largely for traffic reasons. The primary cause for further electrification has been developed by the War. Previous to that time it was considered that wood fuel would suffice during a coal shortage, but experience proved otherwise.

The preventive for such occurrences is now considered to lie in linking up the railways with the already well-developed State Power System, which has an abundant supply of water power. It was thus decided to electrify some of the important lines, of which the Stockholm-Gothenburg line should be the first on account of its having the greatest coal consumption per mile of route.

The single-phase system was chosen with the same line voltage as the earlier electrification, namely 16,000, but using 16⅔ cycles to facilitate conversion from the 50-cycle power system, while the older electrification uses 15 cycles from independent gen-

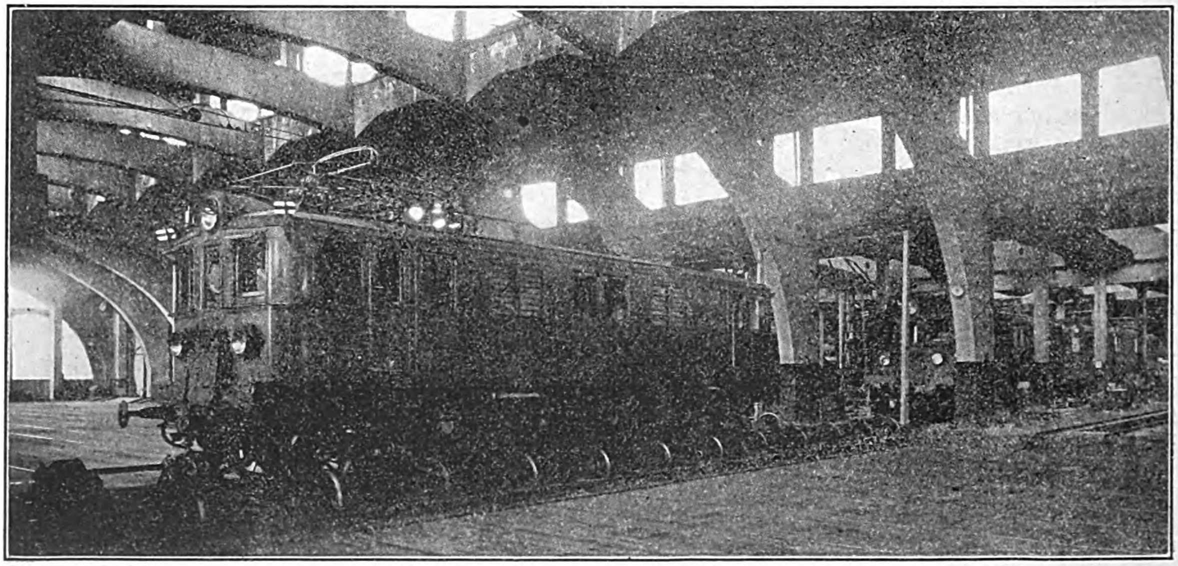

FIG. 13—SWEDISH STATE RAILWAYS—LOCOMOTIVE IN INSPECTION SHOP AT STOCKHOLM.

erators. This slight difference in frequency will not prevent exchange of locomotives between the two lines, although this is unlikely at present as they are several hundred miles apart.

Lulea-Riksgrensen Electrification

The first electrification of the State Railways was on the ore railroad in the northern part of the country. The line extends from Lulea on the Gulf of Bothnia to Riksgrensen on the Norwegian frontier. From here it continues as part of the Norwegian State Railways to the port of Narvik on the Atlantic Coast of Norway. Most of this line is above the Arctic Circle, and it was too far off the itinerary to be visited. Considerable information was secured, which will be briefly stated here.

This line serves the iron mining districts of Kiruna and Gallivare in Northern Sweden. Large tonnages of ore are shipped in both directions to the ports of Lulea and Narvik. Heavy tonnage traffic and availability of water power dictated electrification. The first electrified part went into operation in 1915 and was gradually extended until complete electric operation was accomplished in 1922.

Power is furnished from the northern detached section of the Swedish State Power System. There is one hydraulic generating station at Porjus which supplies power for the mining district and for many communities. The head is about 184 ft. This plant, built in 1914, now contains 3 generators for power and 4 for railway purposes. The power generators are each 11,000-kw., 3-phase and 25-cycle. The railway generators are each 8500-kw., single-phase and 15-cycle.

The railway energy is transmitted to and along the railway right-of-way at 80,000 volts. There are 13 transformer stations feeding the contact line with 16,000 volts. The average distance between transformer stations is 21.8 miles.

The original freight locomotives were of the type 1 C + C 1, weighing 152 tons. The passenger locomotives were 2 B 2, weighing 90 tons. Since then several different types of locomotives have been purchased for this line, mostly freight locomotives as only a small amount of passenger equipment is required.

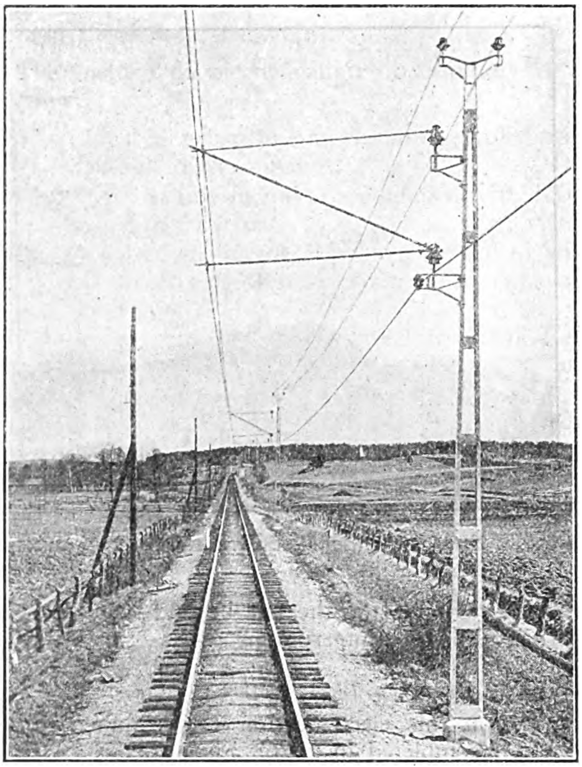

FIG. 14—SWEDISH STATE RAILWAYS—CONTACT LINE ON STOCKHOLM-GOTHENBURG ELECTRIFICATION.

The latest freight locomotives for this line are type 1 C + C 1, weighing 141 tons. They have 2 cabs with one large motor in each. The motor drives by connecting-rods to a jack-shaft from which side-rods link together the 3 driving axles. The speed is 37.3 m.p.h. The maximum train weight is 2095 tons per locomotive.

The Norwegian State Railways provide locomo-

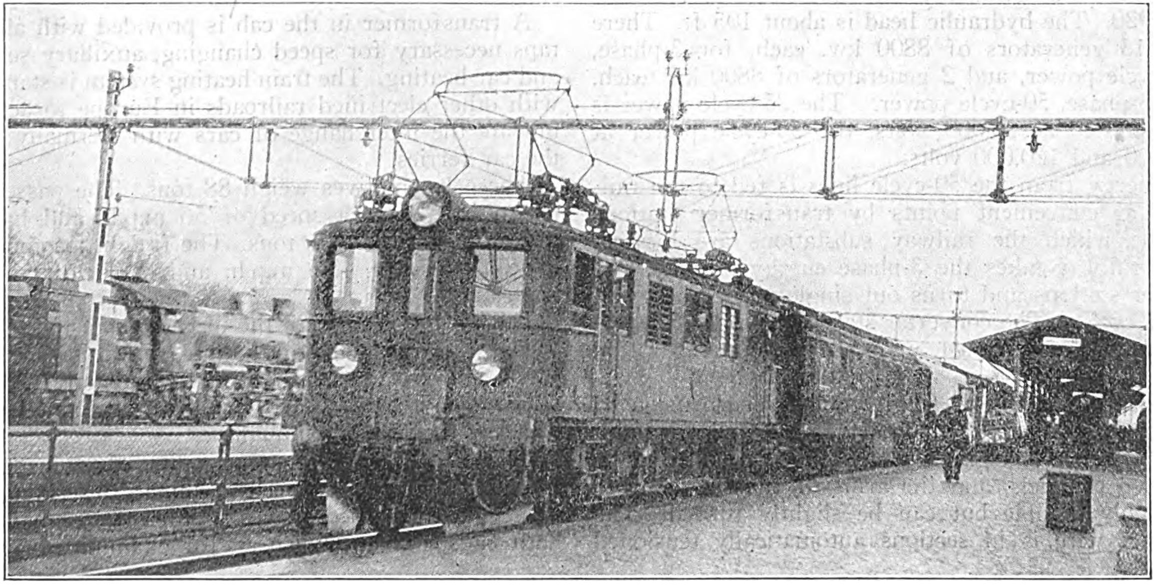

FIG. 15—SWEDISH STATE RAILWAYS—TRAIN AT HALLSBERG ON STOCKHOLM-GOTHENBURG LINE.

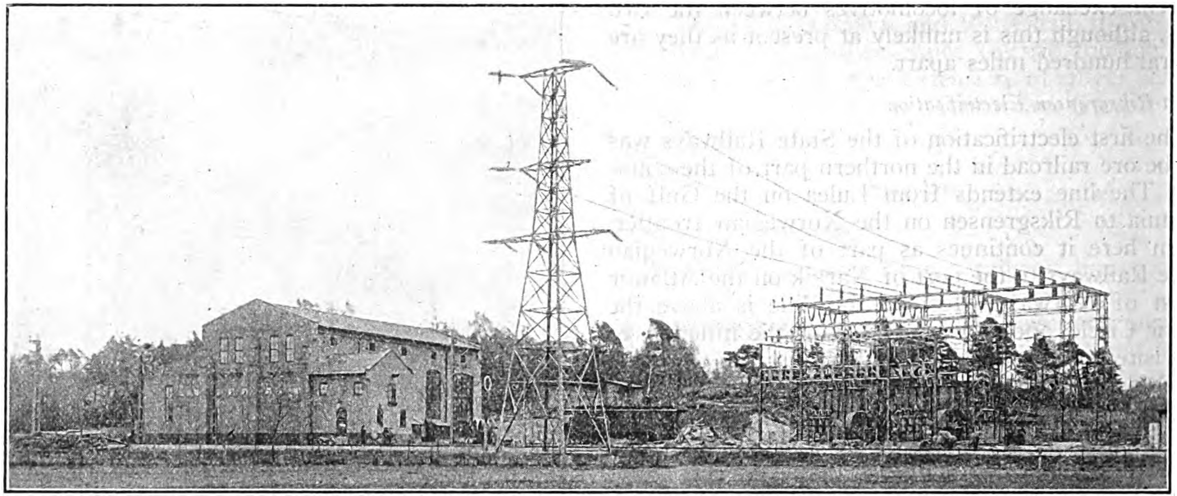

FIG. 16—SWEDISH STATE RAILWAYS—ALINGSAS CONVERTER STATION ON STOCKHOLM-GOTHENBURG ELECTRIFICATION.

tives for their end of the line beyond Riksgrensen. There is also some interrunning.

Stockholm-Gothenburg Electrification

Work on this electrification was commenced in 1923 and completed in 1926. Since Oct. 1 of that year the operation has been electric for all trains over the whole line.

Energy for this new electrification is supplied from an interconnected network of the State Power System which covers the whole district through which the railroad line extends. The network is fed by one steam station and 4 hydraulic generating stations. Two of the hydroelectric stations were visited—Motala and Trollhattan.

The Motala power station, in service since 1922, has a head of about 49 ft. The present installation consists of two 4800-kw. generators for 3-phase, 50-cycle power. Transmission is at 70,000 volts.

The Trollhattan power station is the largest in the State Power System. It commenced operation in 1910 and was gradually extended to its present size in 1920. The hydraulic head is about 105 ft. There are 13 generators of 8800 kw. each, for 3-phase, 25-cycle power, and 2 generators of 8800 kw. each, for 3-phase, 50-cycle power. The 25-cycle power is transmitted at 50,000 volts, the 50-cycle power at 50,000 and 120,000 volts.

Energy from the 50-cycle lines is fed to the railway at convenient points by transformer stations beside which the railway substations are located. The railway takes the 3-phase energy into its converter stations and turns out single-phase energy at 16⅔ cycles. The converter stations number 5, averaging 58.5 miles apart, with a maximum separation of 80 miles.

The contact line is single catenary suspension of Z-type construction which had been well tried out on the Lulea-Riksgrensen line. The poles are made of two channels, and the arms of tubes which are not only flexible but can be slightly turned. The contact wire is in sections automatically tensioned at each end by counterweighting devices attached to the supporting poles.

It is not necessary to use an auxiliary feeder in addition to the contact wire. There is a return wire carried on the supporting poles. This wire takes current from the rails at frequent intervals through booster transformers. The rails are not bonded.

A great deal of experimenting was done on the Lulea-Riksgrensen line with regard to communication circuits. The return feed wire was, as a result, applied to the new electrification, and the communication circuits cabled underground. It is said that the results are quite satisfactory.

The locomotives of this line are alike for passenger and freight trains, excepting the gear ratio. They are all of the same design, made by 3 locomotive factories from identical drawings. They are of the type 1 C 1. The single cab contains a twin motor of 1700 horsepower with the 2 halves electrically connected in series. The armatures are geared to a jack-shaft which connects to the 3 driving axles by side-rods.

A transformer in the cab is provided with all the taps necessary for speed changing, auxiliary service and car heating. The train heating system is standard with other electrified railroads in Europe to accommodate the interchange of cars with Germany over the car ferries.

These locomotives weigh 88 tons. The passenger locomotives have a speed of 56 m.p.h. and haul a maximum train of 550 tons. The freight locomotives have a speed of 43.5 m.p.h. and haul a maximum train of 990 tons.

During the year 1927 the maximum distance covered by any passenger locomotive of this type was 101,300 miles, and by any freight locomotive 58,900 miles. The average yearly mileage was about 15 per cent less than the maximum.

The Stockholm-Gothenburg line was inspected most of the way between terminals by riding on passenger-train locomotives. Stops were made at both ends and at Hallsberg for examining various special features. Side trips were made from Hallsberg to Motala and Orebro, and from Gothenburg to Trollhattan. These side trips covered locomotive factories, hydroelectric stations, and the main locomotive shop at Orebro.

This electrification seems to be very satisfactory, and the comparative statistics of train operation and traffic show a great improvement over steam operation. Since the installation of electric motive power the running time has been very much reduced for both freight and passenger trains. Congestion has been eliminated and the capacity of the line greatly increased. As a result, the passenger service has been augmented by many more trains which seem to be appreciated by the railroad's patrons.

General and Future

Since 1926, the Swedish State Railways have 570 miles of line operated by electricity. This is 17.5 per cent of the line, but the traffic involved is not less than 25 per cent of the total train-miles. There are 109 electric locomotives and 2 electric motor cars.

Future plans call for extension of electric traction on the lines of heavy traffic. The lines under consideration at present are Stockholm-Malmo, Gothenburg-Malmo, and Stockholm-Upsala. A definite announcement of the undertaking of some of this work will probably be made soon.

Germany

Germany stands third among the countries of Europe in respect to miles of railroad electrified. Switzerland and Italy are the only countries that have electrified more miles of line. Since all the main-line railways of the country are embraced in one organization under control of the National Government it is only necessary to describe the electrical operations of this one company.

German Government Railways

The history of electrification in Germany is as follows:

1903—Short suburban line at Berlin electrified with 550-volt direct current.
1908-09—Short line in Bavaria equipped with 1000-volt direct current.
1908—A suburban line at Hamburg electrified with 6000-volt single-phase power. This was extended in 1924.
1910—An experimental line installed in Middle Germany for test of high-voltage alternating current.
1911—Hamburg Harbor line electrified with 3000-volt single-phase power.
1912-13—Mittenwald Railway between Garmisch and Innsbruck (Austria) built for initial operation by electric power.
1913—A few miles of high-voltage single-phase electrification installed in the southern part of Baden.
1914—The first Silesian line equipped for high-voltage single-phase operation. Gradual extensions of this installation have been made up to the year 1928.
1916—First Bavarian electrification in operation with high-voltage single-phase power. Other Bavarian lines electrified in 1925 and each year to 1928.
1916—Small narrow-gage line electrified in Saxony.
1922—First section of high-voltage single-phase electrification in Middle Germany completed. It was extended in 1923-25-27.
1924—Berlin suburban electrification first began to operate (with third rail). Added to gradually ever since and nearly completed at end of 1928.

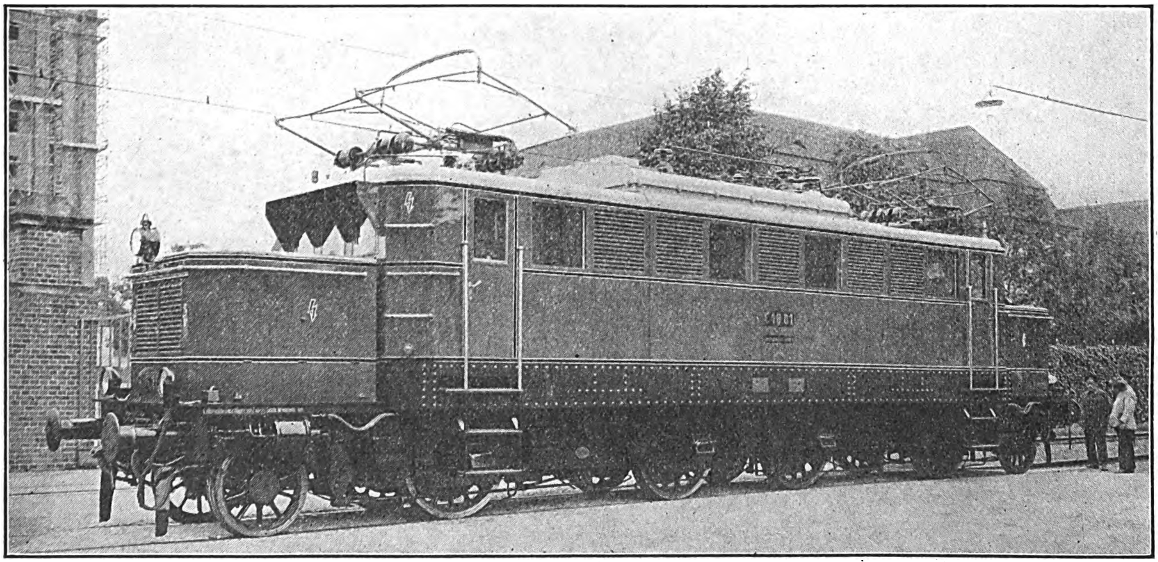

FIG. 17—GERMAN GOVERNMENT RAILWAYS—BAVARIAN DISTRICT—HIGH-SPEED LOCOMOTIVE WITH INDIVIDUAL-AXLE DRIVE.

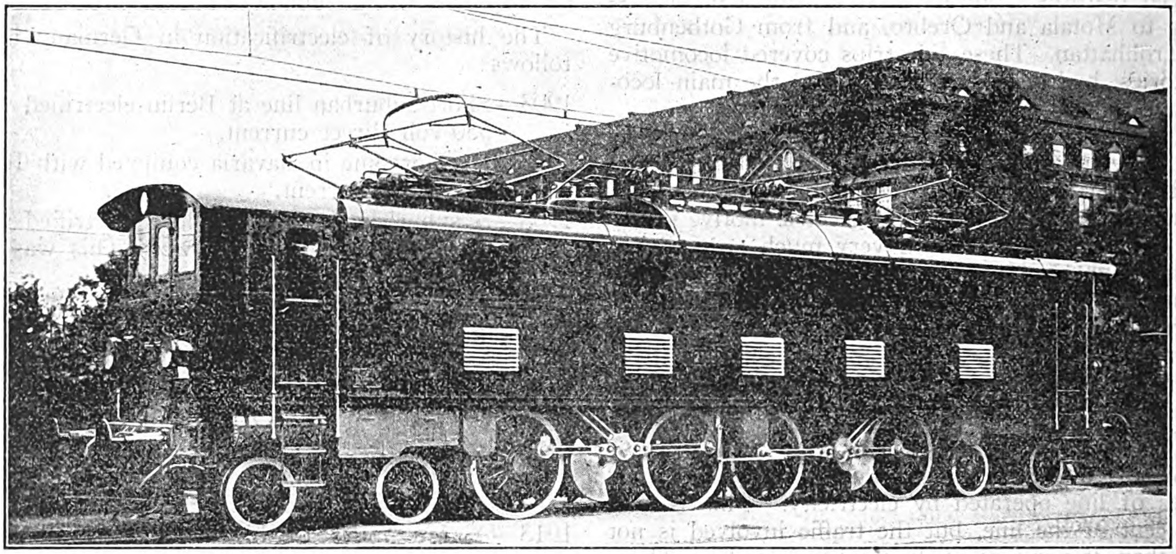

FIG. 18—GERMAN GOVERNMENT RAILWAYS—BAVARIAN DISTRICT—PASSENGER LOCOMOTIVE WITH SIDE-ROD DRIVE.

In 1910, as stated above, an experimental line was equipped in Middle Germany for train operation with alternating current. The progress of main-line electrification starts from this time. Plans were made shortly thereafter for electrification of considerable mileage in widely separated districts, on the flat lines of Middle Germany and on the mountain lines of Silesia, also in Bavaria. Only a small mileage, in the last 2 districts, had been electrified when the War caused almost complete cessation of activity. The work, when resumed after hostilities, began to show its effects about 1922, and since then there has been a steady increase in electric operation.

The following figures show the extent of electrification at the end of the last 3 years, and the per cent of the whole system electrified:

	Route Miles	Per Cent of System
1926	625	1.9
1927	757	2.3
1928	963	2.9

The German Government Railways now have 4 principal zones of electrification. Arranged in order of size, according to the route miles, they are:

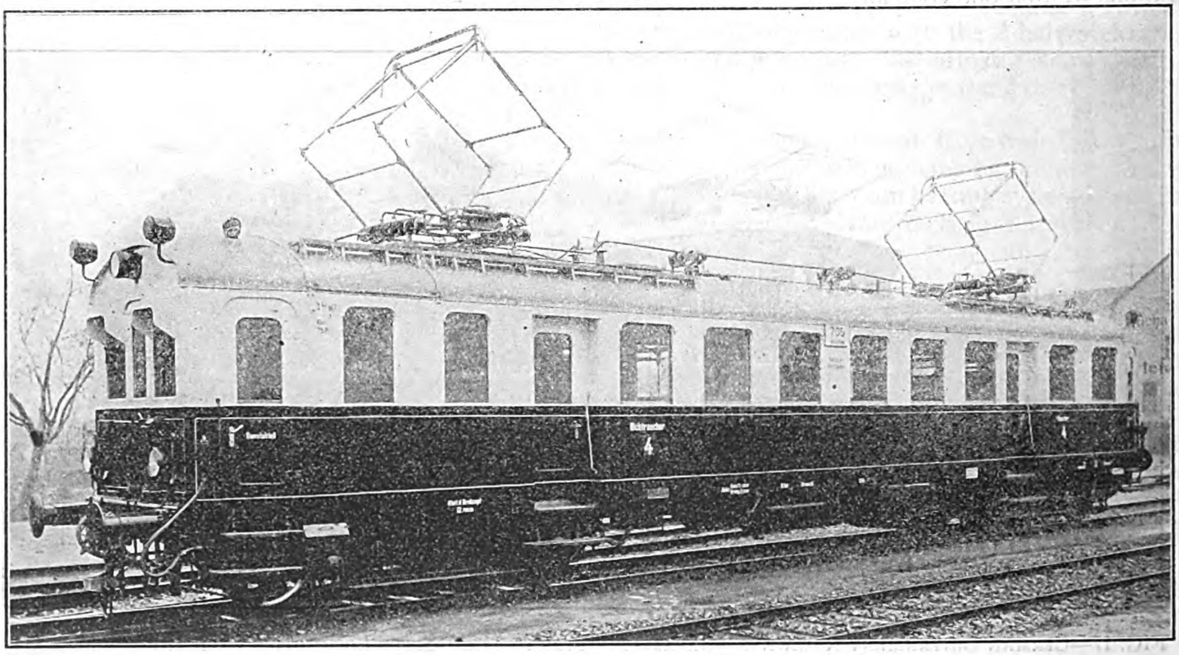

FIG. 19—GERMAN GOVERNMENT RAILWAYS—BAVARIAN DISTRICT—MOTOR CAR FOR 15,000-VOLT LINES.

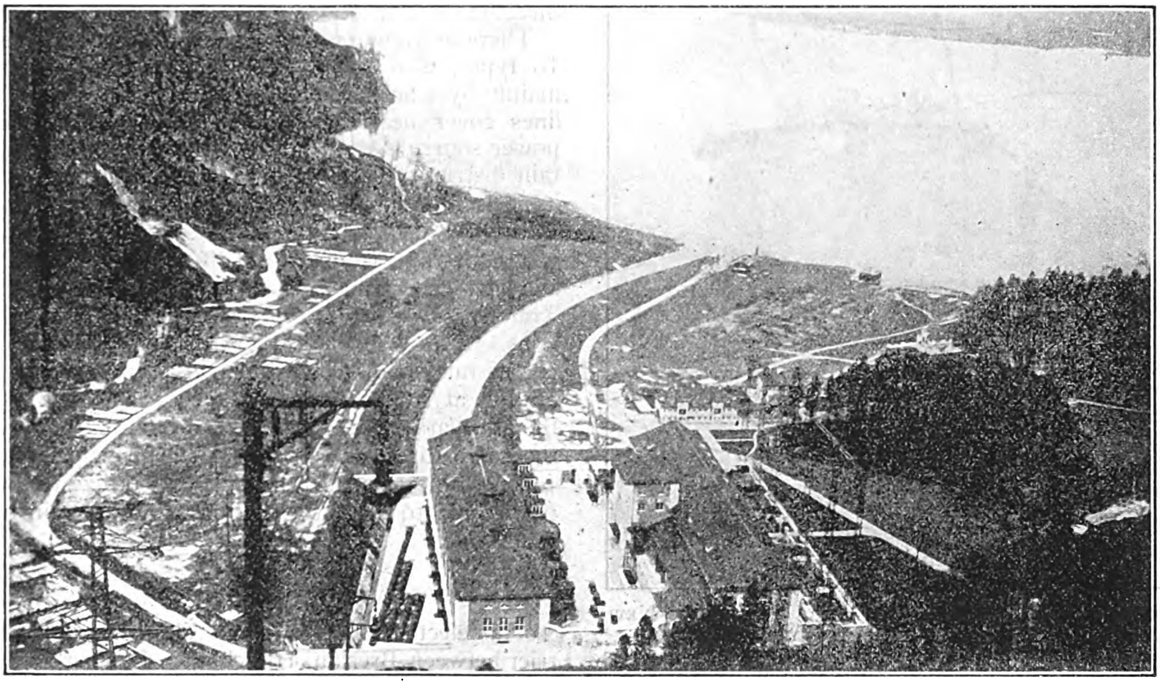

FIG. 20—BAVARIAN POWER COMPANY—WALCHENSEE HYDRO-ELECTRIC POWER STATION.

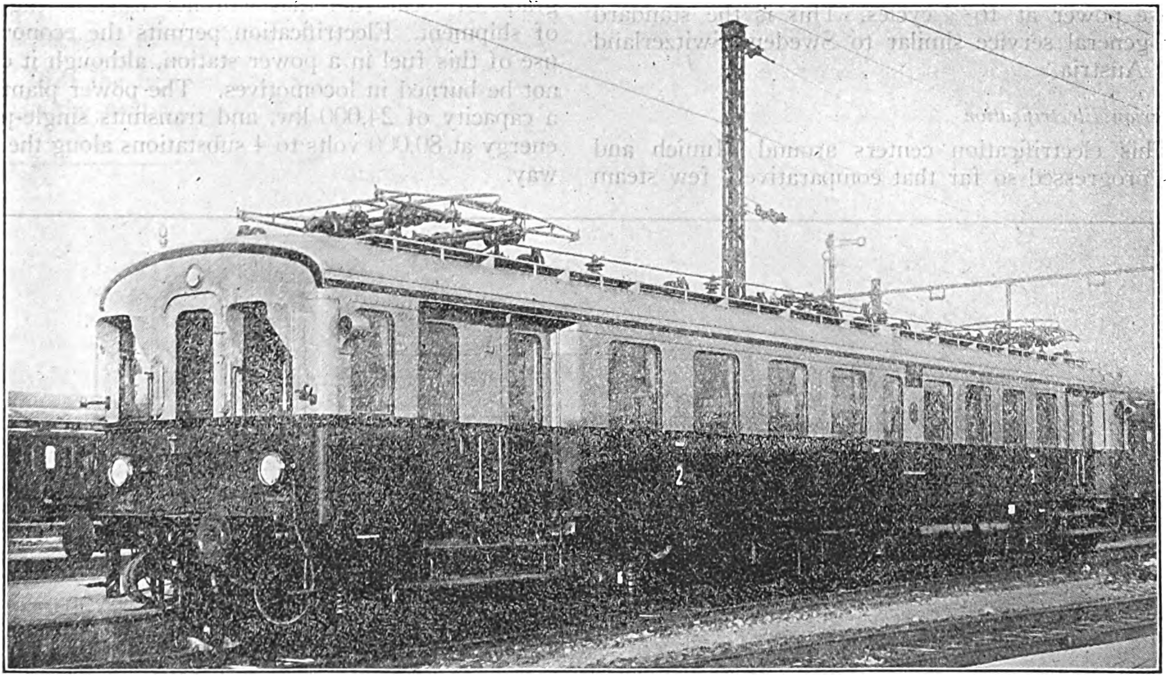

FIG. 21—GERMAN GOVERNMENT RAILWAYS—HALLE DISTRICT—MOTOR CAR FOR 15,000-VOLT LINES.

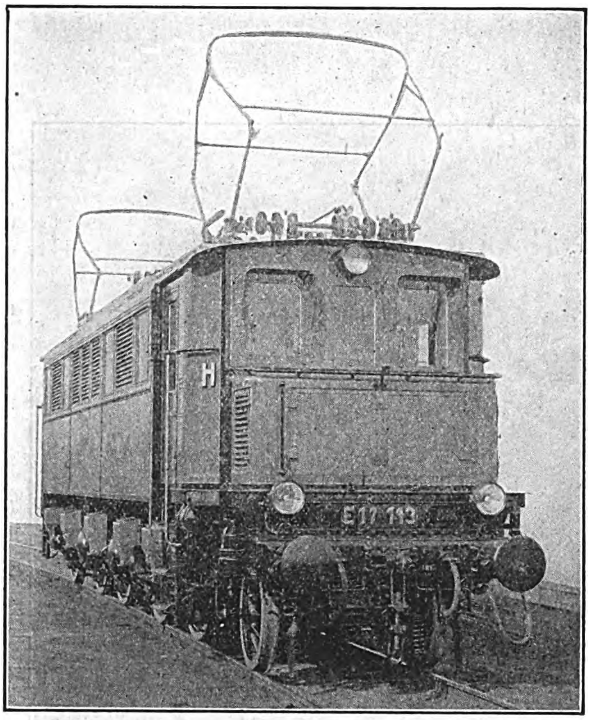

FIG. 22—GERMAN GOVERNMENT RAILWAYS—NEW STANDARD PASSENGER LOCOMOTIVE, FRONT VIEW.

	Route Miles
Bavaria	434
Silesia	215
Berlin (Suburban)	145
Middle Germany	114

Excepting the Berlin suburban lines, these important zones are energized with 15,000-volt single-phase power at 16⅔ cycles. This is the standard for general service similar to Sweden, Switzerland and Austria.

Bavarian Electrification

This electrification centers around Munich and has progressed so far that comparatively few steam locomotives are seen in that vicinity. Electric operation extends to Regensburg on the north and into Austria in 4 places on the south. About 434 miles are electrified, including the 11 miles electrified with direct current in 1908.

There are now on this division 196 locomotives of 16 types, also 40 motor cars. Power is supplied mainly by a large hydroelectric power system whose lines cover nearly the whole state. The principal power source is the Walchensee station in the mountain district south of Munich. As the power system itself is three-phase, the railways have arranged for the power company to install separate single-phase generators and transmission lines. There is 80,000 kw. of generating capacity for railway service. Transmission is at 110,000 volts to 6 railway substations.

The railway also owns 2 small power stations generating at trolley voltage. One of 5000 kw. is for the alternating-current lines and one of 600 kw. for the small direct-current line. The principal reasons for electrification in Bavaria are to utilize the water power and to increase the capacity of certain heavy grade lines.

Silesian Electrification

This electrification is in the Silesian mountain district between Breslau, Hirschburg, Lauban and Gorlitz. About 215 miles are involved. Grades are heavy and traffic considerable. There are 92 locomotives of 10 types and 21 motor cars. Power is supplied by the railway's own power station at Mittelsteine in the southern part of Silesia.

Aside from reasons of traffic, another important reason for this electrification is to utilize a very low grade of local fuel that will not warrant the cost of shipment. Electrification permits the economical use of this fuel in a power station, although it could not be burned in locomotives. The power plant has a capacity of 24,000 kw. and transmits single-phase energy at 80,000 volts to 4 substations along the railway.

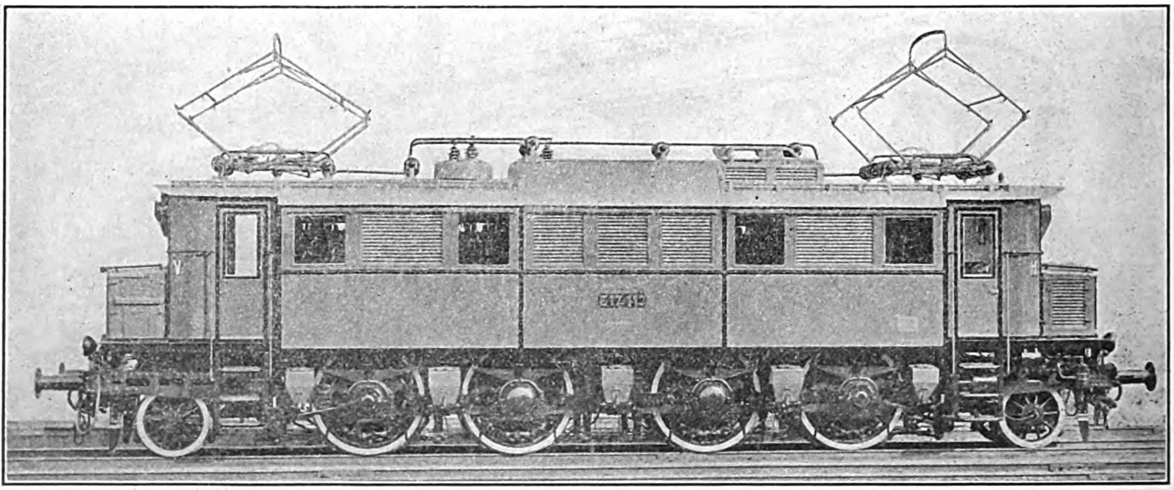

FIG. 23—GERMAN GOVERNMENT RAILWAYS—NEW STANDARD PASSENGER LOCOMOTIVE, SIDE VIEW.

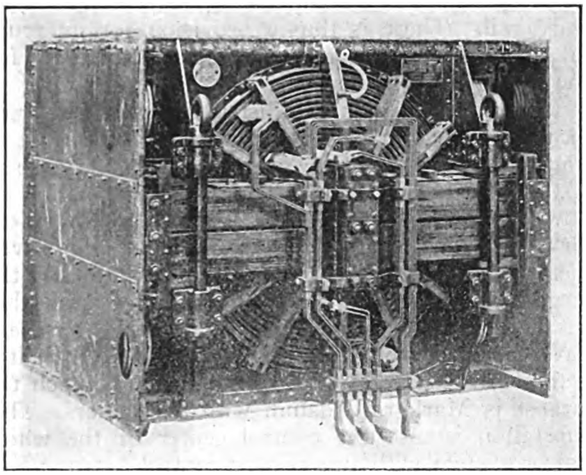

FIG. 24—GERMAN GOVERNMENT RAILWAYS—NEW STANDARD PASSENGER LOCOMOTIVE, AIR-COOLED TRANSFORMER.

Electrification in Middle Germany

This electrification covers a territory extending from Magdeburg to Leipzig and Halle, and the lines total 114 miles. It was undertaken particularly for the purpose of utilizing the local deposits of brown coal. This is of the nature of peat, very low in combustible and containing more than 50 per cent of moisture. It must be consumed on the spot as it will not bear any cost of transportation, neither is it suitable for locomotive fuel.

The railway has erected near Bitterfeld a steam power station of 26,500 kw. The single-phase power is transmitted at 60,000 volts to 3 substations. Traction is furnished by 104 locomotives of 11 types and by 5 motor cars.

Berlin Suburban Electrification

In 1924 the first electrical operation of suburban lines in the vicinity of Berlin was introduced. The whole task of converting the suburban service from steam to electricity comprises 145 miles of the so-called City, Ring and Suburban Railway. This work was nearly completed at the time of the Subcommittee's visit. The motive power consists of 481 motor cars which are being progressively equipped in a large, modern and well-equipped overhaul shop which the railway has built at Nieder Schoneweide on the outskirts of Berlin.

The reason for this electrification was the necessity for the improved handling of the suburban service in the congested districts at the center of the city. This called for more traffic capacity which is being given by the faster movement and more rapid

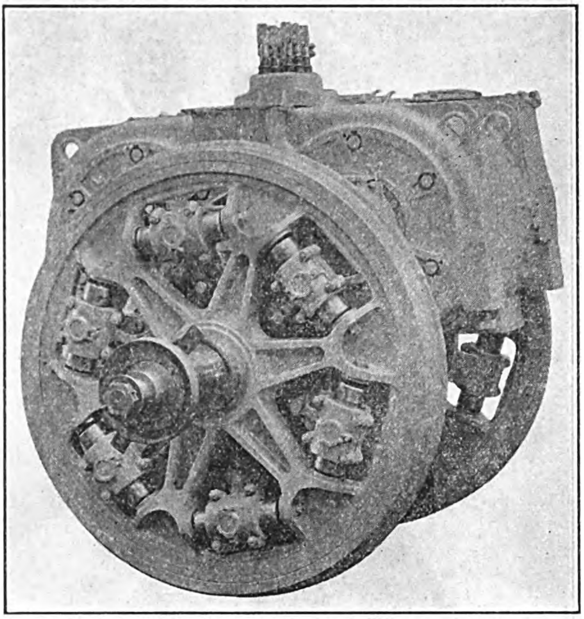

FIG. 25—GERMAN GOVERNMENT RAILWAYS—NEW STANDARD PASSENGER LOCOMOTIVE, TWIN MOTOR AND AXLE ASSEMBLY.

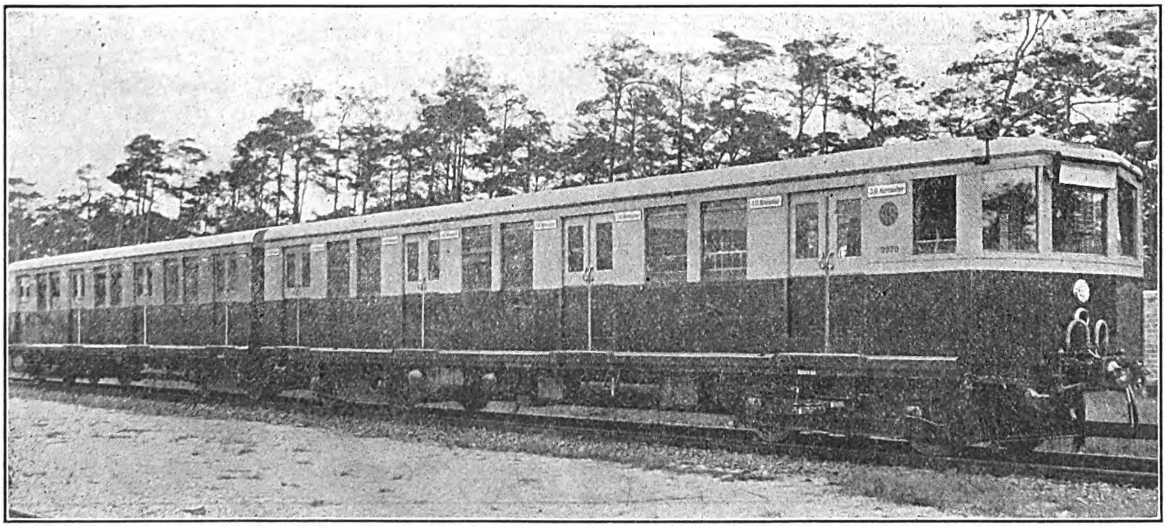

FIG. 26—GERMAN GOVERNMENT RAILWAYS, BERLIN DISTRICT—NEW SUBURBAN CARS FOR THIRD-RAIL OPERATION.

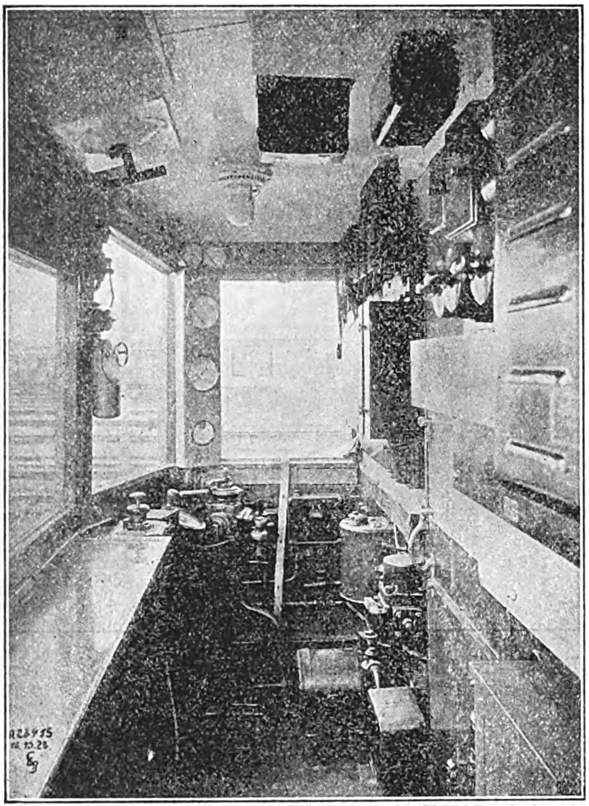

FIG. 27—GERMAN GOVERNMENT RAILWAYS—BERLIN DISTRICT—DRIVER'S CAB ON MOTOR CAR FOR NEW SUBURBAN SERVICE.

acceleration of multiple-unit trains. Direct current with third rail was selected as most suitable for this class of service. A comparatively high voltage was desired, and the pressure of 800 volts was adopted because the Berlin Elevated and Underground Railways system was already using this voltage on its third rail. There is thus a provision for interrunning between the two railways in the future, and for the use of joint substations.

Power for the suburban district is purchased from local power companies generating by steam. It is transmitted to the railway's substations as 3-phase at 30,000 and 110,000 volts. The whole installation of power, cars, shops and substations shows every effort to embody the latest and most improved methods. The conversion equipment is probably the largest aggregation of mercury arc rectifiers that has been installed anywhere. Most of the rectifiers have a capacity of 1200 kw. each. There are altogether 119 rectifiers in 48 substations, of which the largest is Markgrafendamm with 8 rectifiers. This substation is also the control center of the whole power system with supervisory control extending to the others.

Smaller Electrifications

In the state of Baden there are about 30 miles electrified between Basle, Zell and Sackingen. This is also 15,000-volt and single-phase, but the frequency is 15 cycles. There are 16 locomotives of two types. Power is purchased from a water power station at 6800 volts and 50 cycles. This is converted by the railway in a substation of 4000 kw. capacity.

In the Hamburg district there is a suburban line about 20 miles long operated with 25-cycle single-phase power. The overhead contact line is energized at 6000 volts. Motive power is furnished by 150 motor cars. This is an early installation and the rolling stock is all compartment type with side doors for each compartment. There is also a line to the Hamburg Harbor about 2 miles in length. This uses 3 locomotives with the same frequency but at 3000 volts. The railway company operates a steam power station with 28,500 kw. installed. Generation is

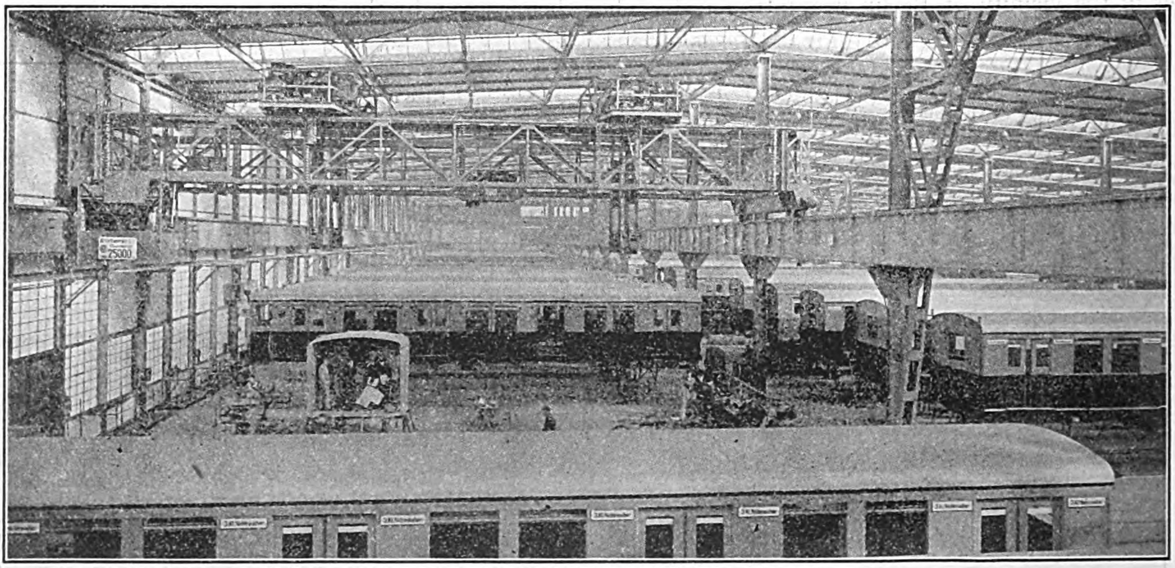

FIG. 28—GERMAN GOVERNMENT RAILWAYS—BERLIN DISTRICT—NEW SHOP FOR SUBURBAN CARS, BODY DEPARTMENT.

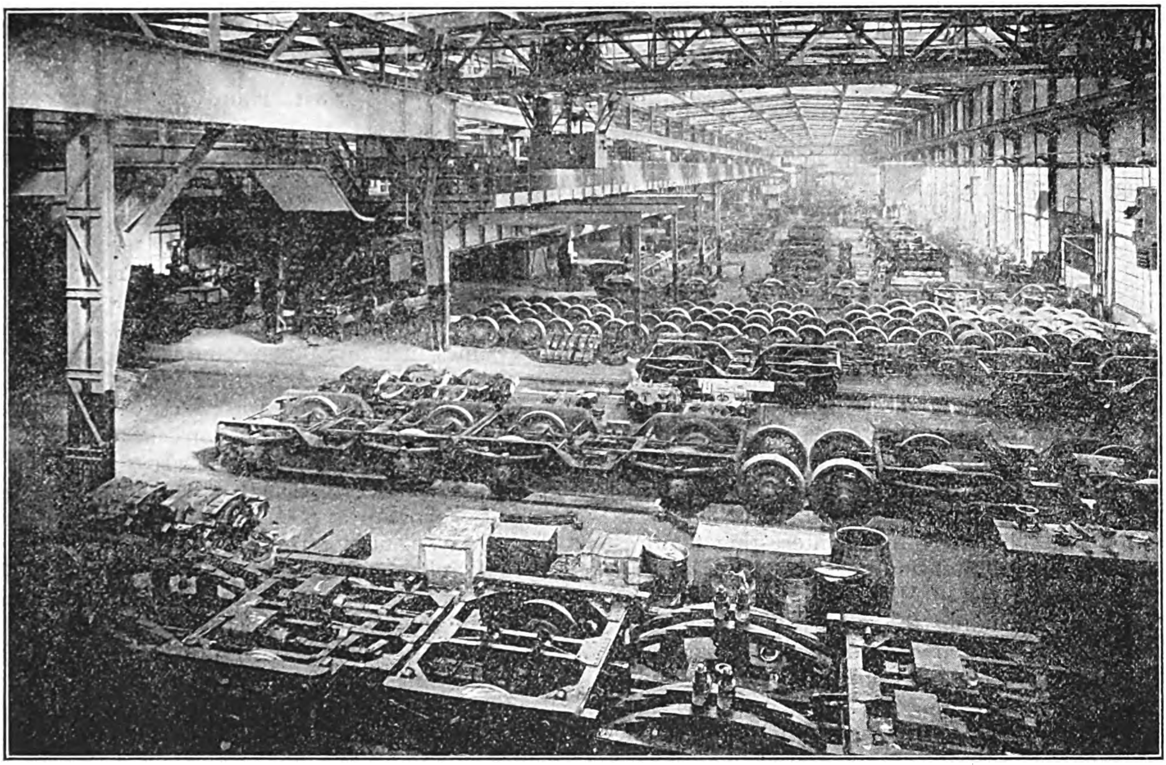

FIG. 29—GERMAN GOVERNMENT RAILWAYS—BERLIN DISTRICT—NEW SHOP FOR SUBURBAN CARS, TRUCK DEPARTMENT.

single-phase at 25 cycles and 6000 volts, but power is transmitted to one substation at 30,000 volts.

In Saxony, at Untersachsenberg, about 3 miles of narrow-gage railway are electrified with 650-volt direct current. Power is purchased at trolley voltage from a municipal steam power station. Two locomotives and 2 motor cars furnish the traction.

General and Future

There are many things of interest to both power and railway companies in the German electrifications. One is the apparent willingness to purchase power or to generate it according to the conditions in each district. Another is the diverse operating conditions of the several sections electrified and the different types of equipment that have been purchased for each.

The use of a separate generating and distributing system for railways has been the subject of much discussion in all countries. It is apparently preferred by the German railway engineers and executives. They justify it as being more reliable and as the cheapest way of securing 16⅔ cycles at the con-

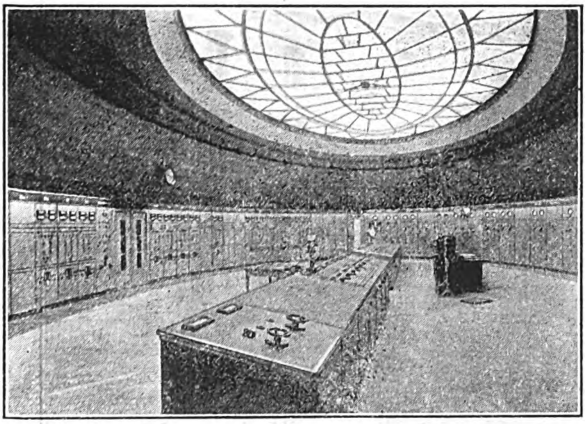

FIG. 30—GERMAN GOVERNMENT RAILWAYS—BERLIN DISTRICT—CONTROL ROOM FOR SUBSTATIONS OF SUBURBAN ELECTRIFICATION.

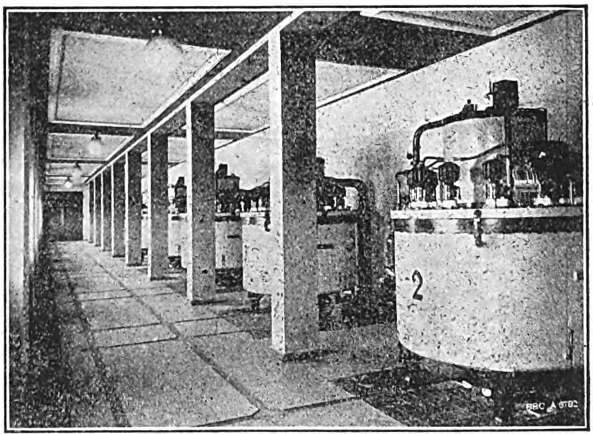

FIG. 31—GERMAN GOVERNMENT RAILWAYS—BERLIN DISTRICT—RECTIFIERS AT MARKGRAFENDAMM SUBSTATION ON SUBURBAN ELECTRIFICATION.

tact line. This is mentioned, not as criticism, but simply to record the impressions received in the field.

Two tendencies of locomotive design were observed here. One is the tendency toward individual-axle drive for high-speed service, doing away with jack-shafts and side-rods. The other is the tendency toward standardization in locomotive design, including the manufacture to standard design by more than one locomotive works. The latter was also mentioned in connection with Sweden and became further impressed on the Subcommittee in other countries.

One of the new standard designs in Germany is of the class 1 D_o 1 for high-speed passenger service. It has 4 twin motors geared to spring quills on the axles. The German engineers expressed considerable satisfaction with this type of drive, including the twin series motor for alternating current.

The motor cars and multiple-unit cars seen in the several districts are substantially built and fine-looking equipment. They have many interesting features for handling the high-tension current on the 15,000-volt motor cars. All of the cars seen, except at Hamburg and including the new rolling stock for Berlin, are of the open type divided by partitions for the different classes and for smoking and non-smoking.

The large program covering the most advisable electrifications has been nearly completed. There will probably be further extensions in the districts above described, particularly in Silesia. About 1600 miles have been studied with the view of electrification in these districts and in the industrial districts of the Rhine. Some of these projected electrifications would connect together the present electrified zones and permit through running of electric trains, but it is not known when they may be undertaken.

Switzerland

Switzerland is a country of special attraction to all students of electrification for two reasons: (1) On account of the early national interest in this subject and the large amount of developmental engineering which was done there, and, (2) on account of the ambitious program of electrification which has been carried out during recent years. As matters now stand, Switzerland has a greater mileage of electrified railway lines than any other country in Europe.

At the end of 1928, 2124 miles, or 62 per cent of the railway route mileage was electrically operated. On the electrically operated sections there was hauled 85 per cent of the total traffic in gross ton-miles of freight and passenger service. These figures include standard-gage railways, narrow-gage railways and rack railways, but not tramways or cable railways. They also include all the lines which were built for electric operation as well as those which were once operated by steam. They show, however, the importance of electric motive power to the whole transportation business of the country.

Coming to the route miles which are classed as electrified, 1180 miles or 51 per cent of the standard-gage lines have actually been changed from steam to electric motive power. With respect to both standard and narrow-gage railways together, the corresponding figure is 1323 miles or 40 per cent. To the 1323 miles should be added, as in the other countries, the extensions of electrified lines into new

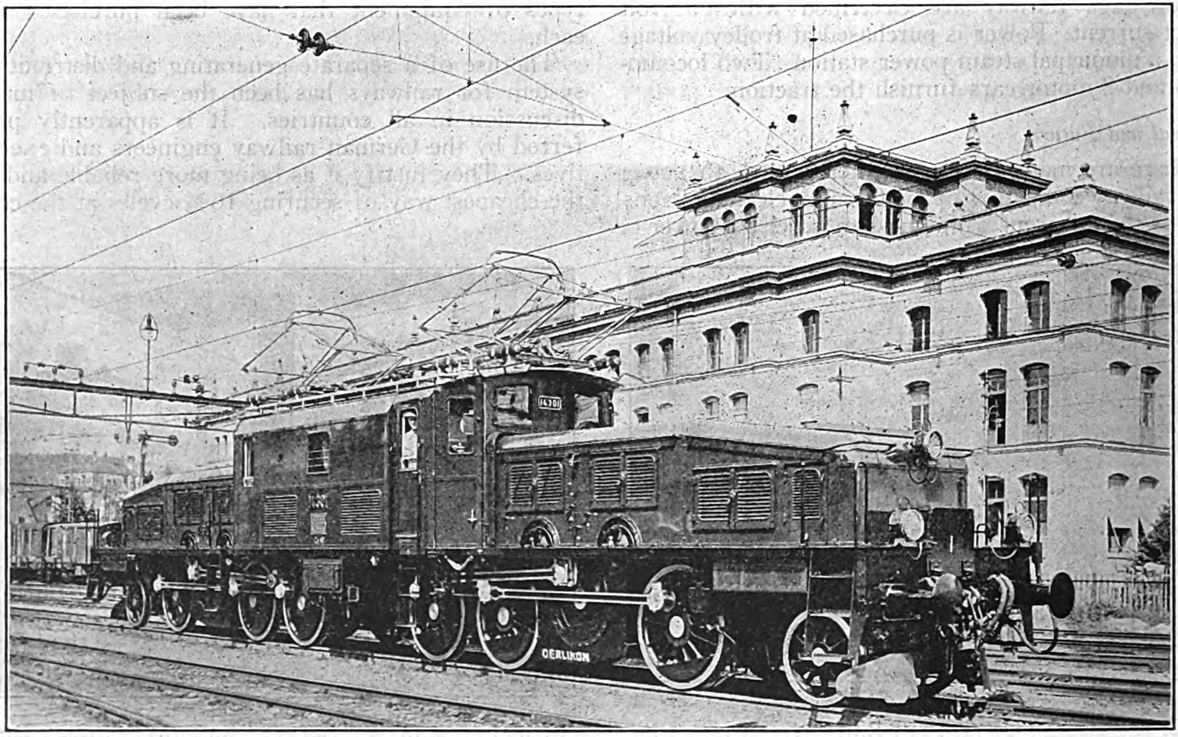

FIG. 32—SWISS FEDERAL RAILWAYS—LATEST TYPE OF FREIGHT LOCOMOTIVE.

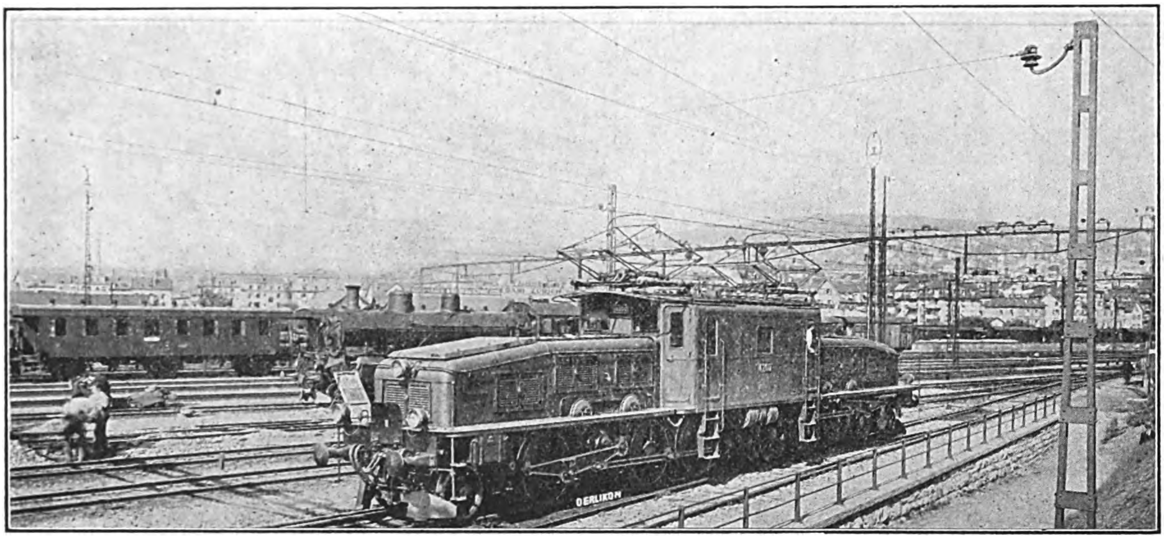

FIG. 33—SWISS FEDERAL RAILWAYS—ANOTHER TYPE OF FREIGHT LOCOMOTIVE.

territory and certain new projects of regular "steam railroad" character and traffic. This results in a total of nearly 1500 miles or 43 per cent of the route miles of the country being classed as electrified.

The reasons behind the change to electricity are several, but the principal one is economic. Switzerland has no coal resources, but has abundance of water power. Before 1900 attempts were made to utilize the water power for railways, and 2 installations were made. One railroad, the Burgdorf-Thun, is worthy of mention for its pioneer work. This road was built by one of the steam railroads and equipped with 3-phase overhead contact line at 750 volts and 40 cycles. The length is 25.5 miles. It still utilizes the same system, although there have been various improvements and replacements of the equipment. The interests in control of this railroad added about 50 per cent to their electrification by a connecting line in 1919.

The meter-gage railways, which perform important service in Switzerland, were among the pioneers to develop and prove the merits of electric traction. One of the early ones was the Montreux-Oberland Railway, which opened 54 miles of line in 1901-1905. This line has many of the features of the other Swiss railways, but has been electric since the beginning. Direct current is used at 1000 volts, and the energy is purchased.

Prior to 1910 the developmental work was done by the smaller railroads, both meter and standard-gage, with the exception of the Simplon tunnel (which is described below under Swiss Federal Railways). In this period there was one significant undertaking in experimental use of high-voltage single phase. A small section about 12 miles long was equipped in 1907 with 15,000 volts at 15 cycles. This was purely a cooperative experiment by some of the electrical manufacturers and lasted 18 months, after which the electrical equipment was dismantled.

Following this experiment the Bernese Alps Railway made plans for utilizing a similar system in the new Loetschberg tunnel, then under construction. It made a trial installation on part of its existing line, commencing in 1910, and extended it to and through the tunnel in 1913, giving it then 47.5 miles of 15,000-volt single-phase electrification. The Bernese Alps Railway is credited with the first commercial installation of this system in 1910. It is interesting to note, however, that the installation was planned to operate on one-half voltage (7500 volts), if necessary, but that this provision was never utilized. The frequency is now 16⅔ cycles instead of 15.

In 1913 the Rhaetian Railway, a meter-gage road, began the installation of an 11,000-volt single-phase trolley at 16⅔ cycles. This work was undertaken in connection with expansion of its system. The first year 30 miles of new electric line were added and about 9 miles of steam-operated line converted to electric. Immediately after the War, conversion of the remainder was pursued vigorously, with result that the whole system of 172 miles has been electric since 1922. They purchase all their power. All service is performed by locomotives.

The economic reasons for electrification, above mentioned, were greatly accentuated during the War when fuel was hard to obtain. Then after the War came an urge to undertake large public improvements as a means of employing workers and providing home industries with business. The elimination of smoke and injurious gases in tunnels was also an important factor in formulating the program.

Swiss Railways have had to cope with a great deal of trouble from the extraordinary number of tunnels, three of which are each in excess of 9 miles. The Simplon and Loetschberg tunnels have been electrified from their openings, in 1906 and 1913 respectively, but the St. Gotthard tunnel was operated for 40 years with steam locomotives.

As a preliminary step toward adoption of electric

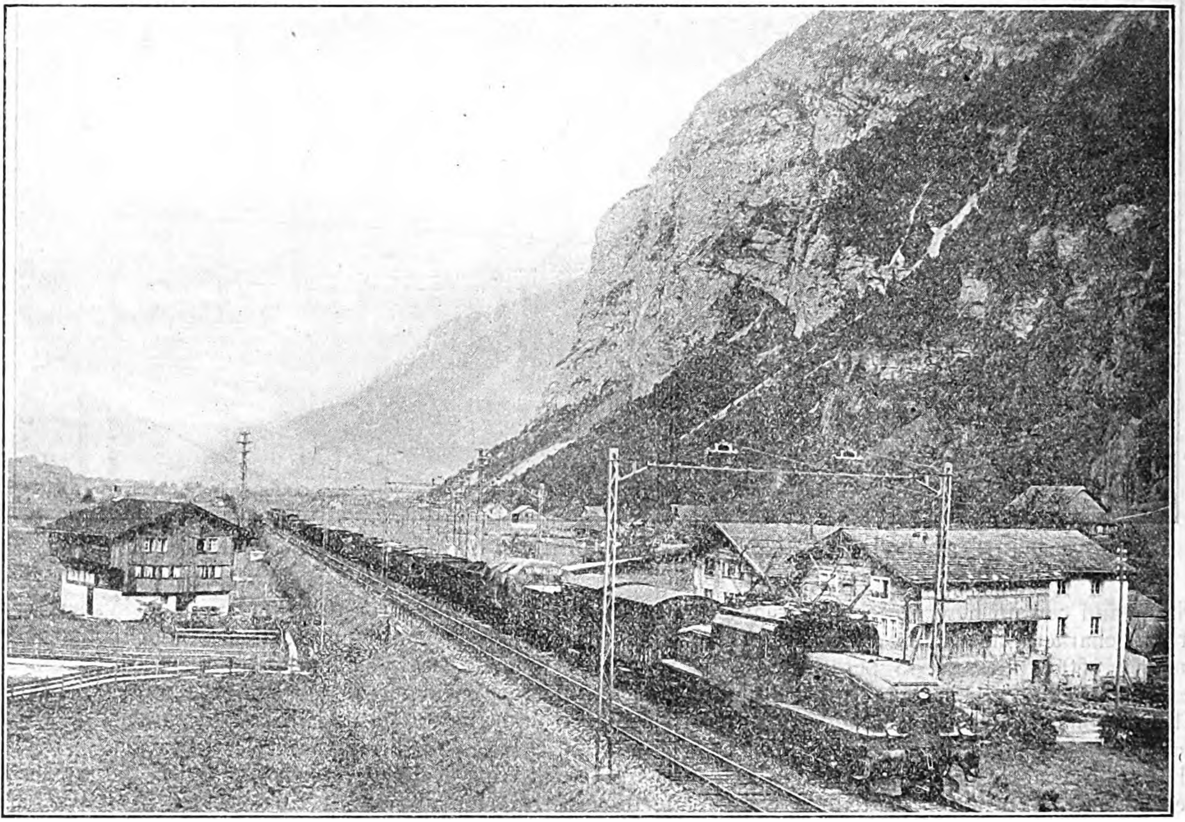

FIG. 34—SWISS FEDERAL RAILWAYS—FREIGHT TRAIN ON ST. GOTTHARD LINE.

traction on a large scale by the Federal Railways, a Research Committee was appointed in 1904. In 1912 this committee submitted a report recommending the use of low-frequency single phase at 15,000 volts. During the intervening period the Federal Government had been active in securing sites for future power plants, and in 1907 a department of the Federal Railways had been established to plan the necessary power developments. The St. Gotthard tunnel electrification was authorized late in 1913, using single-phase current at 15,000 volts and 16⅔ cycles. In February, 1916, the same system of electrification was adopted as standard for the Federal Railways.

A definite program of electrification was laid out for the Federal Railways which has been in effect ever since the War. In the last 5 years a particularly vigorous attempt has been made to complete the program. At the end of 1928 all the most important lines were operating electrically, and the Federal Railways will probably extend electrification on the remainder of its system only very gradually.

Prior to the War there were only about 200 miles of all railways electrified in Switzerland. This increased very slightly during the War. The great growth to nearly 1500 miles now electrified has taken place since 1918, and mostly on the Federal Railways. Their standard system of high-voltage single-phase electrification has been extended to cover nearly 1000 miles of the Federal Railways' lines and about 170 miles of other normal-gage lines. The 15,000-volt single-phase system constitutes 80 per cent of the electrification of Switzerland. The other 20 per cent is divided between several different types of electrification, both alternating and direct current.

There are 2 principal standard-gage railways in Switzerland, the Federal Railways and the Bernese Alps Railway. The latter is also known as the Berne-Loetschberg-Simplon, or more simply as the Loetschberg line. Both of these roads were visited and a brief description of each will follow.

Swiss Federal Railways

As already stated, this railroad operates the principal standard-gage lines of the country, and it handles practically all the international traffic, except such portion as makes part of its journey over the Loetschberg line. It has a number of mountain crossings, including the famous Simplon and St. Gotthard tunnels.

The first important electrification of the Federal Railways was in 1906 when the Simplon tunnel was opened to traffic. During the building of this tunnel, it had been expected until near the end that it would be operated by steam like the older tunnels. There was considerable agitation for it to be operated electrically on account of its great length of 12.3 miles, the longest in the world. The Italians had already achieved some success with 3-phase electrification on main-line railways and urged quite strongly that electric traction be provided. Accordingly the plans were altered to install electric over-

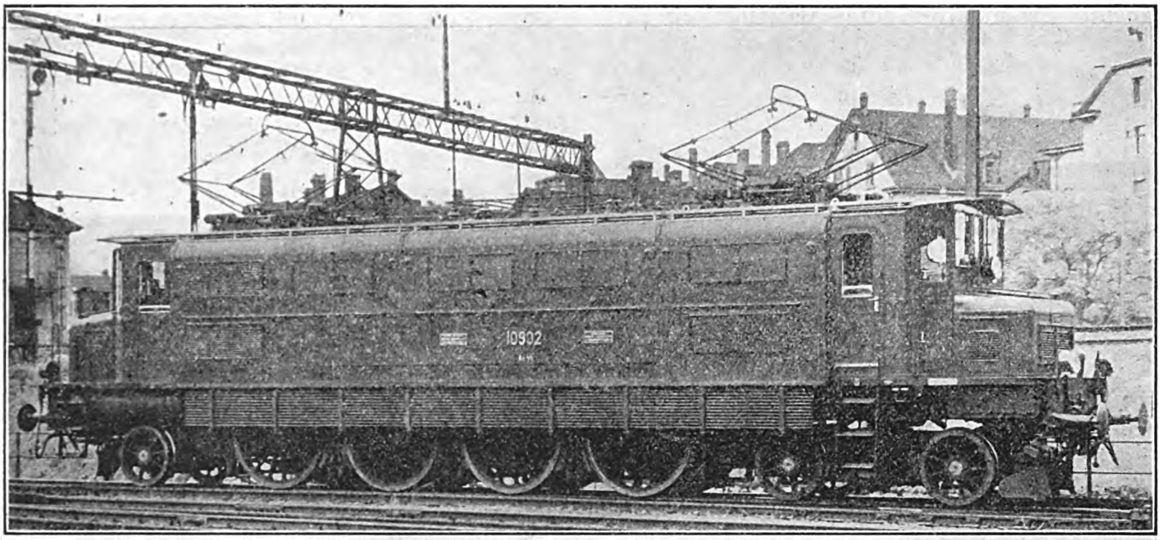

FIG. 35—SWISS FEDERAL RAILWAYS—PASSENGER LOCOMOTIVE WITH INDIVIDUAL-AXLE DRIVE.

head in the tunnel during the last few months before completion. Electric operation was initiated with locomotives borrowed from the Italian State Railways. The 3-phase installation at 3300 volts and 16⅔ cycles is still in operation.

The next important section considered for electrification was the St. Gotthard route which has been mentioned above in its bearing on the general situation. Plans for electrification had been made and construction work started before the War. Due to the difficulties which then ensued, there was not much accomplished for several years. The tunnel itself was changed to electric operation in 1920. The whole project then in hand measured 140 miles from Lucerne to Chiasso, including the tunnel. It was all turned over to electric traction in 1922. It is interesting to note that this stretch of line includes 28.4 miles of tunnels, of which 9.3 miles is in the St. Gotthard bore itself.

In the 5 years since 1923, 70 miles of line have been electrified. The largest amount completed in any year was in 1927 when 300 miles were done. As already stated, this completes the big program of the Federal Railways with all principal trunk lines now electric.

Concurrently with the work on the railways, a

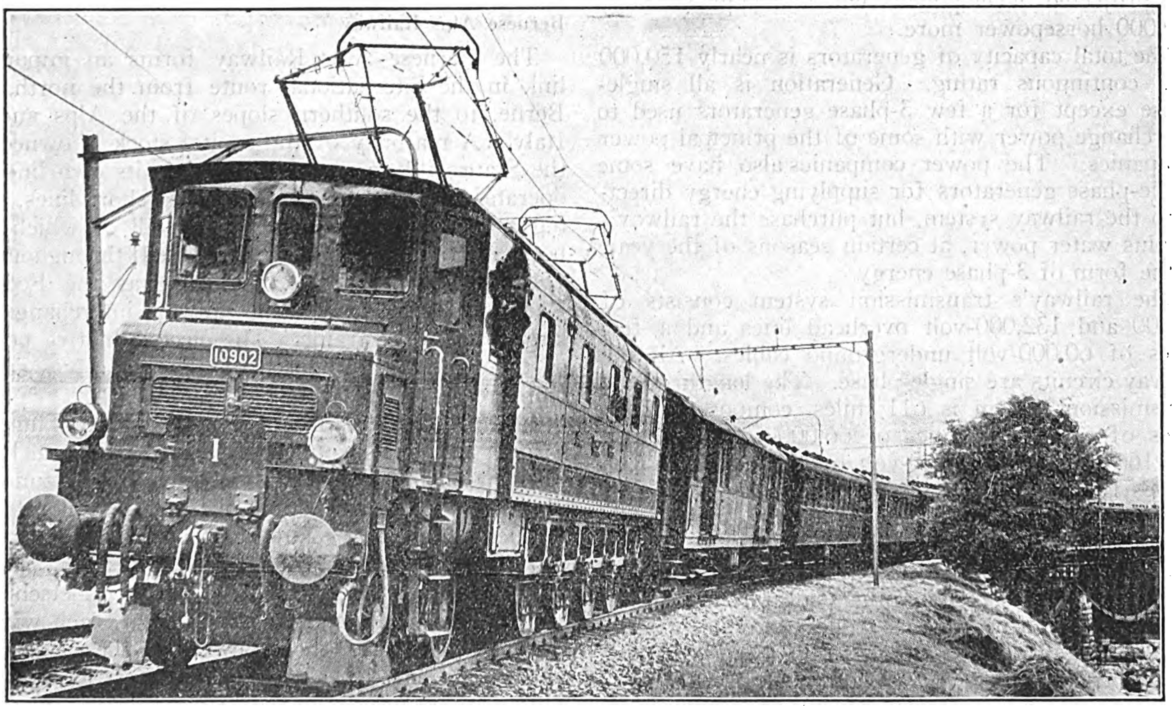

FIG. 36—SWISS FEDERAL RAILWAYS—FRONT VIEW OF PASSENGER LOCOMOTIVE WITH TRAIN.

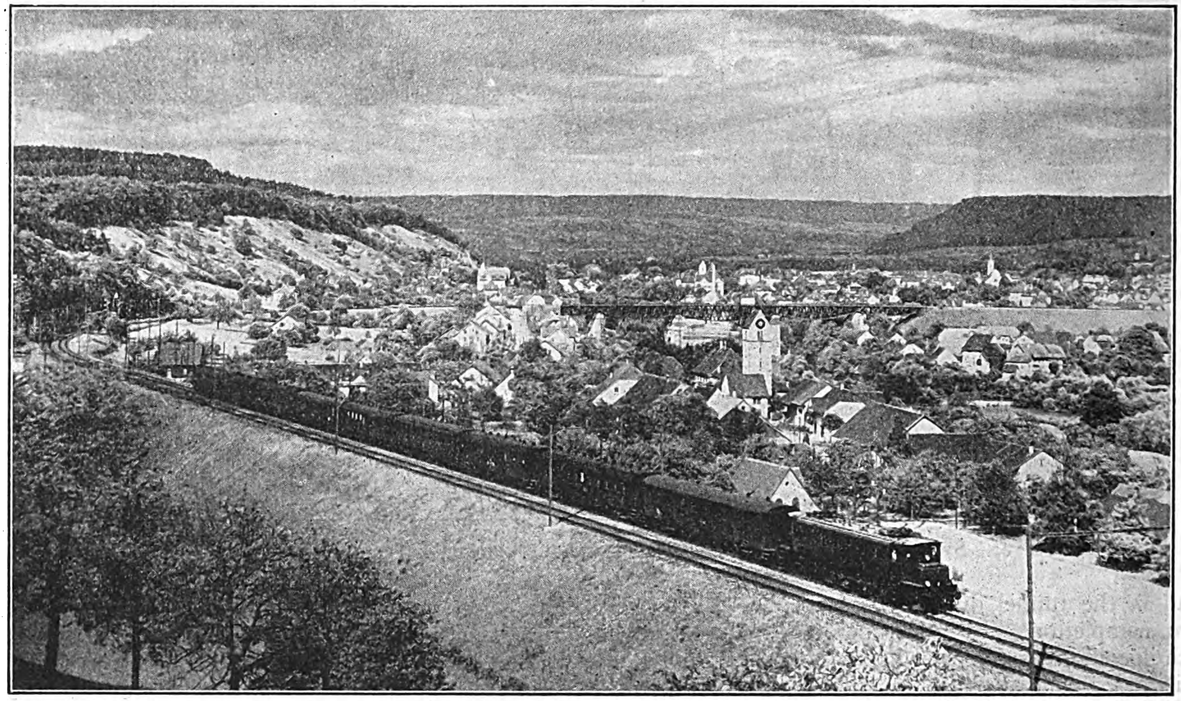

FIG. 37—SWISS FEDERAL RAILWAYS—PASSENGER TRAIN BETWEEN ZURICH AND BASLE.

large power generating and transmitting system has been developed. There are 4 principal power stations, all hydraulic and equipped with Pelton turbines. There are also 2 smaller stations, and property has been acquired for 2 more large stations. The 6 existing water-power developments have a present capacity in excess of 300,000 horsepower, and projected developments will add approximately 200,000 horsepower more.

The total capacity of generators is nearly 150,000 kw., continuous rating. Generation is all single-phase except for a few 3-phase generators used to interchange power with some of the principal power companies. The power companies also have some single-phase generators for supplying energy directly to the railway system, but purchase the railway's surplus water power, at certain seasons of the year, in the form of 3-phase energy.

The railway's transmission system consists of 66,000 and 132,000-volt overhead lines and a few miles of 60,000-volt underground cables. All the railway circuits are single-phase. The length of the transmission system is 611 miles, composed of 38 miles of cable, 407 miles of 66,000-volt overhead, and 166 miles of 132,000-volt overhead. Each line carries from 2 to 8 circuits.

This transmission system feeds 26 substations. Three of these, with capacities of 18,000 or 27,000 kv-a. each, are used to tie together the 66,000 and 132,000-volt lines. The other substations supply 15,000-volt energy to the trolley circuits. They range in size from 3000 to 15,000 kv-a., with individual transformers of 3000 and 5000 kv-a. each.

The motive power in December, 1928, consisted of 364 single-phase locomotives of 10 different types, 56 motor cars of 3 different types, and 7 three-phase locomotives for the Simplon tunnel. There were also 16 storage-battery locomotives for switching. The early tendency of the Federal Railways was to use side-rod drive for all locomotives. In the last few years they have been specifying individual-axle drive for high-speed passenger locomotives.

Bernese Alps Railway

The Bernese Alps Railway forms an important link in the international route from the north, via Berne, to the southern slopes of the Alps and to Italy. A majority of the capital stock is owned by the State of Berne. In addition to its own lines, it operates an equal amount of other short lines, giving a total route mileage of 157, all of which has been electrified. The system used throughout is 15,000-volt single-phase, the same as the Federal Railways with which this railway interchanges a large part of its traffic. The electric motive power of the system is composed of 33 locomotives and 5 motor cars.

The principal main line extends from Thun to Brigue, 52.2 miles, connecting with the Federal Railways at each end. This line includes 35 tunnels, of which the Loetschberg is the longest—more than 9 miles. This is the important part of the system, and further remarks refer specifically to it.

The first locomotives provided for the Loetschberg tunnel were of 90 and 96 tons weight, each with 2 motors. The rated horsepower of the 2 designs was 2000 and 1600 respectively per locomotive. There are now in use on this line 22 locomotives which have been progressively increased in size until the last ones delivered in 1926 are 4500 horsepower each.

There are two of these locomotives, said to be the largest in Europe. They are of the class 1 C—C 1 with overall length about 67 feet and weight 156 tons. Each of the 6 driving axles has a twin motor geared to a spring quill. Control is mechanical-pneumatic. Auxiliary power is 220 volts. This locomotive has a maximum speed of 46.5 m.p.h. One of them can haul a 660-ton train up the 2.7 per cent grade at 40 m.p.h.

Power for the Bernese Alps Railway is furnished by the Bernese Power Co. in which also the State of Berne is the principal shareholder.

Train Heating

Before passing from Switzerland some remarks should be made on electric heating of trains, as practised in Switzerland, and its effect on railroads in other countries. In all of the countries visited (except England and the Netherlands, where electrification of passenger service is confined to motor cars), heater cars are more or less prevalent for heating the passenger coaches. These cars, containing steam boilers, are usually hauled directly behind the electric locomotive.

All of the heating, however, is not done by steam, as a great many coaches have been fitted with electric heaters in addition to the usual steam coils. It is, of course, necessary to retain the steam heating for running on tracks not yet electrified.

In the countries employing high-voltage alternating current, it is customary to have the electric heating supplied from 2 or 3 taps on the main transformer in the locomotive, giving voltages in the range between 600 and 1200 volts. A capacity of 400 kw. is usually provided for this purpose on each locomotive. The heating current has to be cabled back through the train to each car.

In this connection the Swiss have developed a special receptacle and jumper to bridge the gaps between the cars. It is capable of serving also for the 1500-volt direct current of the French railways. One type of receptacle has been standardized for heating-cable jumpers by Austria, France, Germany, Italy, Norway, Sweden and Switzerland.

Another interesting piece of equipment seen in Switzerland is the electric heater truck. These trucks are used for the preheating of trains in the stations. They are mobile on standard-gage tracks. Each one carries a large transformer with essential switching and protective equipment. When located for service, the high-tension side is connected to the 15,000-volt contact line, and the low-tension side is connected to underground cables terminating at the various tracks where trains stand for heating.

Italy

Italy commenced electrification in 1901 and has kept at it almost continuously ever since. As a result the State Railways have more than 1000 miles of line electrified. This, with a few small electrifications, places Italy next to Switzerland among European countries in respect to mileage electrified. Italy has another distinction in having made the most thorough use of 3-phase locomotives of any country in the world.

In addition to the State Railways, there are about 700 miles of electrically operated lines belonging to private railways. These are mostly secondary lines and many are narrow-gage. Some have been electric from the start. They will not be discussed further, except to mention the government subsidy and one important electrification.

There is a standard-gage private railway operating out of Milan which was engaged, at the time of the Subcommittee's visit, in the final stages of its first electrification. This undertaking of the North

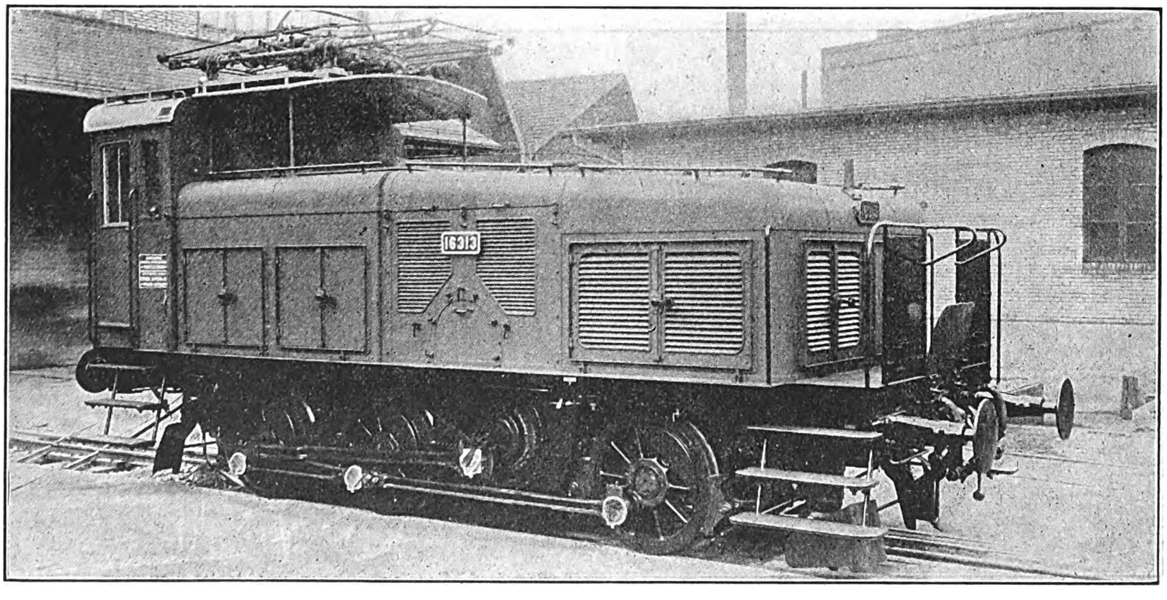

FIG. 38—SWISS FEDERAL RAILWAYS—ELECTRIC SWITCHING LOCOMOTIVE.

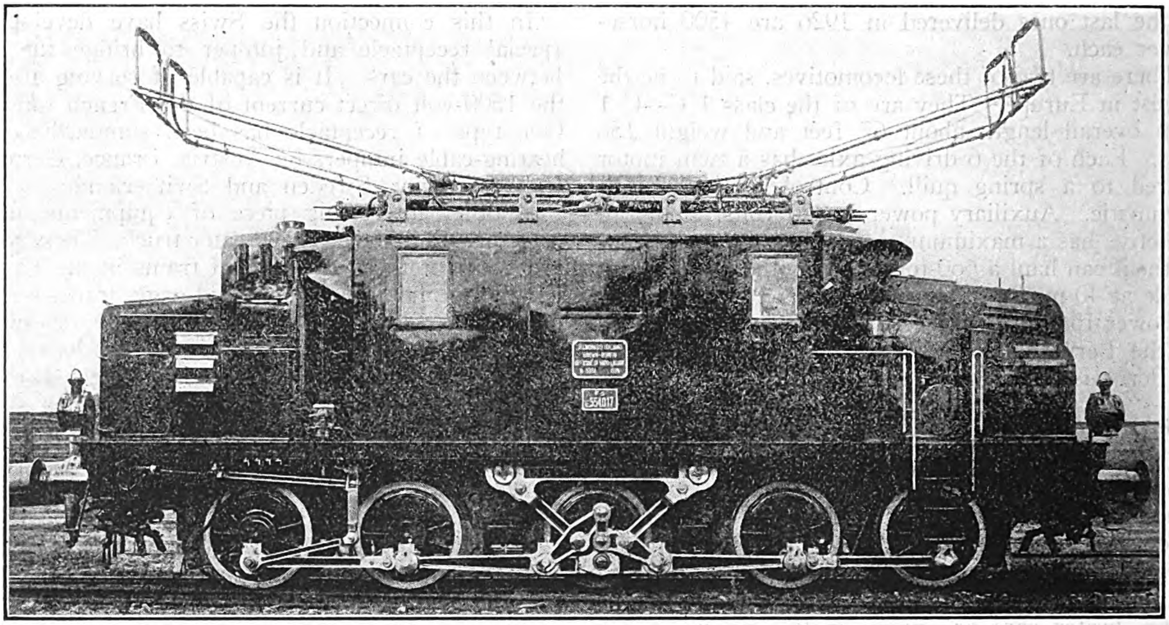

FIG. 39—ITALIAN STATE RAILWAYS—LATEST TYPE OF 3-PHASE, 3700-VOLT, FREIGHT LOCOMOTIVE.

Milan Railway has some very interesting features in the application of high-voltage direct current to suburban service and will be described below.

Since 1924 the Government has offered to private railways a 50-year subsidy to aid in reducing the fixed charges incidental to electrification. There are 2 rates of payment, one for existing lines operating with steam, and a somewhat lower rate for new railways in process of construction.

Italy, like some of the other European countries already described has not much native coal. The country is lined with mountain ranges which offer exceptional opportunities for water-power development. This is particularly true because of the varied climate. The mountains in the north catch the winter snows and retain them through the summer. The water power here is most abundant during warm weather. The mountains in the central and southern part, on the other hand, furnish the most power in the rainy winter season and the least during the summer. By interconnecting these varied districts, it is possible to get a fairly constant supply of hydraulic energy.

The State Railways, as well as privately owned power companies, are active in developing water power and in promoting the interconnection of power sources. There is already a completely interconnected system in the territory between the Swiss border, Leghorn and Florence, extending all the way across the country. Part of the stations and of

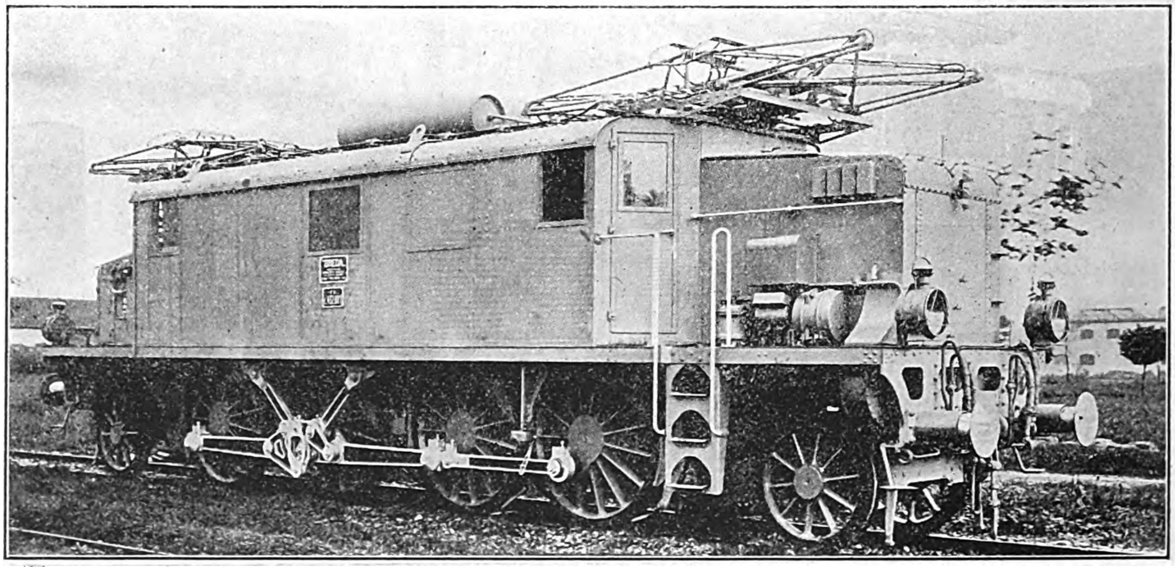

FIG. 40—ITALIAN STATE RAILWAYS—LATEST TYPE OF 3-PHASE, 3700-VOLT, PASSENGER LOCOMOTIVE.

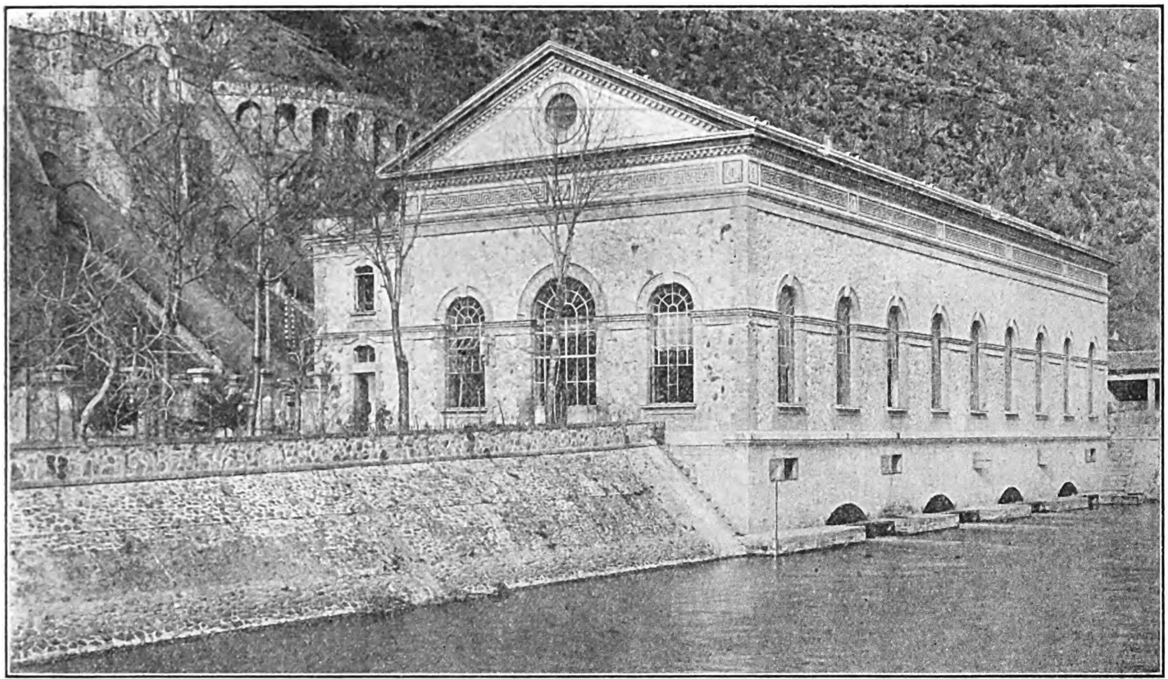

FIG. 41—ITALIAN STATE RAILWAYS—EXTERIOR OF MORBEGNO HYDRO-ELECTRIC STATION

the transmission lines belongs to power companies and part to the State Railways. The railway lines, however, are of low frequency, while the power companies' lines are commercial frequencies. There are a few steam stations located along the west coast, of which one belongs to the State Railways and the others to power companies.

Farther south is another interconnected power network between Rome and Naples, also extending all the way across the country. Since the railway electrification around Rome is at commercial frequency and around Naples is direct current, there is no necessity here for transmission lines of low frequency.

In addition to the economic reason of utilizing water-power resources, there are other important ones which have influenced the State Railways in making their electrifications. In the cases of Milan and Naples, suburban traffic was a factor. Elsewhere the reasons are tunnels and heavy grades. A check of the sections electrified shows that the ones so far converted are in the regions of most difficult operation.

Italian State Railways

At the end of 1928 the State Railways had 1005 miles of line electrified. The systems in use are: (1) 650-volt direct current with third rail, (2) 800-volt direct current, (3) 3000-volt 3-phase current at 15 cycles, (4) 3700-volt 3-phase current at 16⅔ cycles, (5) 10,000-volt 3-phase current at 45 cycles, and (6) 3000-volt direct current. As the last 3 systems are the most important to Italy, the greatest attention will be paid to them after a few words on the history of the development.

In 1897 a commission was appointed by the Minister of Public Works to study electrification of railways for the purpose of reducing the cost of operation. As a result it was decided to try 3 systems of electrification: (1) storage-battery cars, (2) 3000-volt 3-phase current at 15 cycles, and (3) 650-volt direct current with third rail.

The storage-battery coaches were not satisfactory and were abandoned after a few years. The third rail was installed on a suburban line out of Milan in 1901. This is the line now extending to Varese and Porto Ceresio, a distance of 45 miles.

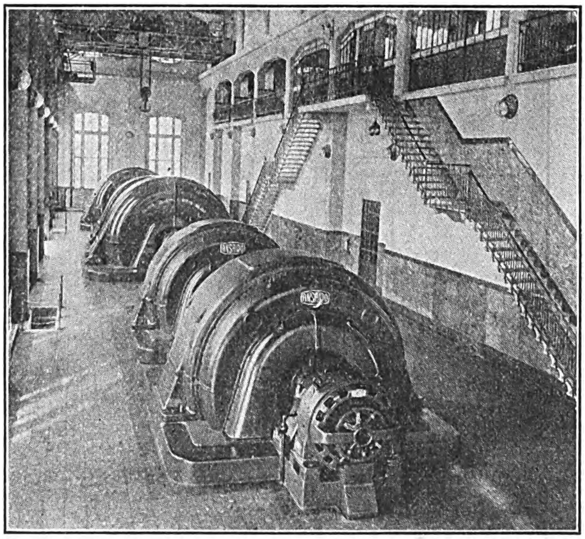

FIG. 42—ITALIAN STATE RAILWAYS—INTERIOR OF SANTA VIOLA SUBSTATION AT BOLOGNA.

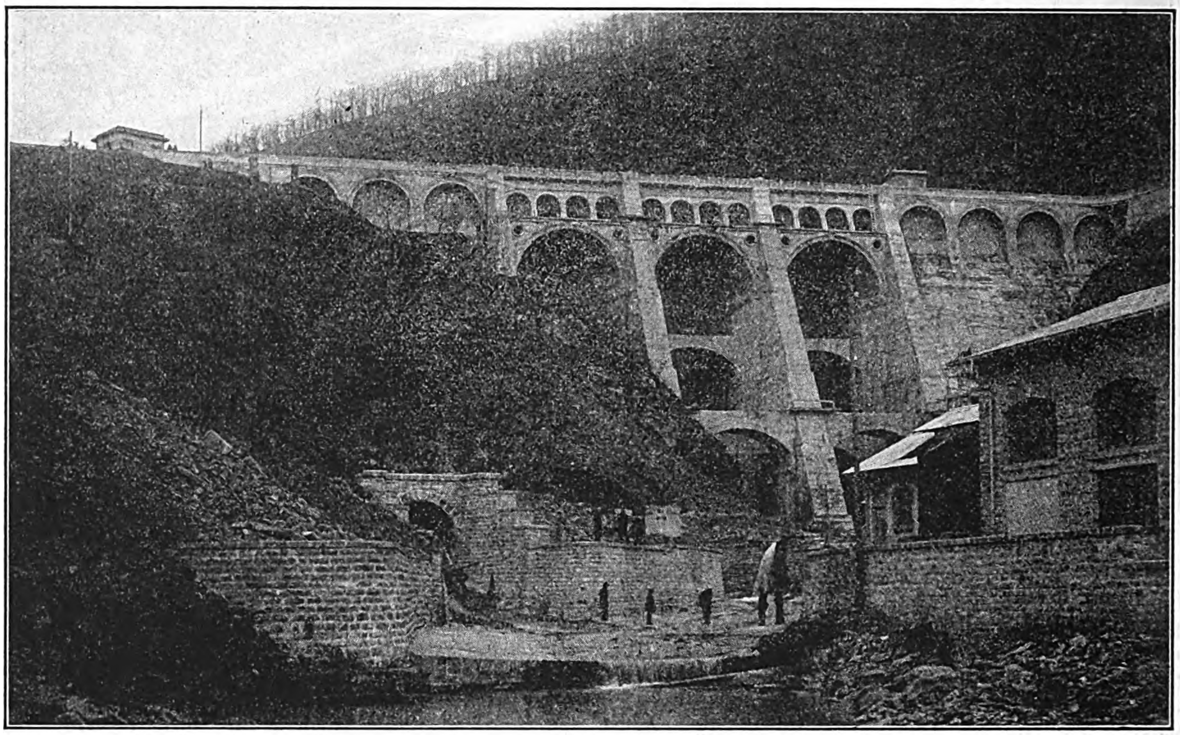

FIG. 43—ITALIAN STATE RAILWAYS—EXTERIOR OF PAVANA HYDRO-ELECTRIC STATION.

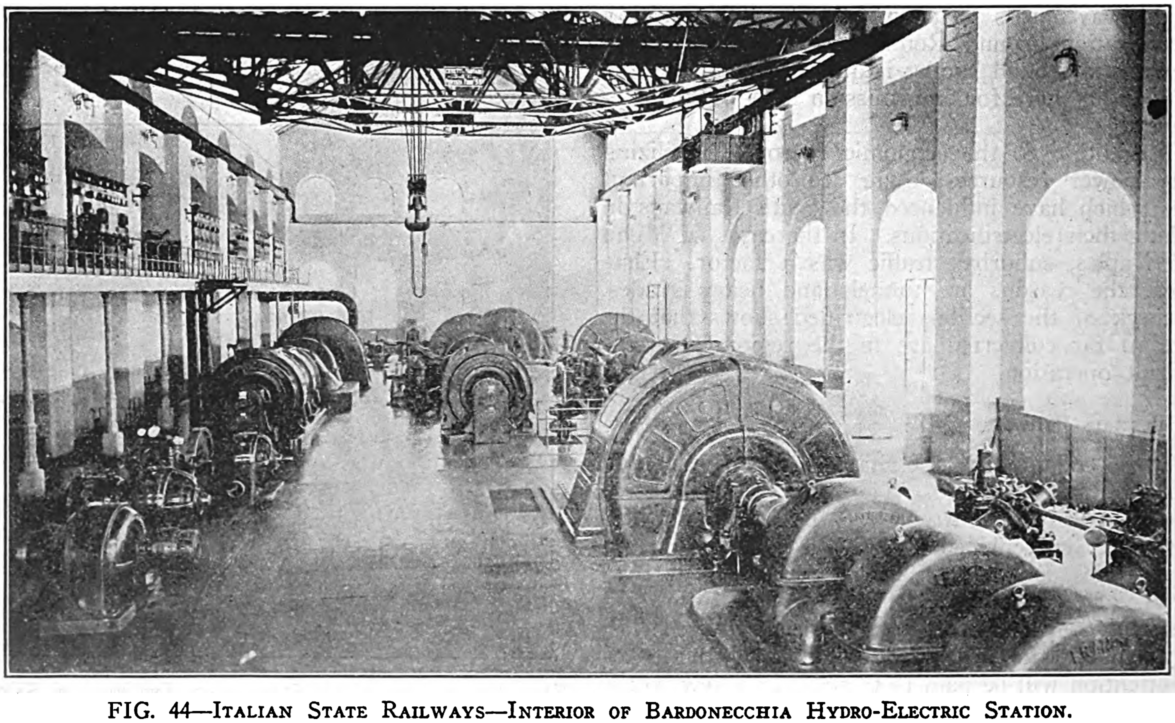

FIG. 44—ITALIAN STATE RAILWAYS—INTERIOR OF BARDONECCHIA HYDRO-ELECTRIC STATION.

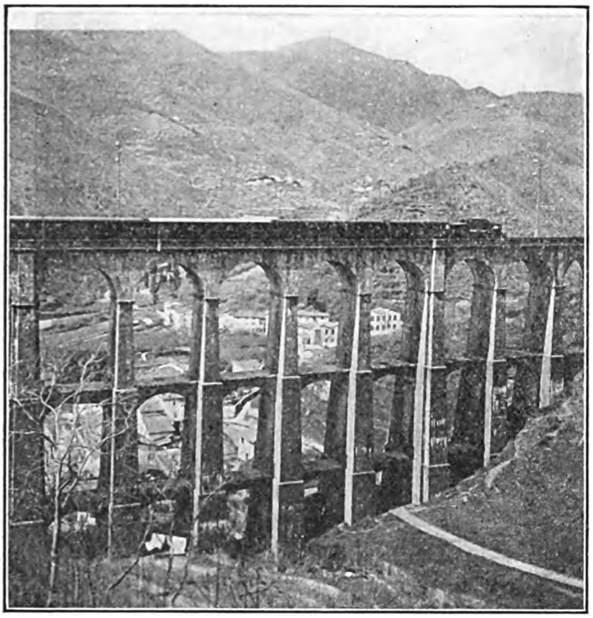

FIG. 45—ITALIAN STATE RAILWAYS—TRAIN ON VIADUCT OF ELECTRIFIED LINE BETWEEN BOLOGNA AND FLORENCE.

The 3-phase system was installed in 1902 on a line somewhat north of Milan between Lecco, Colico, Sondrio and Chiavenna. In 1914 it was continued south from Lecco almost to Milan, where it now terminates at Monza. There are now about 90 miles of this system. The smaller systems are all covered in tables of the general report of this Committee, to which the readers are referred for other details.

In 1911 the first of the present 3 major systems was initiated at Genoa. This is the 3700-volt 3-phase system at 16⅔ cycles. Some of the conditions regarding this installation are interesting. The harbor of Genoa is the principal port of Italy and handles a large tonnage both of import and of export freight. Much of the tonnage must be carried by rail between the port and the inland industrial centers, of which Milan and Turin are conspicuous examples.

The ascent from the harbor is very abrupt and mountainous. Grades are as steep as 3.5 per cent and tunnels numerous. There are two routes from Genoa to Ronco, and on one of these the 3-phase system was installed with very satisfactory results. Train loads were made much heavier, and operating speeds increased. The second line over the mountains was then electrified, and a third line, now under construction, will be electrified also.

In the period since 1911 a great expansion of electrification has occurred in the northwestern part of Italy between Genoa and the French border. At Genoa itself all traffic in and out of the city is now electrified. The only steam power left at Genoa consists of 3 or 4 locomotives retained for special switching. The main through route to France is electrified all the way from Genoa via Turin to Modane, including the long tunnel through the mountains near the border. The Mediterranean route to France via Ventimiglia is now being changed to electric power. On the south of Genoa toward Rome, electric operation prevails as far as Leghorn.

Other 3-phase electrifications have been made between Bologna and Florence, and in the north between Bolzano and Brenner on the Austrian border

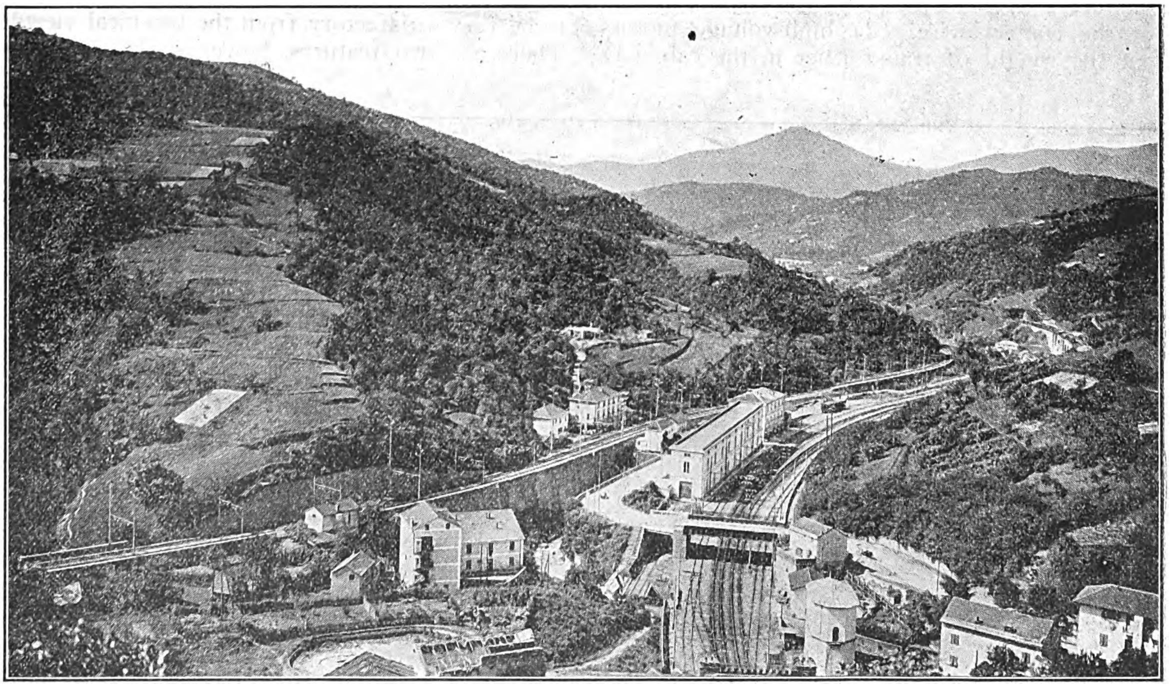

FIG. 46—ITALIAN STATE RAILWAYS—TWO DOUBLE-TRACK LINES ASCENDING FROM THE PORT OF GENOA APPROACH TUNNELS AT MIGNANEGO.

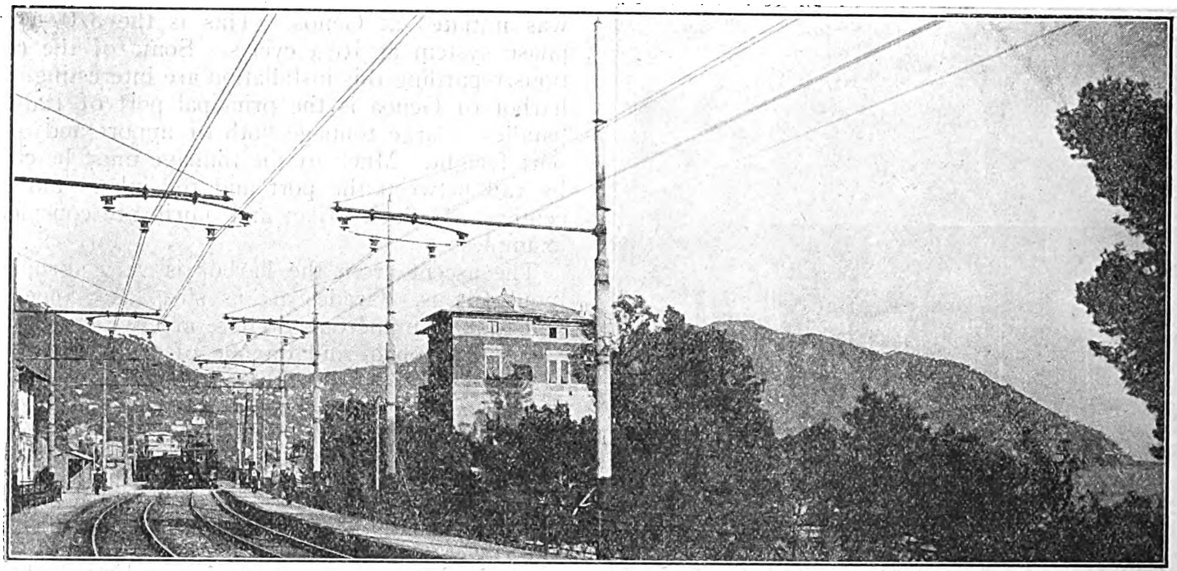

FIG. 47—ITALIAN STATE RAILWAYS—VIEW ON ELECTRIFIED LINE BETWEEN GENOA AND SPEZIA.

where connection is made with trains from Innsbruck, Munich and Berlin. A considerable mileage is now being changed in the neighborhood of Trieste. Summing up the whole activity with regard to the 3-phase lines at 3700 volts, there are 696 miles of this system comprising nearly 70 per cent of the whole State Railways electrification.

This system was adopted in the first place because of the known advantages of 3-phase power for industrial applications. At a time when little was known about heavy electric traction, to enable comparison with other systems, it offered many desirable features: (1) Use of comparatively high voltage at the contact wire, (2) high-voltage motors without the weight of transformer in the cab, (3) several running speeds by changing the number of poles, (4) constant running speed, and (5) automatic regeneration.

The types of locomotive generally used on the 3-phase system all have 2 large motors driving through a Scotch yoke, or equivalent mechanism, to the side-rods. The freight locomotives generally have 5 driving axles, either with or without guiding axles. The passenger locomotives have usually 3 driving axles and guiding axles at each end. These 3-phase locomotives use bow trolleys.

The 3-phase traction at low frequency has been steadily improved since the start and is considered to be very satisfactory from the technical viewpoint. There are two features, however, that have caused

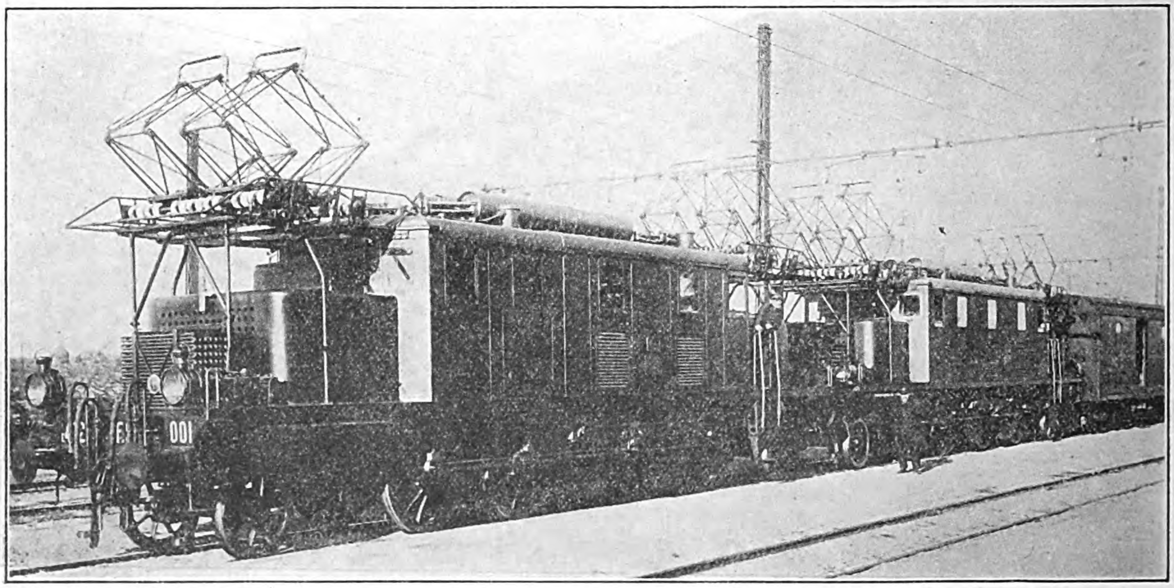

FIG. 48—ITALIAN STATE RAILWAYS—LOCOMOTIVES OF 3-PHASE, 10,000-VOLT ELECTRIFICATION BETWEEN ROME AND SULMONA.

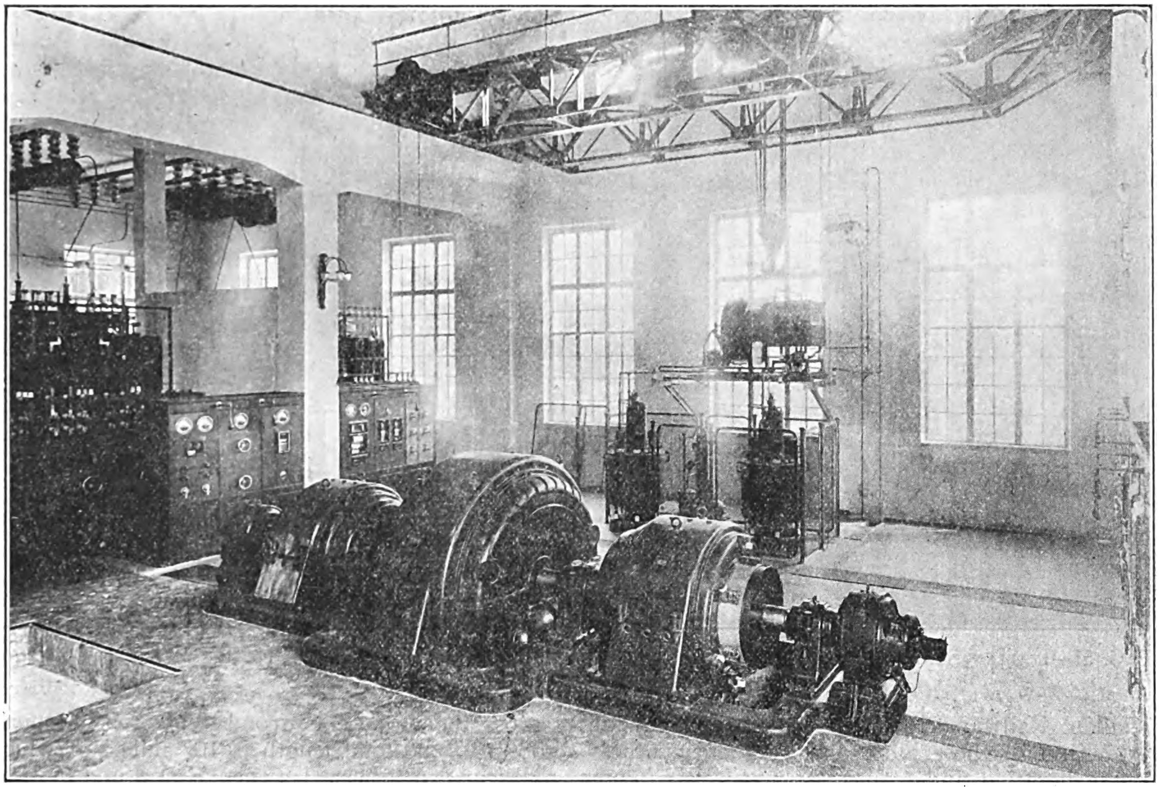

FIG. 49—Italian State Railways—Interior of Apice Substation on 3000-Volt Direct-Current Electrification Between Benevento and Foggia.

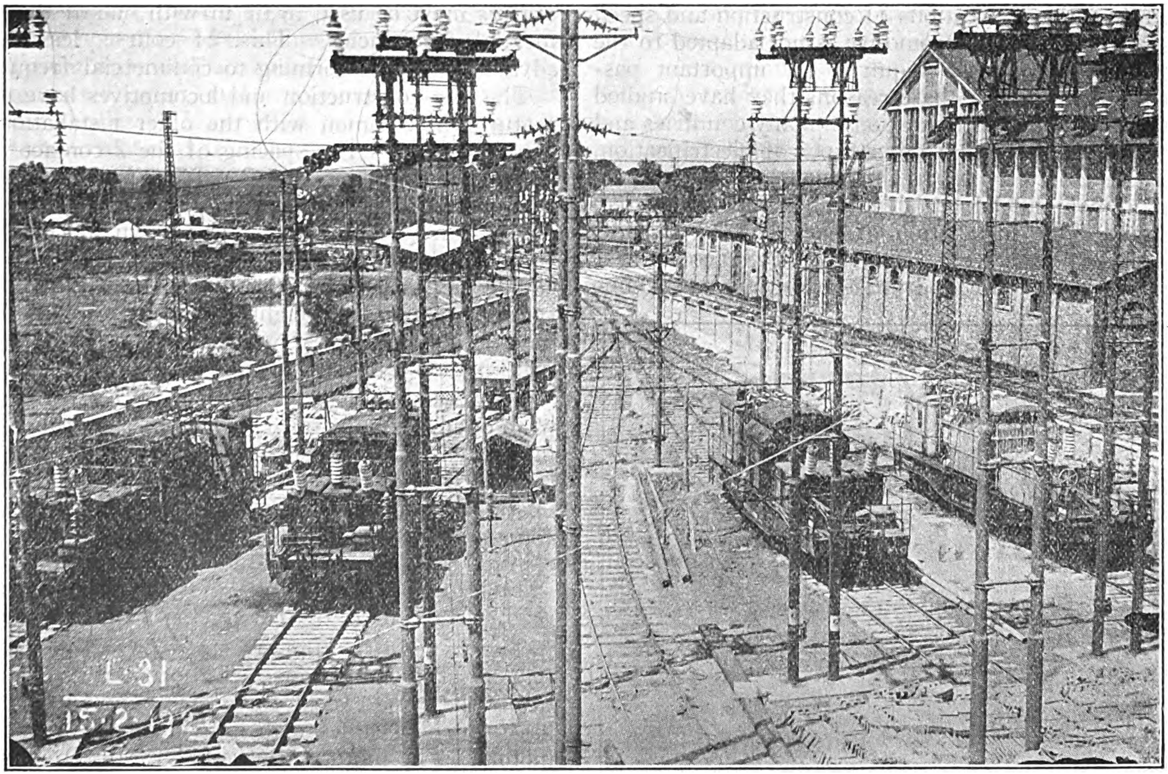

FIG. 50—Italian State Railways—Portable Substations.

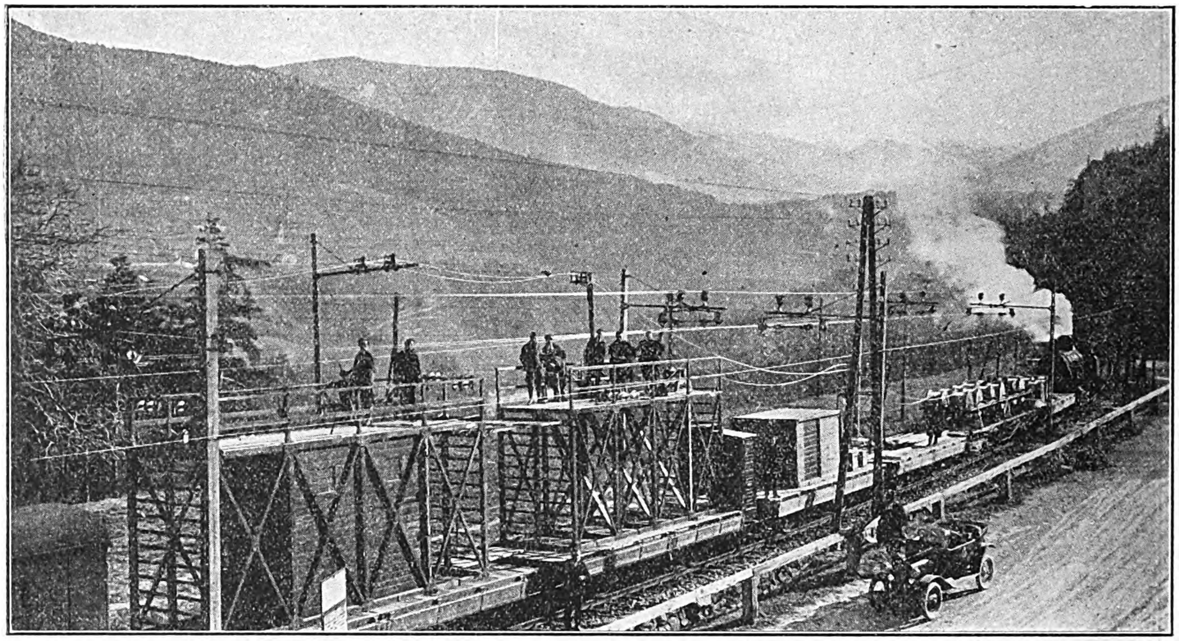

FIG. 51—ITALIAN STATE RAILWAYS—INSTALLING CONTACT LINE ON 3-PHASE ELECTRIFICATION BETWEEN BOLZANO AND BRENNER.

the Italian Railways to consider other types of power. First of these is the low frequency, necessitating generation and transmission separate from the commercial systems of the country, or the use of frequency converters. Second is the fact that the double trolley does not operate well at high speeds, in excess of about 55 m.p.h. Partly on this account, and also due to limitations of construction and speed control, the 3-phase locomotive is not adapted to the very high speed now required for important passenger service. For these reasons they have studied other systems of electrification in many countries and finally decided to try 2 other types of electrification.

These 2 new types are high-voltage 3-phase current at commercial frequency and 3000-volt direct current. One installation of each has been made, and these 2 lines were visited by the Subcommittee.

For the 10,000-volt 3-phase experiment, the line across the mountains from Rome to Sulmona was chosen. The total length is 107 miles, of which 67 miles are in service between Rome and Avezzano. The frequency is 45 cycles. Part of the power is generated by the railway and part purchased. As there are 2 commercial frequencies in this part of the country—namely, 42 and 45 cycles—motor generators must be used to tie in with one of the commercial frequencies. This, of course, lessens the advantages of conforming to commercial frequency.

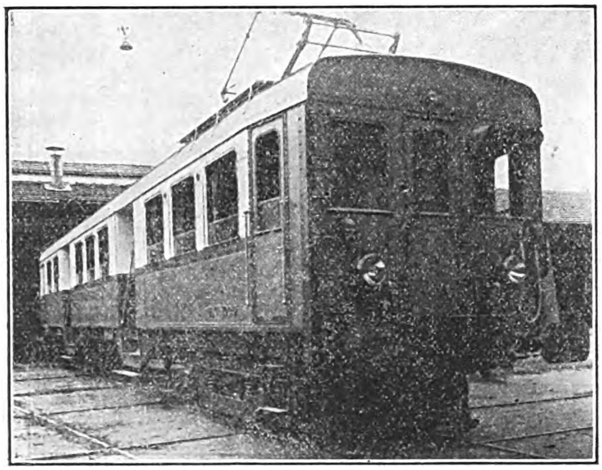

FIG. 52—NORTH MILAN RAILWAY—MULTIPLE-UNIT CAR FOR 3000-VOLT DIRECT CURRENT.

The line construction and locomotives have many features in common with the older installations at low frequency. The spacing of the 2 contact wires is somewhat greater, and 2 narrow pantographs are used instead of a bow trolley. Each locomotive carries a transformer for stepping down the line voltage. Passenger locomotives of class 1 D 1 have 4 coupled axles, weigh 100 tons and have a maximum speed of 62 m.p.h. Freight locomotives of class 1 E 1 have 5 coupled axles, weigh 84 tons, and have a maximum speed of 31 m.p.h.

The installation of 3000-volt direct current is planned to extend from Naples across the mountains to Foggia, a distance of 122 miles. The section between Benevento and Foggia is already in operation, 63 miles. Power is purchased from 2 commercial power systems, both using 45 cycles. The railway has its own transmission line feeding 3 substations. Both motor-generators and mercury arc rectifiers are used for conversion to direct current.

Two types of locomotives are provided for passenger and freight trains. The locomotives are practically the same except for gearing and speed. Both have 6 driving axles with individual nose-suspended motors. The motors are wound for 1500 volts and connected two in series. They have forced ventilation. Each motor is rated 400 horsepower, or a total of 2400 horsepower for the locomotive. The freight locomotives weigh 95 tons and have a speed of 28 m.p.h. The passenger locomotives weigh 102.5 tons and have a speed of 47 miles.

Future plans of the State Railways which have already been announced include 285 miles of electrification now under way and 325 miles still in the planning stage. The 285 miles in process is divided between the 3 important systems as follows: 185 miles in the 3-phase district north of Florence, 40 miles in completion of the 10,000-volt 3-phase line east of Rome, and 60 miles in completion of the 3000-volt direct-current line east of Naples. In general the 3-phase system at 16⅔ cycles will be hereafter used in the northern part of the country where so much of it is already installed. In the central and southern part it is now the intention to use 3000-volt direct current for important main lines where high speed is desirable.

The heating of passenger coaches on the State Railways has, up to this time, all been done with heater cars carrying coal-fired boilers. On the latest passenger locomotives being delivered in 1928, an oil-fired boiler is placed at one end of the cab.

North Milan Railway

This is a standard-gage railway operating a system of about 156 miles of line in the district to the north of Milan, between Milan and the Lakes Como and Maggiore. It has a large suburban passenger business and a 2-track approach to the Milan terminal. In order to relieve congestion and to speed up the suburban service in competition with other means of travel, the management has adopted electricity for operation of the lines nearest Milan. The installation was well advanced at the time of the Subcommittee's visit, and it was expected to initiate the new service in May, 1929.

Direct current at 3000 volts has been chosen, using an overhead contact line. Power will be purchased from a neighboring water-power company.

One substation has been built about 4 miles from Milan. Power will be received at 23,000 volts, 42 cycles, over 2 circuits. There are 4 groups of mercury arc rectifiers of 2000 kw. each. Rectifiers and feeders are protected by high-speed circuit breakers.

The contact line has catenary suspension outside the Milan terminal zone. In the latter case on account of low clearance, simple suspension from bracket arms is used. On the main line the pivot type of bracket is used for the catenary with counterweighted messenger and contact wires.

The present extent of this electrification embraces 2 routes from the Milan terminal over a common line to Bovisa and then branching to Saronno and to Meda. The length is 31 miles, all double track. Multiple-unit cars will be used for the suburban service and locomotives for other passenger and freight trains. Current collection will be by pantographs.

Eight multiple-unit motor cars have been purchased and 8 driving trailers. The motor cars weigh 58.5 tons and seat 78. The trailers weigh 42 tons and seat 102. Both kinds of cars have 2 large side doors for rapid loading and unloading.

Each motor car has 4 motors of 185 horsepower each, connected permanently two in series. Motors are nose-suspended, and axles have roller bearings. The motor cars have a maximum speed of 62 m.p.h., and it is expected to maintain schedule speeds of about 28 to 38 m.p.h. for the different kinds of trains. Control is of the camshaft type, electropneumatically operated and with automatic acceleration. Control and lighting currents are furnished by a 36-volt battery and chain-driven axle generator. The air compressor and car heaters are operated at line voltage.

In addition to the driving trailers there will be ordinary trailers and baggage cars fitted with control cables, heating conductors, etc. It is proposed to convert some of the old 2-axle coaches into 2-coupled units with large side doors. These units will weigh 25 tons each and seat 100.

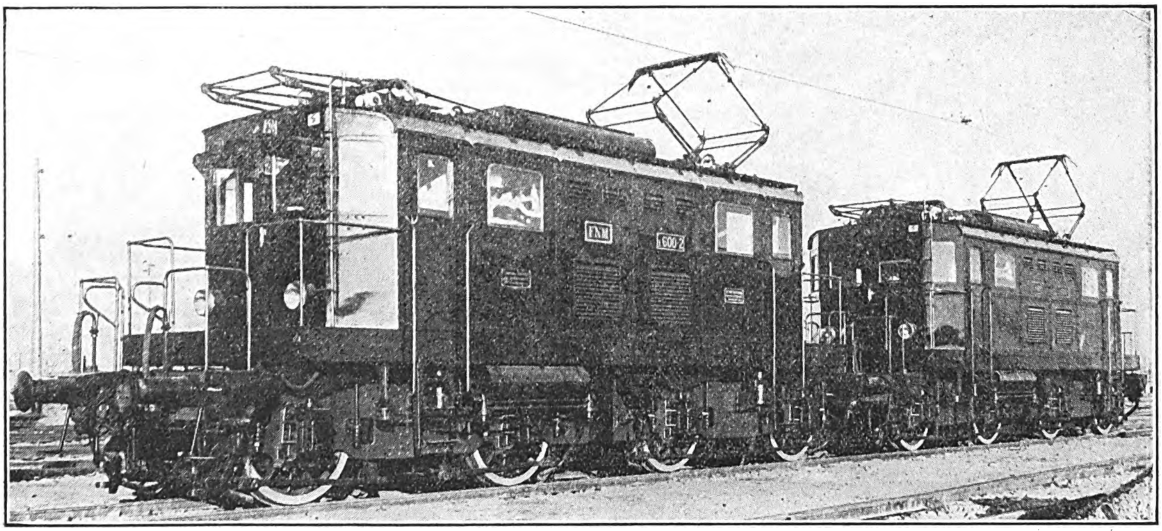

FIG. 53—NORTH MILAN RAILWAY—FREIGHT LOCOMOTIVES FOR 3000-VOLT DIRECT CURRENT.

The 4 locomotives which have been purchased for freight service weigh about 70 tons each, with all weight on drivers. There are two trucks with an articulated joint between. Each of the 4 axles has a 350-horsepower motor driving through elastic gearing. The one-hour rating is approximately 20,000 lb. tractive effort at 25 m.p.h. The maximum speed is 46.5 m.p.h. The traction motors are permanently connected two in series. Auxiliary circuits are fed from a dynamotor.

France

Electrification in France had its start in 1900, when the State Railways electrified a small part of its suburban system and the Paris-Orleans Railway electrified the tunnel between its Quai d'Orsay and Austerlitz stations. Both of these railways used the ordinary type of third-rail construction, and both made further short extensions prior to the War.

The Midi Railway in the extreme southern part of France commenced electrification in 1910 when a short, new, narrow-gage line was opened, using a third rail of 850 volts. This was followed by the electrification of several branch lines with high-voltage single-phase overhead, and construction of the same type had been started on a section of main line when the War caused a halt.

The Paris-Orleans and Midi Railways desired to make extensive expansion of their electrifications, and the Paris, Lyons & Mediterranean Railway also proposed a large program for conversion to electric traction. As a result the Government, shortly after the Armistice, appointed a committee to determine how electrification shall be arranged for the greatest good of the country. The committee made its report, which was adopted by the Ministry of Public Works in August, 1920. This very long report in general had 3 important conclusions. First, 5500 miles of route on these 3 large railway systems were judged suitable for electrification. Of the suitable mileage 5000 miles were already in operation with steam locomotives, and 500 miles were to be built new. Second, direct current at the tension of 1500 volts should be used with either overhead conductor or third rail. A higher pressure of 3000 volts was made permissive for special cases. Third, energy should be supplied to the substation as 3-phase and 50-cycle, thereby conforming to the standard already set for commercial power systems.

It should be stated that the 3 railways involved in this large program all operate to the south of Paris, in a region composing more than half of France. The other railways were not included in the discussion, and except for the Paris suburban lines of the State Railways are not yet engaged in electrification.

The conditions to the south of Paris are most in accord with that policy of national economics which dictates a reduction of coal imports. The territory is traversed by several mountain ranges which make heavy grades on the much traveled lines. This part of the country is farthest from the domestic coal resources and is moreover well supplied with natural water-power sites. These sites are being developed both by the railways and by power companies, in some cases cooperatively. The Government has aided the railways in their electrification programs by making favorable concessions of water-power privileges.

As a result of the decision above described, the Paris-Orleans and Midi Railways changed their existing electrifications to 1500-volt direct current. The P. L. M. launched its program on the same basis.

Paris-Orleans Railway

In 1900 this company inaugurated electric operation of a double-track tunnel, about 3 miles long, connecting its 2 principal Paris stations, Quai d'Orsay and Austerlitz. The system used was third rail

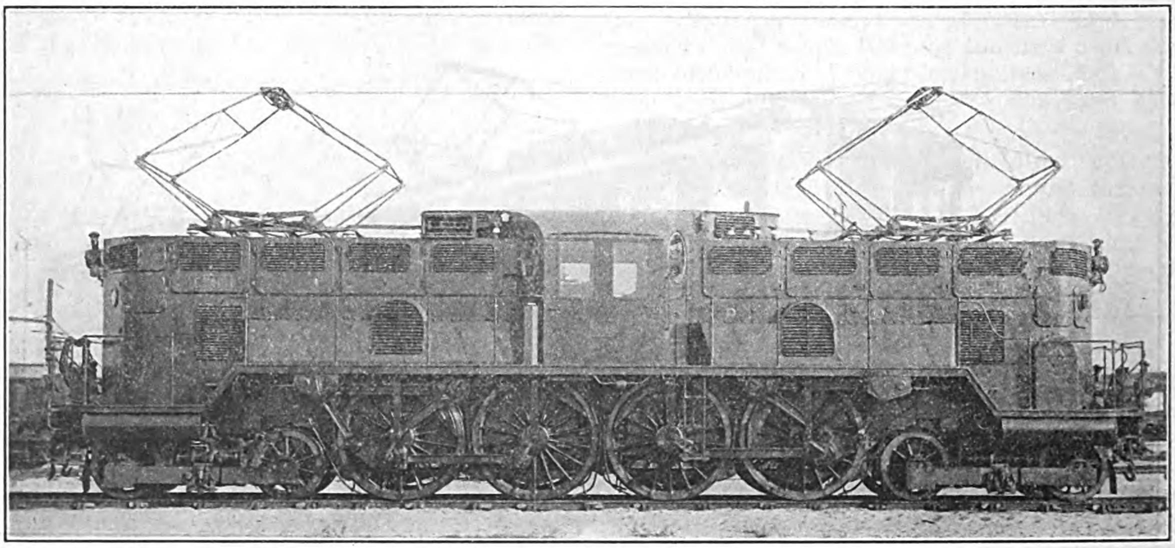

FIG. 54—PARIS-ORLEANS RAILWAY—HIGH-SPEED PASSENGER LOCOMOTIVE WITH SIDE-ROD DRIVE.

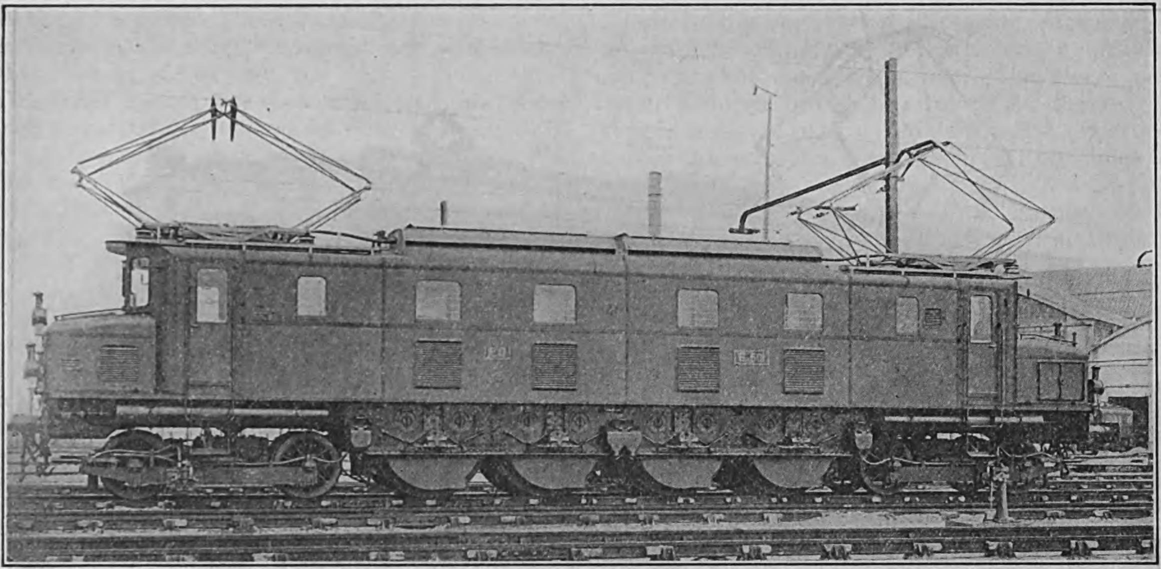

FIG. 55—Paris-Orleans Railway—High-Speed Passenger Locomotive with Individual-Axle Drive.

at 600 volts. In 1904 electric service was extended from Austerlitz to the nearby suburb of Juvisy, about 14 miles. This line has since been provided with overhead contact line of 1500 volts and the new system extended to Vierzon, 126 miles from Paris. Of this the 35 miles from Austerlitz to Etampes is 4-track and the remainder double-track. There are also 2 branches electrified. The total is about 150 miles of route and 600 miles of all tracks. The general type of overhead construction is compound catenary.

Suburban service is furnished by multiple-unit trains. The cars for this service are quite modern and of all steel construction. There are 80 motor cars and 80 trailers. The motor cars each have four 250-horsepower motors (750 volts per motor) and electro-pneumatic control.

For the distance trains there are 10 high-speed passenger locomotives of several different types. There are 193 freight locomotives, which can also be used for passenger trains not requiring the highest speed.

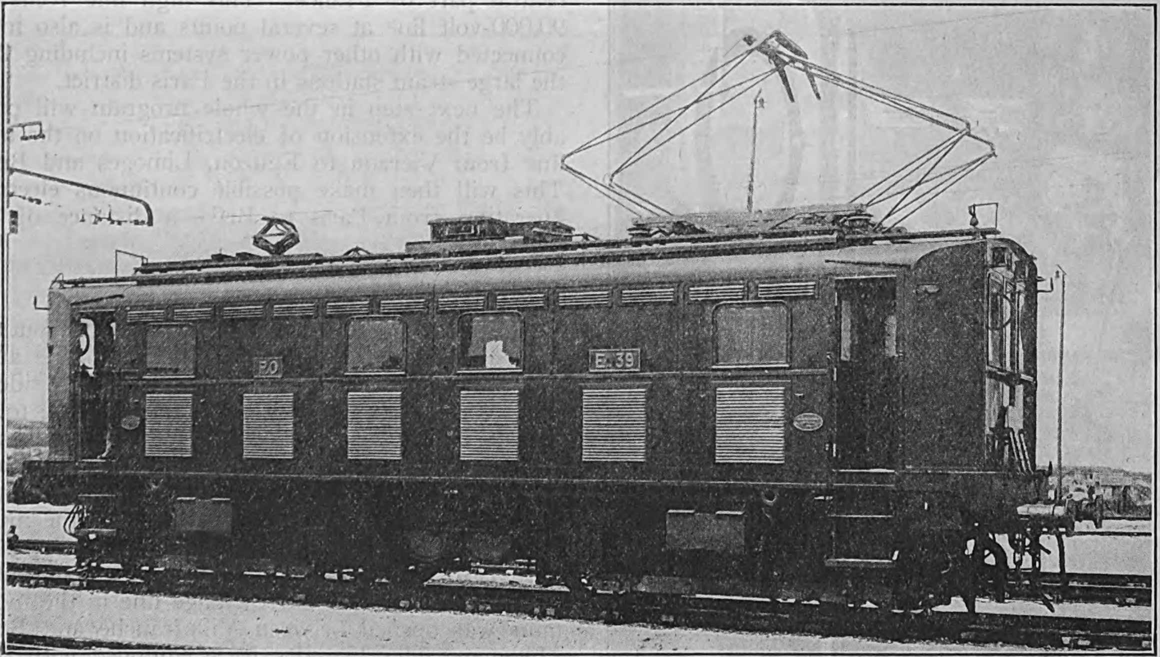

FIG. 56—Paris-Orleans Railway—One Type of Locomotive for Combination Freight or Local Passenger Service.

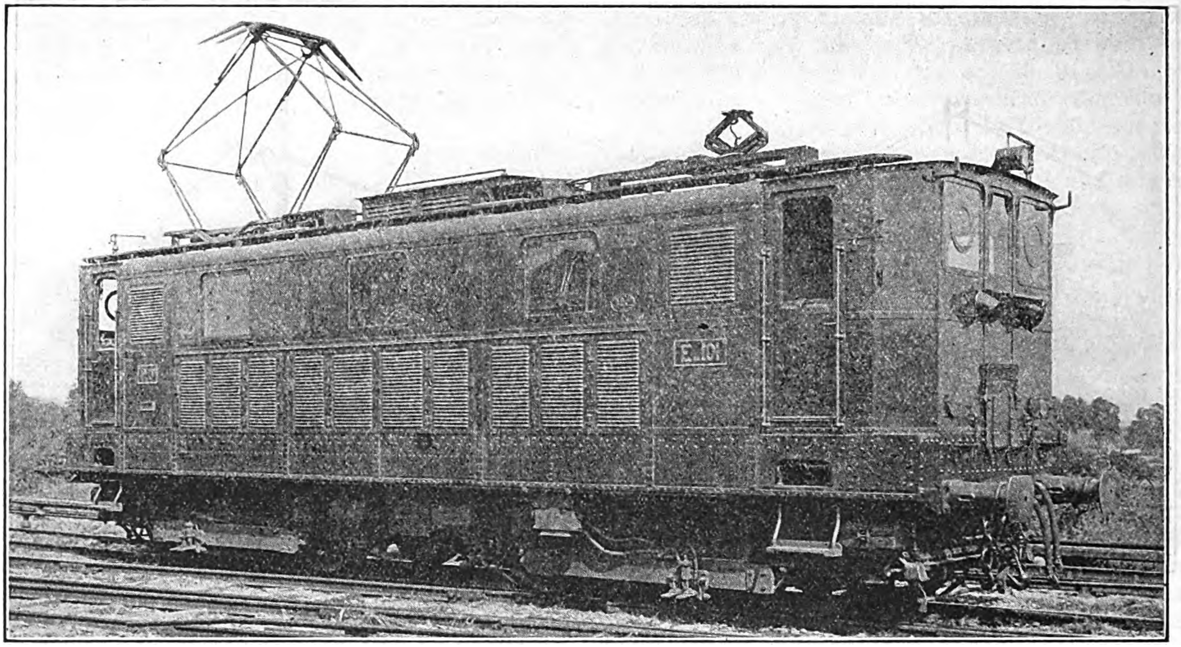

FIG. 57—PARIS-ORLEANS RAILWAY—ANOTHER TYPE OF LOCOMOTIVE FOR COMBINATION FREIGHT OR LOCAL PASSENGER SERVICE.

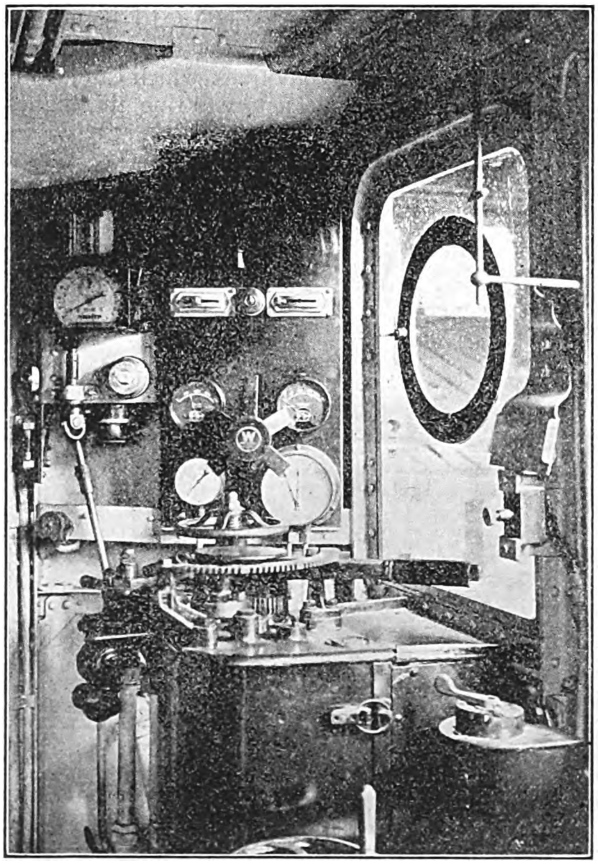

FIG. 58—PARIS-ORLEANS RAILWAY—DRIVER'S CAB FOR LOCOMOTIVE IN FIG. 56.

There are 11 substations containing rotary converters, 750 volts each and connected two in series. Power is supplied to the 2 most northerly ones from one of the power companies in Paris. Power is supplied to the others from the railway company's own transmission lines. There is a system of 90,000-volt lines to feed the substations and a trunk line of 150,000 volts bringing the power to Paris from the railway's distant water-power stations in the south-central part of France. This high line feeds the 90,000-volt line at several points and is also interconnected with other power systems including 2 of the large steam stations in the Paris district.

The next step in the whole program will probably be the extension of electrification on the main line from Vierzon to Eguzon, Limoges and Brive. This will then make possible continuous electrical operation from Paris to Brive a distance of 313 miles.

Midi Railway

This company operates in the extreme southern part of France. Its territory makes a zone about 100 miles wide extending along the north side of the Pyrenees all the way from the Atlantic to the Mediterranean coast. At either end of the Pyrenees its lines connect France with Spain along the coastal levels. Its lines project into the mountain range in many places, but have never crossed the mountains until recently.

In 1910 the Midi Company made its first venture in electrification. A narrow-gage line in the mountains was opened between Villefranche and Bourg Madame. The 35 miles were equipped with third rail of 850 volts. This was followed by electrification of the connecting standard-gage line from Villefranche to Perpignan, about 29 miles. On this, however, high-voltage single-phase current was used—12,000 volts at 16⅔ cycles.

This latter system was then introduced on 3 more branch lines (of 16, 14 and 13 miles respectively), and an important installation commenced on the double-track main line between Bayonne and Toulouse. This section comprised about 70 miles between Pau and Montrejeau, with one branch of 22 miles. The overhead had been placed when the War stopped development. The company then possessed 72 miles of single-phase electrification in operation and a like amount partly completed. It also had a large program formulated for the future, which included development of its own power facilities.

After the decision of the Ministry in 1920, all the single-phase lines were changed to 1500-volt direct current. The power stations and transmission lines were changed to 50 cycles, and the large program of electrification fully launched. This program embraced about 2100 route miles, including about 10 per cent of new lines, and would cover about three-quarters of the company's system. At the end of 1927 about 500 miles of route were electrified. It was expected to have 625 miles done by 1929, and to proceed at the rate of about 120 miles per year.

The part of the territory chosen particularly for electrification is in general the southern edge adjoining the slope of the Pyrenees and extending up into the mountains. The first stage, which has received most attention up to now, is the west end of the system between Bordeaux and Hendaye on the west and Toulouse on the east.

Involved in the program are 2 lines piercing the mountains into Spain through long tunnels, which would hardly be practical to operate, except by electricity. These lines are the first to communicate with Spain except along the coast. They were chosen from a dozen prospective routes by the two governments as the most desirable for first undertaking. Concessions for the French part of the lines were granted to the Midi Company in 1907. One route required a new link from Pau, France, to Jaca, Spain, the other from Ax-les-Thermes, France, to Ripoll, Spain.

The line from Pau to Jaca was completed and opened with much ceremony in July, 1928. It was the good fortune of the Subcommittee to view the French section of the line only 5 months later. It is a picturesque line, displaying very difficult engineering as well as marvelous scenery. The line has steep grades, up to and exceeding 4 per cent, and many tunnels culminating in the international tunnel of Somport (5 miles long and on one of the steepest grades), which emerges into Spain at the station of Canfranc. The second line, including the long tunnels of Puymorens (in France) and of Tosas (in Spain) will probably be ready some time in 1929. It will connect Toulouse to Barcelona by a direct route.

The Midi Company uses some motor cars hauling ordinary passenger cars as trailers. The motor cars are partly rebuilt from the old single-phase cars and partly new. All the motor cars are equipped with four 750-volt motors of 175 horsepower each, giving a rating of 700 horsepower for the car. The maximum speed is 53 miles per hour. The cars have multiple-unit control, and a motor-generator set provides 120 volts for control, lighting and auxiliary power.

Most of the electrical operation is conducted with

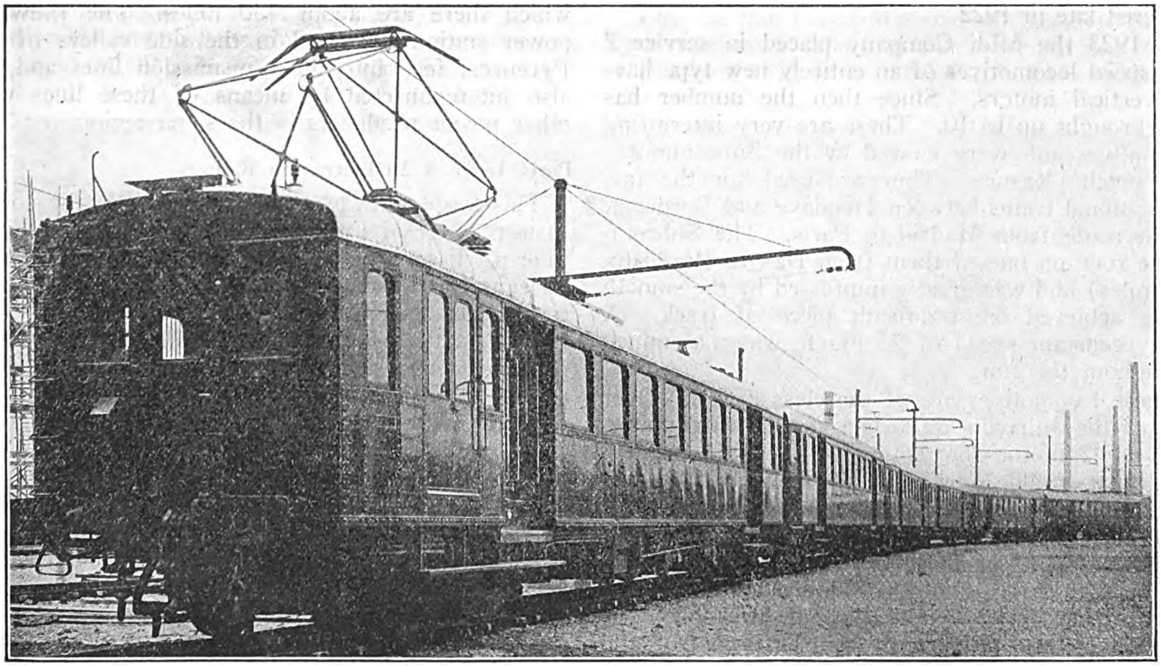

FIG. 59—PARIS-ORLEANS RAILWAY—MULTIPLE-UNIT TRAIN FOR 1500-VOLT DIRECT CURRENT.

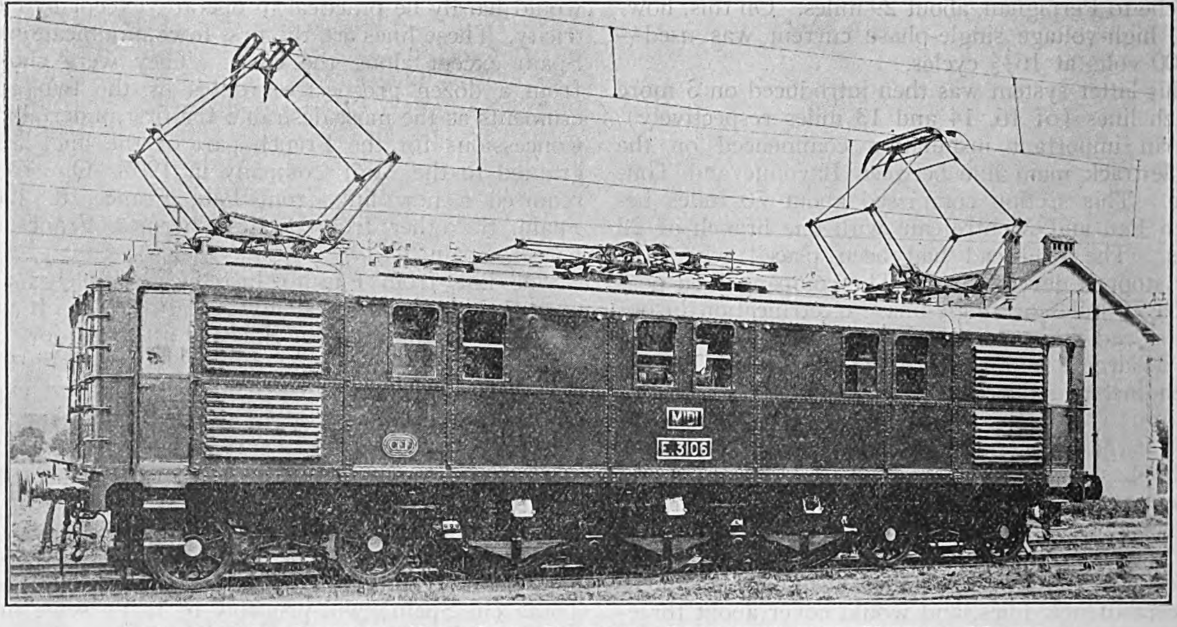

FIG. 60—MIDI RAILWAY—HIGH-SPEED PASSENGER LOCOMOTIVE WITH VERTICAL MOTORS.

locomotives. The ordinary locomotive is of type B-B and fitted with multiple-unit control. The weight is about 78 tons. The two bogies are each mounted with two 1500-volt, nose-suspended motors of 350 horsepower, making a total of 1400 horsepower per locomotive. There are 100 of these machines, the same for passenger and for freight service except for gear ratios giving maximum speeds of 56 and 37 m.p.h., respectively. A motor-generator set provides 120 volts for control, lights and auxiliary power, and there is equipment for regenerative braking. The first of these locomotives was delivered late in 1922.

In 1923 the Midi Company placed in service 2 high-speed locomotives of an entirely new type having vertical motors. Since then the number has been brought up to 10. These are very interesting locomotives and were viewed by the Subcommittee with much pleasure. They are used for the fast international trains between Hendaye and Bordeaux on the route from Madrid to Paris. The Subcommittee rode on one of them from Dax to Bordeaux (93 miles) and was greatly impressed by the smooth riding achieved on a difficult piece of track. A nearly constant speed of 75 m.p.h. was maintained throughout the run.

These locomotives are of the class 2 C 2. Over each of the 3 driving axles is a vertical twin motor, with the 2 motor shafts turning the axle through bevel gears. The motors are wound for 500 volts and have a capacity of 700 horsepower for the pair. This makes 2100 horsepower for the locomotive. The rated speed of these locomotives is 75 m.p.h., but they can safely go up to 81 miles and have been tested higher. The weight is about 115 tons. The locomotives are fitted with camshaft control and with motor-generator sets to provide 120 volts for the control, lights and small motors.

Direct current is furnished to the electrified lines of the Midi Company from 43 substations of 1000 to 4500 kw. capacity each. Most of the substations contain rotary converters, either 750-volt units in series or units wound for 1500 volts. Five of the substations have mercury arc rectifiers only. Each rectifier is composed of 2 bowls in parallel and there is a total of 16 of these groups.

There are also 10 high-tension transforming and switching stations. The substations are served by about 460 miles of 60,000-volt distributing lines, which are fed from trunk lines at 150,000 volts of which there are about 430 miles. The railway's power stations, situated in the side valleys of the Pyrenees, feed into the transmission lines and are also interconnected by means of these lines with other power producers in the same region.

Paris, Lyons & Mediterranean Railway

This large railway system operates in the southeastern sector of France from Paris to the Mediterranean. It serves a territory to the east of the Paris-Orleans and north of the Midi. It has some heavy traffic lines encumbered with steep grades and many tunnels in the southern part of the system. It also passes through a region well supplied with water power. Consequently the management has for many years had under discussion the electrification of a considerable mileage.

The double-track line from Culoz to Modane was chosen for first electrification. Starting work after the standardization in 1920, the railway opened in 1925 an experimental service on the short section between Chambery and St. Pierre d'Albigny, a distance of 15.5 miles.

The company has now in course of electrification the balance of the length between Culoz and Modane which will be done in 3 steps between 1929 and

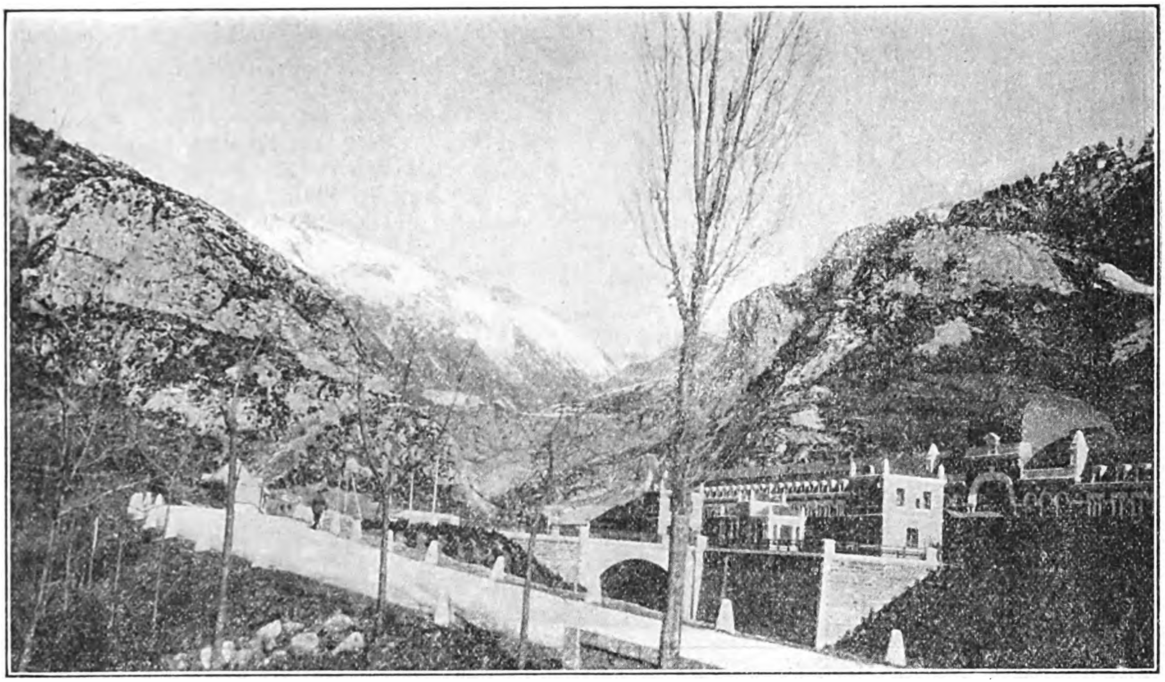

FIG. 61—Midi Railway—International Station of Canfrance, at Spanish End of Somport Tunnel, on Electrified Line Between Pau and Canfranc.

1932. There will then be 83.5 miles of double-track route, and 189 miles of all track, electrified. The line has long heavy grades, as steep as 3 per cent, and 22 tunnels. It is expected that the capacity will be greatly increased and much fuel saved.

The P. L. M. selected for its contact system a third rail at 1500 volts. This was done for several reasons, such as: ease of installation, inspection and maintenance, preventing of corrosion from passage of steam locomotives, avoidance of moving communication circuits, and avoidance of sleet troubles. It has been found that, with an overrunning rail and adjustable contact pressure, practically any desired quantity of current may be collected under any condition of the weather. The third rail is protected by insulating planks. It is carried through small local stations on the express tracks. On the ordinary tracks of the passenger stations and on the freight delivery tracks, however, an overhead contact line is substituted. All locomotives have both pantographs and third-rail shoes.

For the line Culoz-Modane, 37 locomotives have been purchased. The first ones were put into service in 1925 and 1926 with additional deliveries each year

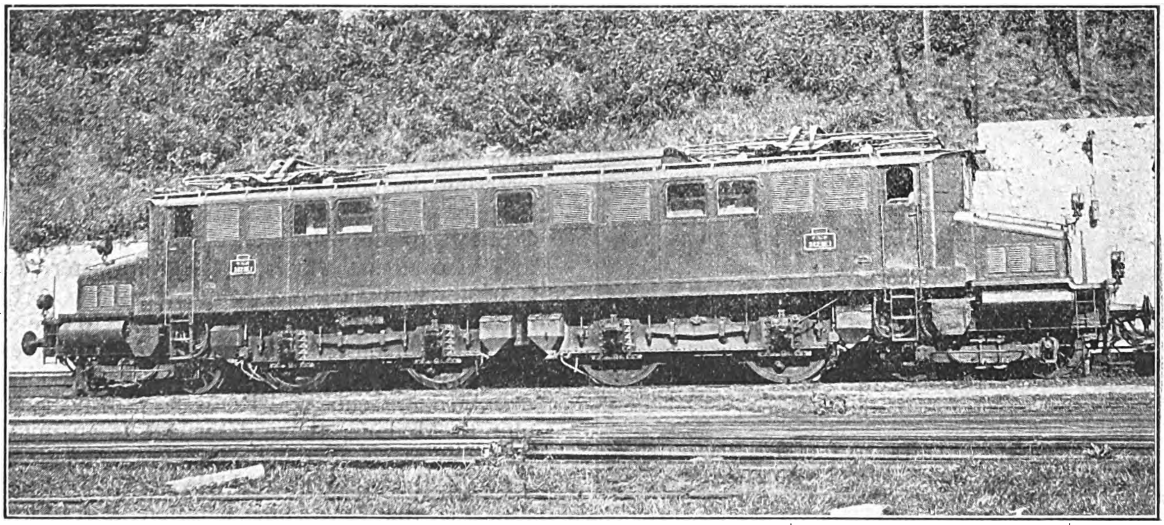

FIG. 62—Paris, Lyons & Mediterranean Railway—One Type of Passenger Locomotive for the Electrification Between Culoz and Modane.

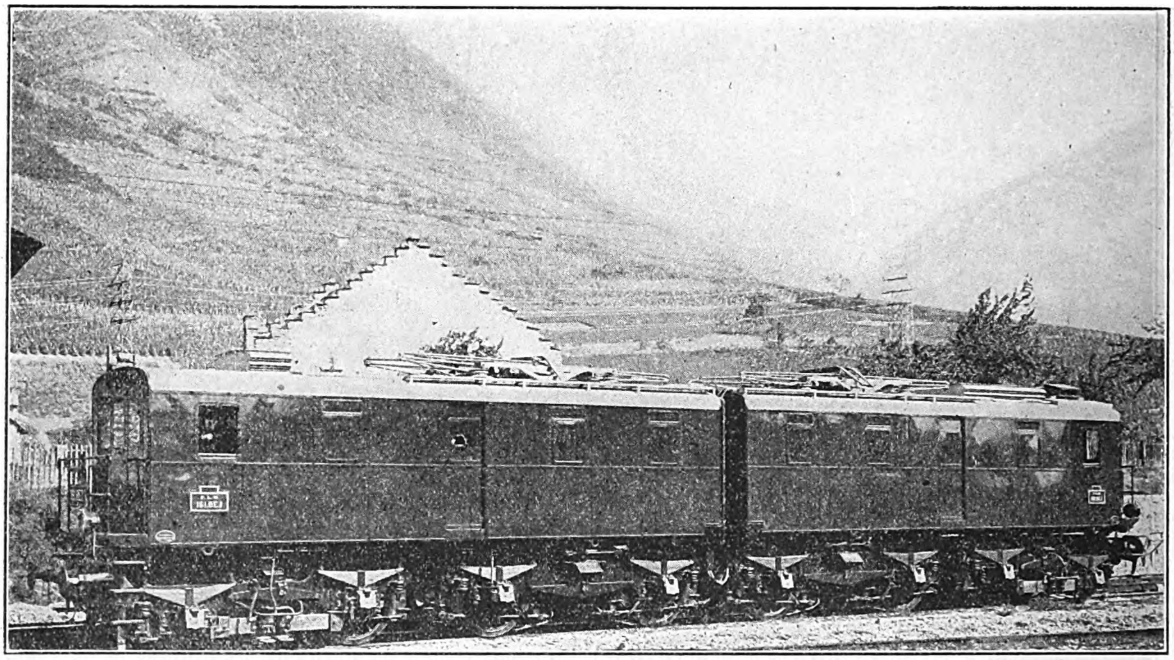

FIG. 63—PARIS, LYONS & MEDITERRANEAN RAILWAY—ONE TYPE OF FREIGHT LOCOMOTIVE FOR THE ELECTRIFICATION BETWEEN CULOZ AND MODANE.

up to 1929. All the locomotives are gear driven (with 4 or 6 driving axles), have 750-volt motors in series by pairs, and are equipped for regenerative braking.

There are three designs of passenger locomotives of class 2 B—B 2. All weigh about 140 tons, have about 2500 horsepower of motors, and a maximum speed of 68 m.p.h. A fourth type of passenger engine has recently been ordered which is called "fast express." It has 6 driving axles of the classification 2 C—C 2 and a weight of 175 tons. With 6 twin motors totaling 5400 horsepower, it is said to be the most powerful single-cab locomotive in the world. The maximum speed is 81 m.p.h. and the full rated power will be developed at 54 m.p.h. Experience with earlier designs has led the railway to favor twin motors with quill drive for its recent purchases.

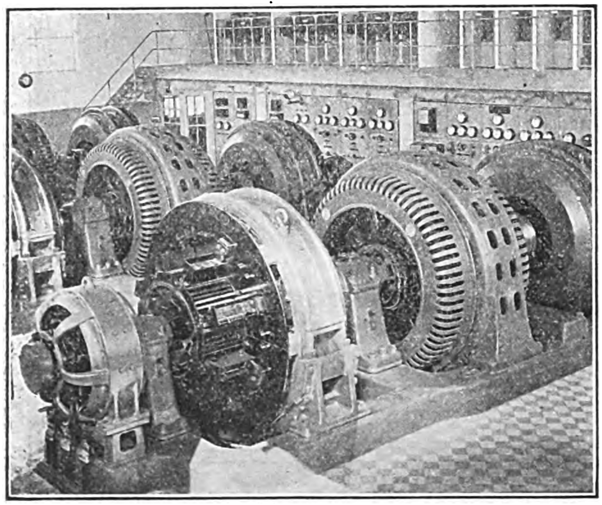

FIG. 64—PARIS, LYONS & MEDITERRANEAN RAILWAY—INTERIOR OF SUBSTATION AT ST. PIERRE D'ALBIGNY EQUIPPED WITH SYNCHRONOUS MOTOR-GENERATOR SETS.

There are also 3 designs of freight locomotives all of the same general type, 1 C + C 1. They weigh about 140 tons, and have a maximum speed of 50 m.p.h. The one-hour rating is 2400 horsepower at 21.7 m.p.h.

For power supply to the section Culoz-Modane, the railway has arranged with a large power system for delivery of high-tension energy. The railway does its own converting to direct current. Two converter substations have been in service since 1925, and 2 more will be ready in 1929. Eight will be required for the whole 83.5 miles. The general type of substation is for 3 pairs of rotaries with the capacity of 2000 kw. per pair, 2 pairs usually being sufficient for the initial installation. In one substation, however, there are 3 synchronous motor-generator sets, instead of rotaries, for the purpose of correcting the power factor.

Future plans of this company contemplate the electrification of suburban service in the vicinity of Paris, also all main lines in the southeastern section of the territory, from a point somewhat northwest of Lyons to the Mediterranean and to the Swiss and Italian frontiers. This program involves the through route from Paris to the Italian cities of Turin, Milan, Genoa and Rome, of which the section Culoz to Modane, above described, is an important part.

One of the other lines singled out for special attention is the coast line between Marseilles and Genoa, of which the section Carnoules-Nice-Ventimiglia will probably be the first step in electrification. This division of 98 miles will connect with the electrification of the Italian State Railways now in progress between Ventimiglia and Savonna (near Genoa).

The P. L. M. is also operating a short section of meter-gage railway with electric power. There are about 23 miles between the Swiss frontier and Chamonix. In the summer this line forms part of a route from Martigny (Switzerland) to Chamonix, with connections there for the rest of France. The line was built for electric operation from the beginning with 750-volt third rail. Operation of the French section is conducted successfully all winter in spite of heavy snow and sleet.

State Railways of France

This company, in addition to its distance trains, furnishes the transportation for a densely populated suburban district at the west of Paris. This suburban traffic is handled at 3 city terminal stations. As early as 1900 electric traction was adopted on one route out of the Invalides Station. In 1919 another short section was added.

The first installation in 1900 was made with electric locomotives. Motor cars were added in 1912 and 1921, and in 1922 more and heavier locomotives.

Electrification of the lines from the St. Lazare Station was taken up after the War and has progressed ever since. At the end of 1928, 6 suburban lines out of this station were electrified, and all operated with motor cars. This was the station needing the most relief from congestion. In the interest of flexibility of equipment, motor cars and trailers for this installation have been provided in sets of two coupled together, with one driver's cab at each end of the set, and automatic couplers on the cab ends of the sets. Each motor car has 4 motors of 165 horsepower. The motor cars weigh 63 tons and the trailers 41.5 tons. The seating capacity of the motor cars is 82 and of the trailers 90.

The route miles electrified out of both stations total now about 60. Two more lines are under consideration from the St. Lazare Station, one of which may be operated with locomotives using the same rolling stock as the steam trains.

The system of electrification used by this road is 650-volt third rail with U-shaped head for underrunning contact shoes. All the equipment bought since the War is, however, adapted to running on 1500 volts with the motors in series by pairs. The newer locomotives are provided with pantographs as well as contact shoes, so that they can run on the other railways if desired.

Energy is obtained from one of the local electric power companies which generates by steam. There are altogether 13 substations receiving power as 3-phase, 25-cycle. Conversion is now mostly by rotaries, but it is desired to have an installation which can be cut over from 25 cycles to the national standard of 50 cycles. Hence some mercury arc rectifiers have been installed for trial where additional converter capacity has been needed.

Other Countries

Considerable information was gathered about electrification in countries adjoining those visited. A short description of the accomplishments in Austria, Czechoslovakia and Spain is given here.

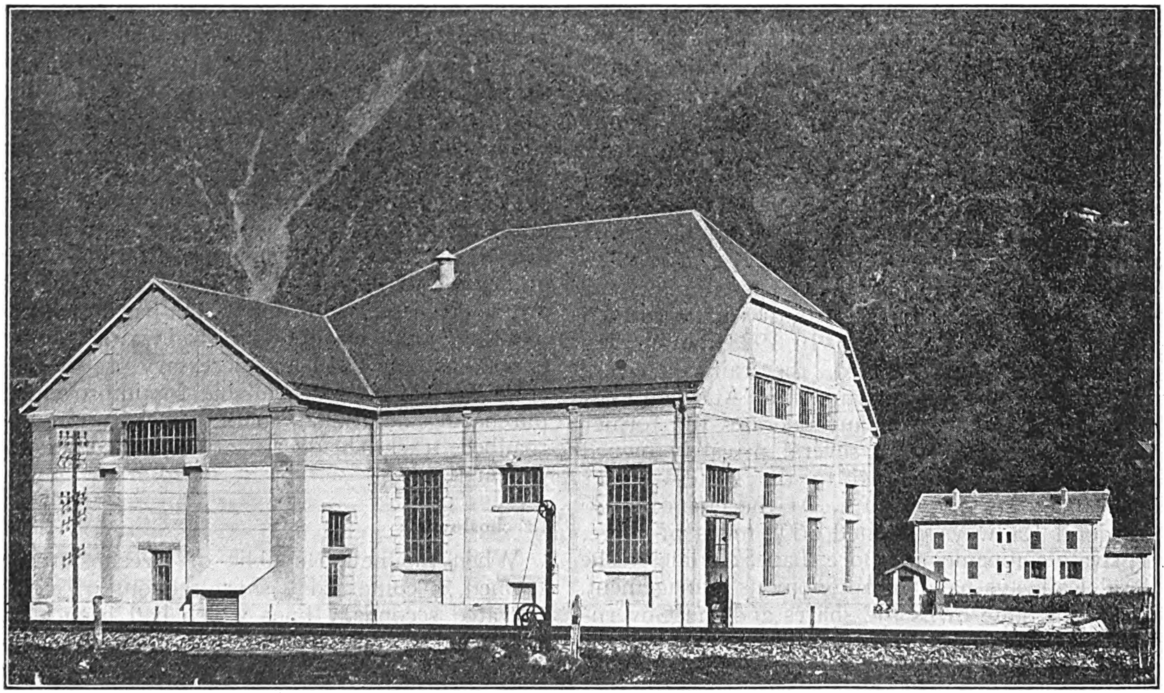

FIG. 65—PARIS, LYONS & MEDITERRANEAN RAILWAY—EXTERIOR OF SUBSTATION AT CHAMBERY.

Austria

Prior to the World War there was little railroad electrification in the Austrian State of the Austro-Hungarian Empire. Two small branches had been electrified, and 56.5 miles of narrow-gage line between St. Polten, Mariazell and Gusswerk. As for the normal-gage railroads, 2 private lines were operated by electricity—the Mittenwald Railway and the Vienna Pressburg Railway.

The Mittenwald Railway commenced operation in 1912, using electricity from the start. Although formerly a private railroad, the sections in Austria are now operated as part of the Austrian Federal Railways. There are 2 lines from Garmisch (Germany) to Innsbruck and Reutte, with the sections Scharnitz-Innsbruck and Schober-Reutte in Austria.

The Vienna Pressburg Railway operates between these two cities, paralleling the Danube, and was electrified in 1914. Pressburg is now in Czechoslovakia with a very small amount of the line likewise. The greater part of the line (between Vienna, Hainburg and the border) is now in Austria and is operated as a part of the Austrian Federal Railways.

As a result of the Treaty of Versailles, the Republic of Austria came into being as a small independent country with 33,000 square miles of area (approximately the size of the State of Indiana) and a population of 6,500,000 people. The principal source of coal passed outside the national borders into the newly created republic of Czechoslovakia.

This new country of Austria faced a series of economic problems wholly different from those its people had known before as a part of a larger and more complete economic system. Power for railroad operation was one of the problems and still continues to be after 10 years. Electrification has been made an issue of importance in the national economic program. Austria lacks a native supply of good steam coal and in addition incurs annually an unfavorable balance in international trade. As there is a great deal of potential water power, one way of improving the balance of trade seems to be electrification of railroads and consequent decrease of coal imports.

In 1920 the Austrian parliament passed an act for the electrification of definite parts of what was then the Austrian State Railways. In 1923, before this work could be accomplished, the railways were formed into a company known as the "Austrian Federal Railways." This company operates the former state-owned lines and also several privately owned lines that have been added to the system under various operating agreements. At the end of 1926 the Federal Railways operated 3608 miles of route, and private companies no more than 520 miles. The Federal Railways have an autonomous management, although the state owns the shares and the Government has supervisory powers. The policy of the Federal Railways in regard to electrification will be outlined here.

One of the first decisions was to electrify the mountain roads in the Austrian Tyrol including the principal east-to-west line from Salzburg west to the Swiss border. The purpose was to secure economies in operation of the mountain sections, to utilize water power, and to reduce the importation of coal. It was also announced that the remainder of the through east-to-west line would be electrified between Salzburg and Vienna via Linz, and the Southern line from Vienna to Gratz. This would completely electrify the principal trunk lines of the Federal Railways.

Since the formation of the Federal Railways electrification has been completed on 2 routes. The Salzkammergut line was electrified from Stainach-Irdning to Attnang-Puchheim in 1924. The Arlberg line has been changed to electric motive power as follows: Innsbruck to Bludenz in 1925, Bludenz to Feldkirch and Buchs in 1926, Feldkirch to Bregenz in 1927, Innsbruck to Worgl and Kufstein in 1927, and Worgl to Saalfelden in 1928. The 90-mile stretch between Saalfelden and Salzburg is in process of electrification and will probably be changed from steam in 1929. There will then be some 390 miles of continuous main-line electrification between Salzburg and the Swiss frontier.

The total electrified mileage of the Austrian Federal Railways at the end of 1928 was about 419 miles of line and 494 miles of main track.

In the fall of 1927 the management of the Federal Railways reconsidered the possibilities of electrification and decided to suspend work except on those sections where construction was already under way. The reason for this decision (as announced) was that operating results on the lines so far electrified did not show as much economy as had been expected. There were other reasons such as: difficulty of securing capital, need for new capital on other developments of the railways, and the fact that relations with Czechoslovakia were so good that coal could be secured cheaply and there was slight possibility of coal supplies being shut off.

The decision to suspend the electrification program called forth much adverse public criticism, also considerable opposition from the electrical equipment industries. At the present, however, there is no other course, since the electrification project was dependent on negotiation of a large foreign loan, which was for a time discussed with bankers but has now been postponed. In the meantime the railway's management is making very good and necessary use of the moderate sum of capital available for improvements by purchasing additional rolling stock, improving the roadbed, tracks, bridges, stations and other physical properties.

Czechoslovakia

When the new Republic of Czechoslovakia was formed, it contained 4 short sections of electrically operated secondary lines which had been electrified between 1903 and 1914. Three were standard-gage, totaling 34 miles, and one was narrow-gage of 22 miles in length. The voltages ranged from 550 to 1500, all direct-current.

The first electrification on the principal lines has recently been installed. After a study of several years it was decided to electrify the mid-city section of the State Railways at Prague, the capital, as part of a comprehensive plan for the development of railway facilities. The decision to electrify was largely on account of a tunnel at the south extremity of the Wilson Station or principal terminal. This tunnel is 3609 ft. in length. The relief of terminal congestion was also a factor. Coal is reasonable in price and fuel saving not the prime object in electrification.

It was especially desirable to electrify between the Wilson Station and 4 principal outlying stations where the traffic diverges. This is the present scope of the project. No decision has been reached regarding further electrification, but it is expected that electrification of some suburban lines will naturally follow. It may also be desirable to extend north from Prague to meet the German lines of Silesia which are already electrified. The intervening area is mountainous and a good prospect for electrification.

In May, 1928, electric traction was inaugurated on lines to the north of the Wilson Station, and later in the year on lines to the south. About 12 miles are electrified with an overhead line composed of 2 contact wires suspended by a catenary and messenger.

The system of electrification chosen is 1500-volt direct current. Direct current was preferred on account of taking power from the general network of 50-cycle, 3-phase lines supplying industrial and mining loads. The voltage of 1500 is considered satisfactory for both terminal and main-line electrification on account of the small size of the country and the moderate weight of the trains that will be hauled.

Electrical energy for the initial electrification is purchased from the municipal electric power system of Prague over 22,000-volt cables to the railroad substation. The substation contains 2 groups of rotary converters rated at 1000 kw. and 2000 kw. respectively. These will be supplemented by a mercury arc rectifier of 4300 kw. already ordered.

Delivery has been made of 16 electric locomotives and 2 storage-battery locomotives. All the locomotives were constructed in Czechoslovakia. There are 6 passenger locomotives of 3 types, 4 freight locomotives of one type, and 6 switching locomotives of 3 types. The battery locomotives are also for switching. All the locomotives, excepting 2 freight locomotives, have individual-axle drive.

Spain

Prior to 1928 there was not much electrification of main-line railroads in Spain. An official list of electrically operated lines names 25 sections with a total of 863 miles, but most of these are light railways or interurbans. Many of them have used electric traction from the start and are intimately connected with the urban street-car systems.

There is, however, a growing interest in electrification. One of the main-line railroads, The Northern (or El Norte), electrified a steep section of its line shortly after the War, on account of the heavy coal traffic. This was partly caused by the renewed activity in domestic coal mining as a result of embargoes on coal exports by other countries during hostilities. The increased tonnage made traffic relief imperative. Since then there have been several suburban lines electrified for reasons of traffic and economy.

Just at present there is a great deal of study being given to the general improvement of railroad service throughout the country, to the unification of gages, and to the establishment of better through lines, particularly for international traffic. Electrification is looked upon as a means for accomplishing a great deal of the desired improvement, where grades and congestion are the present difficulties, on account of its being adaptable without change in roadway and structures, or in the load gage. There is also a desire to make use as fully as possibly of the country's natural resource of water power. The government is actively cooperating in the plans and in devising means for financing the improvements which will probably have to be done by some form of subsidy or advances to the railroads. A state railway fund is already in existence.

The railroad network of Spain has been rather isolated from the rest of Europe due to two causes, the mountains and the gage. The Pyrenees form a natural barrier between Spain and France which was not overcome by railways until 1928. All railroad traffic between Spain and outside countries has been obliged to detour around the Pyrenees along the coast on either the Atlantic or the Mediterranean end of the mountains. As for the gage, the principal trunk lines of Spain use the broad gage so that passengers and freight from the standard-gage railroads of France must be transferred at the boundary.

For several years two lines have been in process of construction by tunneling the Pyrenees. The first to be completed, in July, 1928, is the line from Pau, France, to Jaca, Spain, already referred to under France. This line debouches into Spain from the long Somport tunnel at the international station in Canfranc, Spain. It is operated from Pau through the mountain section to Canfranc by the Midi Railway of France with electric locomotives of its standard types.

The second line through the Pyrenees will make a link between Ax-les-Thermes, France, and Ripoll, Spain, via the Spanish border town of Puigcerda. It will complete a through electrified route from Toulouse to Barcelona. The Spanish section has been constructed from Ripoll to Puigcerda. This part was built by the government and will be leased to the Northern Railway of Spain. The French section is to be a part of the Midi Railway. This part is scheduled for completion some time in 1929.

The first move toward the standard gage on international lines will be made in connection with the new through route from Toulouse, France, to Barcelona, Spain. This is the line just referred to as passing through Puigcerda and Ripoll. From the French border at Puigcerda as far as Ripoll this line will be converted to standard gage (4 ft. 8½ in.).

From Ripoll to Barcelona a third or parallel rail will be laid, so that cars of standard gage can travel this section as well as broad-gage cars. This will more effectively open the port of Barcelona to international traffic.

Northern Railway of Spain

In 1924 this company electrified its Pajares grade between Ujo and Busdongo, measuring 38.5 miles. This line was mentioned above in the general discussion. In 1928 they electrified the sections Barcelona-Manresa, 39.8 miles, and Barcelona-Ripoll-San Juan de las Abadesas, 65.9 miles. They are about to take over from the Government, for electric operation, the line between Ripoll and Puigcerda (at the French border), which is a part of the second international line through the Pyrenees described above.

The Northern has also in process the electrification of a section from Irun (at the French border) to Alsasua. This is a part of the present main western route between Paris and Madrid or Lisbon.

The Pajares grade was electrified with 3000-volt direct current for locomotive operation. The other lines are using 1500-volt direct current for both locomotive and multiple-unit operation. The lines running into Barcelona have multiple-unit trains for suburban service, and it is proposed to use similar equipment on the lines radiating from Madrid which are mentioned below under "Future Plans."

Madrid, Zaragossa and Alicante Railway

This is one of the 2 largest railway systems in the country having almost as many miles of line as the Northern. They have prepared specifications for electrification of suburban service out of Barcelona. It is reported that this will require 64 motor cars.

Southern Railway of Spain

The Southern Railway has a short section of line electrified between Naciemento and Gador. The length is 18.6 miles, using 3-phase current at 5500 volts. This company is a part of the Andalusian Railway which operates an extensive system in the southern part of the country.

The Catalan Railway

This is a short line of meter-gage operating in the vicinity of Barcelona. In 1926 they electrified 7.5 miles of terminal section with 1500-volt direct current for locomotive operation. This was largely on account of a tunnel.

Island of Majorca

The railway from Palma to Soller is being electrified with 1200-volt direct current. This line is about 11 miles in length.

Future Plans

Several reports have been made recommending specific lines for electrification. One published in February, 1928, listed 1306 miles of electrification as economically justified. A more recent report, in February, 1929, selects for immediate work the following sections: Madrid-Avila, Madrid-Segovia-Medina, Madrid-Villanueva de la Reina, Valencia-La Encina, Mirando-Bilbao and the Santander Line. It is expected that specifications will soon be issued for these sections as a preliminary to awarding contracts for their electrification.

Portugal

A few words may be appended about Portugal. There is no real electrification in Portugal as yet, although the electric railway between Lisbon and Cascaes is sometimes classified as electrified. This railroad is a double-track line of broad gage about 16.2 miles in length. It was, however, built about 1921 largely for resort traffic and has always used electric traction. The contact line is energized with 1500-volt direct current.

CONCLUSION

Some of the most interesting general features and developments observed in the seven countries visited will be summarized:

1. Electrification has so far been undertaken in definite localities for certain special reasons. The compelling reason is usually some condition difficult for steam operation, such as: congested traffic, suburban service in the neighborhood of large cities, heavy grades, long tunnels, or the absence of good steam coal. In the latter case the existence of water power has an important influence on the course followed.

2. Electrification will be extended where it now exists, and introduced into new districts, for the same compelling reasons. There is not at present any general tendency toward complete electrification of railroads in any of the countries.*

3. Most of the electrification in Europe has come into existence since the War. There were only a few miles in any country prior to 1915, and most of the development has been realized since 1922. Much experimental work on electrification, however, had been done between 1900 and 1914. The more rapid progress in recent years has benefited by the earlier research.

4. The establishment of large commercial power systems (both private and state owned) in Europe has also been a post-War development, followed by interconnection of power systems so as to provide large pools of power. This has made electric power more generally accessible to the railroads, enabling them (1) to utilize the energy with a minimum of investment for transmission lines, (2) to reinforce their own power systems by interconnection with the commercial power systems, and (3) to trade surplus energy both ways with the commercial power systems.

5. Recognition of the technical advantages of securing power from the large commercial networks seems quite general and constantly increasing in effect. Even where the railroad has established its own power stations there is usually some form of interconnection with the industrial power systems.

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* Switzerland has more electrification and a higher percentage of lines electrified than any of the other countries, but the country is small and the railway lines throughout have nearly the same topographic and economic problems. Even here they do not anticipate complete electrification.

APPRECIATION

This report would not be complete without a tribute to the unfailing courtesy and hospitality accorded the Subcommittee in all countries visited. The most cordial cooperation in the objects of the trip was given by railways, underground railways, electrical manufacturers, sales representatives, power systems, and consulting engineers. Many valuable contacts were established which it will be the pleasure of the Subcommittee to maintain for the benefit of the general Committee in future years.

Several delegations of European railway engineers have already visited the United States and more are planning to come within the next few years. This it is hoped will give the Electrification of Steam Railroads Committee some opportunity to repay the many favors extended to its representatives on their visit to Europe.

Thanks are also gratefully extended to the members of the general Committee and to other friends who assisted in planning this inspection trip, also to all those who provided the Subcommittee with introductions to European engineers and executives or who otherwise contributed to the success of this investigation.

APPENDIX B

REPORT OF SUBCOMMITTEE ON FORM OF CONTRACT

Foreword

Anyone examining the following analysis of 15 contracts covering power supply for railroad electrifications in the United States will probably be impressed with the fact that there is considerable variation in the terms and conditions of these contracts, and, if each of these contracts could be examined, the necessity for clarity of expression would immediately be the outstanding thought.

With the great diversity of conditions as to railroad requirements and central station supply, it is not surprising that variations should appear, particularly in the older contracts. Nevertheless, it seems to the Subcommittee that it will be possible in the future to greatly simplify and standardize the terms and conditions. It is recommended that the problem be approached with a broad point of view, knowing that in the long run difficult terms, and conditions that are only irritating, will be either ignored or modified.

Statement of the Problem

Electrification of steam railroads has advanced to the point where there is a great deal of accumulated experience to guide the future progress. If this information can be gathered into one place it will have great value. One of the important points on which much remains to be done is the matter of contractual relations between railway and power companies. The study embodied in this report was undertaken with the purpose of submitting to the power industry and the railroads a uniform basis for such contractual relations in event of the extension of electrification into new places.

As the electrified zones expand and spread into the territories of additional power companies there will be a distinct advantage in having similar agreements, similar contracts and relationships, and, in a word, analogous operating conditions in adjacent portions of the railway systems. Without doubt the power companies may find it advisable, or even necessary, to interchange energy for railroad purposes, or, as it might be expressed, to pool their facilities along extensive electrifications. This, then, will require a certain similarity of contractual relations.

It should be plainly stated that the price paid for energy is only one feature of the contract, although admittedly of utmost importance. The contract form can be discussed and planned quite independent of the price. In fact, a properly designed contract form may be used in one part of the country with certain prices inserted in the rate section, and may be used elsewhere with other prices inserted in the rate section to meet different conditions in the cost of producing or supplying electrical energy. In the interest of standardization, however, the rate form, like the remainder of the contract, should be shaped to a standard expression requiring only the substitution of proper, adequate prices depending upon local conditions.

When general acceptance is accorded by both railway and power industries to the principle of standardizing, so far as possible, the terms and conditions of large power contracts, it is the opinion of this Subcommittee that a great deal will have been accomplished toward better mutual understanding.* It is not the expectation of this Subcommittee that at this time one standard form and phraseology can be submitted by a small group of men that will satisfy all the requirements of every situation. There are, however, certain basic features of contract designing, certain inherent features of the power business, and other inherent features of the railway business that are fairly universal and well-known. These should be recognized in any contract, and then should be supplemented (but, if possible, not altered) by such provisions as adapt the whole to the specific locality where the contract will be applied.

The Subcommittee has thus for this year's work adopted the plan of presenting an outline of all the desiderata for inclusion in a well-rounded contract. The outline which concludes this report is intended to cover all the conditions which are likely to arise in connection with electricity supply for traction and for other railroad service along the right-of-way. This proposed form of headlines, or titles, can probably be simplified in many cases, but it is submitted as something to which both railroads and central stations may refer when negotiations are opened between them in any part of the country.

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*As an indication of the attitude of the railroads toward this matter, it may be stated that associations of railway engineers and executives are now engaged in studying the essentials of a standard power contract.

Analysis of Contracts

For the purpose of analysis the Subcommittee collected 15 actual, existing contracts covering supply of energy to 13 railroads for their electrified sections. The contracts date from 1912 to 1929, and all are in effect at the present time.

These contracts come from widely scattered parts of the country and include supply from both water-power and steam-power companies. They are probably quite representative, as they include most of the power sales for electrification, excepting sales from one railroad to another. In size, the contracts vary from a few hundred kilowatts up to 25,000 kw. or more.

As a class, they are rather special, and contain many provisions not used in ordinary power contracts. They are also quite varied among themselves, the only similarity of form or expression being in cases where contracts have been executed by related power companies.

Several of the contracts were furnished with the comment that they were special and not generally applicable. This proved to be true, and one was in such unusual form that comparison with the others was not practicable. Hence it was dropped from consideration and an analysis made of the remaining 14 contracts.

All of these contracts contain some special or unusual conditions except three that conform to regular contracts given to large industrial power users. All of them, in spite of their variations and differences of viewpoint, present interesting and valuable features which may be incorporated into a standard form of contract of much more general applicability.

The contracts analyzed are so at variance in arrangement and in content that it is almost impossible to get them into shape so that direct comparison can be made. This immediately shows the difficulty faced by railroad and power company officials in trying to ascertain what is good practice in designing a power contract.

The most essential features of the fourteen contracts are as follows:

Term

Varying from 3 to 99 years.

10 years most frequent (6 cases).

Longest in connection with water-power companies (30-99 years).

Renewal

Mostly renewable except those for long periods.

Six are indefinitely or perpetually renewable by terms of one to five years each.

When renewable, usually require 12 to 24-month notice of intention to terminate, although two small ones do not require more than 30 days.

Increase of Capacity

Capacity where not definitely limited may usually be increased on 12-month notice during early years of contract, or later in term if renewal or extension is agreed.

Place of Delivery

9 at railroad substations.
3 at power-company generating stations.
2 at power-company substations.

Form of Energy

8 contracts for 3-phase energy at 60 cycles and voltages from 11,000 to 100,000.
4 contracts for 3-phase energy at 25 cycles and 11,000 or 13,000 volts (one also includes single-phase energy).
1 contract for 1500-volt direct current.

Metering

Considerable uniformity in provisions for metering, similar to the usual contracts for large industrial power customers.

Unbalance

Usually not stated.

One contract limits to 100 kv-a. and one limits to 10 per cent.

Strike, Riot, Fire, Explosion, or Act of the Elements

Calamity due to causes not controllable by either party is variously treated.

Some contracts allow relief to one party only, and some to both. Individual provisions are as follows:

a. Omit all periods of one week or longer.
b. Omit all days affected.
c. Omit all periods but extend term of contract accordingly.

Demand charges and guarantees are usually suspended and the railroad pays an Energy Charge alone during the continuance of calamity.

Interruption of Supply

The companies usually covenant to use diligence in preventing interruption.

Few provide any penalty or means of securing compliance except through power of cancellation as mentioned below.

One provides a cash rebate for long interruptions (over 15 min. per day) and another provides for adjustment of demand and guarantee.

Arbitration

Eight contracts provide for arbitration by a board of three. The provisions in regard to arbitration are quite similar. Some add right of cancellation if loser refuses to accept decision.

Regeneration

Two contracts provide that surplus energy from regenerative braking shall be absorbed by the power company and deducted from the kw-hr. supplied.

Change of Rate

Four contracts protect the railroad against lower rates to other customers for similar service. Five provide for rates to increase or decrease subject to public service commission or state authority. (In one of the latter, railroad may withdraw if rate is increased.) In one contract a reduction of rate is provided in case of certain growth of the railroad's electrical requirements.

Form of Rate

Ten contracts have Hopkinson (or two charge) form. Four are straight-line rates. Of the ten Hopkinson rates, two are the simplest form with single Demand and Energy Charges. Eight have the Demand and Energy Charges (either or both) in blocks, and two of the eight use the Wright (or load-factor) principle in blocking the Energy Charge.

Two of the straight-line rates involve measurements of demand, as one adjusts the rate according to load factor and the other adjusts the guaranteed consumption. The two remaining straight-line rates base the guaranteed consumption on the contract capacity.

Demand Interval

Twelve contracts require the measurement of demand, daily or monthly. Seven use a 60-minute (sometimes clock-hour) period, two use 30 minutes and three use 5 minutes. Several specify that no demand registered immediately after an interruption of service shall be considered in billing.

The Billing Demand

In case of the 60-minute demands, two use the one highest only, three make an average of three demands, one makes an average of six and one averages all the daily demands in the month.

In case of the 30-minute demands, one uses the single highest of the month and the other makes an average of twenty demands.

In case of the 5-minute demands, two use an average of three and one uses an average of all the daily demands in the month.

Period to Which the Billing Demand Applies

Seven contracts use the actual measured or calculated demand each month. Three of these do not allow the billing demand to recede below a certain quantity, either 70 per cent of its highest value in the previous 12 months, or 75 per cent of the highest value attained during the previous life of the contract.

Four contracts make each successive highest monthly demand effective for billing during twelve months, and one retains the highest monthly demand for the remaining life of the contract.

Minimum Charge or Bill

Most of the contracts start with a fixed amount based on demand or consumption or both, followed by increases based on actual use.

The ten contracts with rates of Hopkinson form base the continuing minimum charge as follows: Two on a specified number of kilowatts, two on the established demand, four on the established demand and a guaranteed load factor, one on the miles of line electrified.

The four contracts with straight-line rates base the minimum charge as follows: Three on guaranteed capacity factor, and one on demand plus a guaranteed load factor.

Emergency Demand or Energy

Eight contracts provide for excess service on account of extraordinary operating conditions, usually subject to power company's ability to supply the excess and specifying some previous notice. Three specify the length of time during which excess power may be taken, varying from 24 hours to one week. Two limit the occurrence to three times per year. One limits the taking to double the established demand. During periods of excess demand the guarantees are usually waived and ordinary Energy Charge prevails.

Power Factor

Eight contracts provide that the power factor (particularly at times of heaviest demand) shall not go below certain standards as follows: One limits to 75 per cent, three to 80 per cent, three to 90 per cent and one to 95 per cent. Four of the eight impose penalties for low power factor by correcting the demand proportionately.

Fuel Clause

Ten contracts provide for adjustment of the rate according to the cost of coal, usually by adjustment of the Energy Charge. There are five general types of this adjustment: One contract adjusts monthly according to the cost per B.t.u., five adjust monthly according to the cost per ton, two adjust quarterly according to the cost per B.t.u., one adjusts quarterly according to the cost per ton, and one adjusts annually according to the cost per B.t.u.

Limitation of Demand

One contract provides for limitation by automatic switches, two by power company attendants subject to instructions from railroad.

Cancellation

Eight contracts provide cancellation as a penalty for non-performance. In one case the power company may cancel for default in payment, in four cases the railroad may cancel on account of poor service and in three cases either party may cancel for the respective reasons just stated.

Special Provisions

There are many special provisions of interest. Those that appear most important, selected from the various contracts, are as follows:

1. Power company assumes operation of railway's generating station with option to purchase.
2. Railway may enter and operate power company's generating station in case of necessity.
3. Provisions for placing liability on respective companies in case of accident.
4. Space for substations and transmission lines provided free by railroad (or at nominal rental). Power company may use such space for any purpose incidental to its business, either without charge or with charge based on proportion of non-railway business.
5. On expiration of contract railroad shall purchase equipment installed for its exclusive use by power company and not over fifteen years old.
6. Railroad may terminate contract by purchasing power company's special facilities for its particular service.
7. Power company may rent space for communication circuits on railroad's pole lines.
8. Either party may install equipment in station or substation belonging to the other.
9. Either party at manually operated station or substation will operate equipment of the other without labor charge.
10. Power company will maintain electrical equipment, and transmission or distribution lines, of railroad company, at cost.
11. Railroad may use energy for all purposes incidental to its business and supply these needs at various locations by its own transmission or distribution lines.
12. Railroad may supply energy to subsidiary and related companies.
13. Railroad may supply energy to other railroads for train operation when such operation is conducted electrically over the first road.
14. In event that railroad company extends its electrification into the territory of another power company, the first power company agrees to make a reciprocal contract, with the second power company, for emergency transfer of energy.

Form of Contract

The contract should be as brief and concise as the circumstances permit. On the other hand, no essential provisions should be omitted. For the sake of uniformity all contracts for railroad electrification should be drawn in substantially similar form, using the clauses and provisions that suit the case. The following outline has been drawn to indicate the essential elements to be incorporated in all contracts—it being recognized that in most cases not all of the items will be required, while in certain cases other special provisions to meet local conditions may be necessary.

The general subjects to be provided for in any contract are as follows:

Preamble
I. Term of Contract
II. Quantity and Scope
III. Form of Delivered Power
IV. Points of Delivery
V. Rates
VI. Metering
VII. Determination of Quantities Used in Billing.
VIII. Bills, Payments and Penalties for Non-payment
IX. Special Facilities
X. Operating Arrangements
XI. Protection Against Damages and Claims
XII. Definitions and Units
XIII. Sundry Provisions
XIV. No Discrimination in Rates
XV. Arbitration
XVI. Amendments
XVII. Successors and Assigns.

These general subjects should be elaborated substantially as set out on the remaining pages.

Preamble

a. General conditions
b. General location
c. General purpose.

I—Term of Contract

a. Original term
b. Extensions
c. Renewals, automatic or otherwise
d. Commencement of term
e. Supply of energy during preliminary period.

NOTE: The percentages and quantities stated in various places in this outline are not suggested as universally applicable, but are used only to make the text readily understandable.

II—Quantity and Scope

a. Initial quantity
b. Increase or decrease in quantity
c. Ultimate quantity for which provision is made
d. Notice, time interval and conditions for change in quantity
e. Extent of territory included.

NOTE: See note at end of VII.

III—Form of Delivered Power

a. Principal supply (for traction purposes). Volts, frequency, phases, etc., and allowable variations
b. Secondary supply (for traction purposes)
c. Auxiliary supply (for miscellaneous lighting and power of stations, shops, yards, signal service, etc.).

NOTE: III and IV may be combined if simplification may thereby be accomplished or understanding improved.

IV—Points of Delivery

a. Initial points of delivery
b. Additional or subsequent points of delivery and conditions of establishing them
c. Points of delivery for purposes other than traction.

NOTE: In each case specify the method of connection and the ownership of facilities.

V—Rates

a. Scale of charges
Primary charge (based on demand)
Secondary charge (based on energy used)
b. The guaranteed payment
(Minimum of demand, or demand and energy together, for which payment shall be made. Including provisions for maintaining a definite load factor, if any)
c. Fuel clause
Provision for adjusting the charges according to the cost of fuel, preferably according to the cost per B.t.u. This adjustment may be billed as a separate item each month, and changed yearly or quarterly on the basis of average actual cost of fuel at all applicable stations of the power company.

NOTE: It is suggested that the scale of charges be of the Hopkinson (or two-part) form of rate, blocked in both parts to allow for growth of the business.

VI—Metering

a. Power company to furnish, maintain and read meters
b. Location of meters
c. Railroad to provide space for metering (where necessary)
d. Meters to measure demand, energy used, power factor, regenerated power returned to power company, etc.
e. Standards of accuracy
f. Standards for testing
g. Representatives of both parties may be present at all readings and tests
h. Meters to be tested periodically [e.g., 3 months, 1 year, etc.]
i. Meters to be given special test at any time on request of either party
j. Payment for special test
k. Refund or payment as result of any test [not retroactive more than one month or prior to last test]
l. If meter fails to operate, payment at average rate of other days in same month (or other equitable basis).

VII—Determination of Quantities Used in Billing

a. The demand interval to be a specified number of minutes, may be the clock hour or some certain part thereof.
b. No demand reading or interval, or any part thereof, to be taken within [one hour] of resuming operations after an interruption of service.
c. The maximum demand for the month to be determined by: (1) averaging certain daily (or other periodic) maximum demands at each point of delivery, and adding together the resultant demands for the different points; or (2) computing the simultaneous daily (or other periodic) maximum demands, for all points of delivery together, and averaging certain of the simultaneous demands; or (3) a combination of the two for principal supply and auxiliary supply.
d. The monthly demand so computed to be adjusted for lagging power factor (when the average power factor is less than [80] per cent, or when the power factor at time of maximum demand is less than [90] per cent).
e. The monthly demand so computed to be corrected for unbalance of three-phase power [when over a certain percentage, probably 10 per cent].
f. The result of items "c, d, and e," inclusive, to be the monthly maximum demand used for billing, provided it be not less than the established demand or such other amount as may be fixed by the contract.
g. The established demand to be the highest monthly maximum demand (or a percentage thereof) recorded either (1) within the previous twelve months or (2) within the life of the contract.
h. The demand may be determined yearly at the end of the year, and an adjustment made to correct the charges and payments of the 12-month period.
i. Consumption of energy for billing purposes to be the sum of consumptions at all separate points of delivery after deducting the surplus energy returned by the railroad. This surplus is the energy produced by regenerative braking, which is not absorbed in the railroad's own business.

NOTE: If desired to limit the increase (or rate of increase) of demand on the power company's facilities, provision should be made here or in II for gradual growth of demand [say 10 per cent per annum] unless formal request is made for additional capacity. The same applies to permanent decrease in demand and capacity.

VIII—Bills, Payments, and Penalties for Non-Payment

a. Period covered by bill (and pro-rating of annual charges if any)
b. Date of rendering bill
c. Date for payment of bill
d. Interest for delay in payment
e. Discontinuance of service for non-payment (and charges which continue)
f. Reinstatement of service, with conditions
g. Cancellation of contract for non-payment
h. Estimates used in billing and adjustments at later dates (in case demand, fuel charge, etc., are adjusted at end of quarter or of year).

NOTE: The provisions for arbitration, stated elsewhere, to include provisions for continuance of service and payments during adjudication of dispute.

IX—Special Facilities

a. Power company to extend its facilities to certain places at its expense.

b. Railroad to extend its facilities to certain places at its expense.

c. One party may construct or extend facilities for the other at cost, or agreed price.

d. Either party may build substation on the other's property, or install equipment in the other's station or substation at nominal rental. If such privilege is used in part for other purposes not involved in fulfillment of this contract, a reasonable rental to be charged for the proportionate part of the space.

e. Either party may rent space for communication or control circuits on poles or structures of the other.

f. Contract may provide for communication or control circuits to be installed jointly between places involved.

g. All high-tension power and transmission equipment (or supply system) to conform to standards and practice of power company.

h. All low-tension power and transmission equipment (or utilization system) to conform to standards and practice of railroad company.

i. All engineering and construction plans to be jointly approved by representatives chosen by corporate officials of each party and recorded with the other.

j. Synchronous machines to be usable for power-factor correction.

k. Voltage regulators of field-control type, induction regulators, other types of voltage regulators, or other regulating devices or relays, to be supplied by either party on its own equipment (as needs justify) to maintain quality of service or to enable synchronous machines to operate in step.

l. Power company to promote continuity of service by: (1) furnishing loop or duplicate circuits (from separate sources, if possible), or (2) paralleling railroad with a transmission line, or (3) maintaining interchange connection and agreement with other power companies.

m. At termination of contract, substation buildings to be purchased by owner of land at fair value.

n. At termination of contract, railroad to purchase substation or conversion equipment installed within last [x] years especially for fulfillment of this contract and not desired by the power company for its other business.

o. At termination of contract, railroad to purchase all special facilities of power company (aside from buildings) installed on the railroad's premises for exclusive purpose of serving the railroad within the last [x] years, and not desired by the power company for its other business, at fair value.

p. At termination of contract, power company to purchase all special facilities of railroad company installed on power company's premises and desired by it for its other business, at fair value.

q. At termination of contract, access to be given by either party to the other for removal of equipment from premises, such removal to be accomplished within a specified time.

NOTE: Consideration should be given to the problem of inductive interference whenever this problem necessarily becomes a part of the contractual relations between the two companies.

NOTE: Items "m" to "q," inclusive, may be placed in separate article entitled "Conditions at Termination of Contract."

X—Operating Arrangements

a. Continuity of service essential to mutual satisfaction. Each party to covenant to use diligence in maintaining continuity and in reestablishing service after interruption.

b. In case of interruption of either supply or utilization, a permanent record to be kept by each party, showing time, duration and cause

c. Emergencies beyond control to absolve either party from duty to supply or to receive power. Rate suspended during such period. Such emergencies are: strike, fire, explosion, insurrection, riot, invasion by the public enemy, action of the elements, etc.

d. If intervention by federal or by state government renders compliance with contract temporarily or permanently impossible, the contract may be suspended or terminated without cause for liability or damage, but power company (being enjoined or prevented) to continue service with consent of authorities until other supply can be provided by railroad.

e. During abnormal operating conditions on the railroad, the power company to furnish excess demand (or capacity) and energy, if it has sufficient available capacity, up to [x] per cent in excess of normal (or established) demand. Notice of abnormal operating conditions to be given by railroad to power company with estimate of duration, and when foreseen sufficiently in advance to be given in writing. Such conditions to include abnormal traffic and abnormally low temperature. If power company cannot supply excess demand fully or at all parts of the day, railroad to so arrange its business as to cooperate with power company in using available capacity to the best advantage of both parties. The regular demand charges to be paid for excess demand during months (or days) when used. All emergency energy to be paid for at regular energy charge.

f. Operation of railroad company's generating station may be permitted in parallel with power company's stations.

g. In case railroad continues to operate its own generating station (whether in parallel with power company or otherwise), railroad not entitled to excess demand or energy due to failure of its own power facilities as an abnormal operating condition, unless the four following conditions are fulfilled with regard to railroad's generating station and other power system or equipment: (1) Capacity must be adequate for load which is normally required to be carried, (2) Reserve must be adequate for carrying load during repairs or renewals, (3) Maintenance of facilities must be reasonably good, and (4) Power company specialists in generation and distribution must be permitted to make periodic inspection of railroad's generating station and other power facilities (and records thereof) for purpose of certifying to the first three items just enumerated.

h. Interruptions not due to emergencies (above described) and including operating contingencies of power company's system or equipment (or of railroad company's equipment maintained by the power company) and including cessation or curtailment of service for repairs or renewals by power company, to entitle railroad to rebate on demand charge, if of sufficient duration. All interruptions of [15] minutes or longer to be rebated for monthly (or yearly in case of yearly demand charge) at agreed rate in relation to the actual average demand charge of the period and in proportion to the total length of the interruptions.

i. Provision for joint power control, or power supervision. Representatives may be stationed in each other's offices or power departments. Orders may be given by power supervisors of one company to employes of the other for control of power supply.

j. Either company, at manually operated station or substation, to operate equipment of the other, subject to its orders.

k. Demand may be limited by control devices or by manual operators acting according to instructions of railway company.

l. Provisions for inspection, maintenance and renewal of special facilities or joint equipment, specifying by whom and at whose expense.

m. If contract is terminated before expiration of term, for any reason except non-payment, the power company to continue service until railroad can make effective another source of supply.

XI—Protection Against Damage and Claims

a. Railroad to protect power company from damage to property and to employes from faulty electrical equipment or operation of railroad.

b. Power company conversely to protect railroad company.

c. Power company assumes liability in respect to injury of its employes while working on railroad's premises except as covered by (a).

d. Railroad to protect power company against claims for damage to outside persons or property of others due to faulty electrical equipment or operation of railroad.

e. Power company conversely to protect railroad.

f. Railroad to use due diligence in operating and maintaining its system so as to take and use electrical energy regularly. No claim for damage on part of power company for failure to use energy, the charges for readiness to supply being included in the rate.

g. Power company to use due diligence in operating and maintaining its system to preclude interruption of service to railroad. No claim for damages on part of railway not covered (1) by provisions for waiver or reduction of primary charge during periods of interruption, or (2) by right of cancellation in event of continual interruptions or poor service.

XII—Definitions and Units

a. Preliminary period
b. Installed capacity (of equipment allocated to this contract)
c. Power (kilowatts or horsepower, as required)
d. Energy (kilowatt-hours)
e. British thermal units
f. Demand and maximum demand
g. Consumption
h. Load factor (or capacity factor as required)
i. Power factor and kilovolt-amperes.
j. Day
k. Clock hour
l. Abnormal demand
m. Abnormal hour, day, or period
n. Abnormally heavy railroad traffic
o. Abnormally low temperature
p. Other units and terms as defined at date of this contract by American Institute of Electrical Engineers (or American Standards Association).

XIII—Sundry Provisions

a. Waiver of rights not to estop action in case of subsequent defaults.

b. Railroad to have preferential right to use power as far as legal and justifiable.

c. Operating orders required to be given by an official or supervisor of one party to the other to be given in usual form, oral or written, used by the former for transmitting similar orders to its own employes for similar duties.

d. Energy may be used by railroad for any purpose incidental to its business, also by subsidiary and related companies.

e. Energy not to be resold for general lighting or power purposes or to industrial customers.

f. Energy may be used by trains of other railroads having operating rights over railroad company's electrified tracks.

g. Power company to have access to railroad premises for all purposes in connection with rendering of proper service, care of its property, and reading meters.

h. Each company to have access to other's books, records, and accounts for all purposes concerning: testing of switches, meters and equipment; cost of coal, etc. The same access to be granted to arbitrators in case of arbitration.

i. Statements of demand, consumption, voltage, frequency, irregularities, interruptions of supply or use, as the case may be, may be required daily or periodically by either party.

j. Power company may make contingent contract to operate, lease, and/or purchase railroad's generating station.
k. Energy supplied by power company to be generated by it at its own stations or procured by it from any other reliable source.
l. In event that railroad company extends its electrification into the territory of another power company, the first power company to agree, subject to approval of railroad, (1) to endeavor to make a reciprocal contract with the second power company (or companies) for emergency transfer of energy, or (2) to endeavor to make a sub-contract with the second company for additional supply of energy to the railroad by the second company.
m. Notices under the contract given by either party to be in writing and to be delivered, or sent by registered mail, to designated officials of the other party.

XIV—No Discrimination in Rates

a. Railroad to receive as low rates as any other customer purchasing similar service.
b. Rates subject to control by state public service commission.
c. Railroad may cancel contract within certain period, in event that public service commission orders increase of rate, provided that railroad can secure power elsewhere at a lower cost.

XV—Arbitration

a. Provided for all disputes under the contract
b. Selection of arbitrators
c. Operation to continue during arbitration
d. If dispute relates to amount of charges, two alternatives suggested: (1) Approximate payments to be deposited pending settlement, such payments to be average of three monthly payments made under the contract prior to dispute, or (2) Railroad to pay bills rendered without prejudice to its right to recover back any sum which the arbitrators shall find to be overpayment with interest thereon at rate of [x] per cent.
e. Time, place and notice of arbitration, and duties of arbitrators
f. Rendering of decision
g. Effect of decision
h. Payment of arbitrators.

XVI—Amendments

a. Contract includes all terms and provisions
b. Amendments to be made only by supplemental instruments of equal legality executed by corporate officials.

XVII—Successors and Assigns

a. Contract in duplicate
b. Contract binding upon successors or assigns
c. Conditions governing assignment by either party.

APPENDIX C

STATEMENTS OF RAILROAD PRESIDENTS

PART I

ELECTRIFICATION OF THE PENNSYLVANIA RAILROAD

Announcement by W. W. ATTERBURY, *President, on Oct.* 31, 1928

The Board of Directors of the Pennsylvania Railroad Company has authorized the electrification of the entire road train service, freight and passenger, between New York and Wilmington, Del.

This authority covers a part of a plan which includes also electrification of the grades between the Susquehanna, Schuylkill and Delaware River valleys and our eastern terminals.

The project as now announced covers the passenger and freight service on 325 miles of line and 1300 miles of track, beginning at Hell Gate Bridge, New York, where connection is made with New England, and extending west and south to Wilmington, west from Philadelphia on the Main Line in the direction of Harrisburg as far as Atglen, Pa., and the low-grade freight lines which join at Columbia, Pa., and connect the cities of New York, Philadelphia and Wilmington with the West.

This electrification will far exceed in magnitude and in importance that of any other railroad in the world, in miles of track to be electrified, in volume and density of passenger and freight business handled, in size and amount of equipment required, in the number of trains affected, and in terminal operations involved. The project will be undertaken progressively in sections and extend over a period of years.

It is estimated that the cost of this electrification will be approximately $100,000,000, to be spent, however, during the next seven or eight years at the rate of about $15,000,000 per year; 60 per cent of the total being for catenary, transmission line and substation construction, and 40 per cent for rolling stock. This will be a normal percentage of Pennsylvania Railroad improvement expenditures, which have been averaging $70,000,000 a year; a reasonable portion of which has always been provided out of surplus earnings. These proposed capital expenditures for electrification will make unnecessary certain other capital expenditures on this section of the railroad which would have to be made unless electrification is carried out.

The authorization of the Board of Directors to inaugurate this work follows exhaustive studies of the whole industrial and transportation situations in the eastern part of the country, including the terminal developments already under way or projected for Philadelphia and Newark. While this analysis was worked out in detail on the basis of the traffic estimated for the year 1935, the probability was not lost sight of that by 1950 the metropolitan area around New York would extend to New Brunswick on the west and well out on Long Island on the east and contain 30,000,000 people, and that there would be similar development in other cities.

The system adopted will be such that it will, by the simple addition of increased power and increased rolling stock, handle a movement of any magnitude which it is possible to handle over the existing tracks and at such speed, within the bounds necessary for safe operation, as the demands of the traffic may require from time to time.

Reasons for Electrification

The immediate factors which influenced the decision to proceed with electrification at this time were as follows:

1. The greater economy of electric traction as compared to steam operation in dense traffic territories;

2. The growth of the southern passenger business;

3. The increasing density of both freight and passenger business on our eastern lines and the probability that in the future more rapid movement would be required;

4. The desirability of utilizing the advantages of electric traction in connection with the construction of our new passenger terminals at Philadelphia and Newark;

5. The desirability of building a locomotive that would meet the requirements from the standpoint of weight of train, speed, and reliability that we believe will have to be met in this territory in the next twenty years;

6. The probability that the project, if started now, could be completed with a less total expenditure, all matters considered, than if started at a later date.

Among the more important details of construction and operation which are involved in this project are the following, which are of possible interest to the public:

Locomotives and Motor Cars

We intend to use the alternating-current single-phase system of electric traction, similar to that now in use in our Philadelphia suburban service, because we believe it the best adapted for heavy-traction trunk-line service. Our engineers studied this system abroad a number of years ago, and in anticipation of the future we have been working on its development ever since. It is now used extensively in Germany, Switzerland and Sweden, and in this country on the New Haven, Norfolk & Western, and Virginian Railways.

In suburban service we will use multiple-unit cars similar to those in the subways of New York and Philadelphia and those at present in use on our Philadelphia suburban lines, because they are more desirable from the standpoint of rapid transit on runs where frequent stops must be made.

The through freight and passenger service will be handled by electric locomotives because they handle that kind of service best.

With the assistance of the electric companies we have developed three types of electric locomotives which when used singly or in multiples as required will provide any power demanded by size, weight of trains, or speed. They are so designed as to permit the maximum interchangeability of parts, the minimum cost of maintenance, and the simplest and most direct methods of manufacture.

By the method of operation proposed we expect eventually to reduce the number of freight trains 50 per cent for a given car movement and increase the speed to any reasonable extent required. This of itself provides for a 100 per cent increase in capacity in so far as freight movement is concerned.

In the case of passenger trains, we expect to eliminate all double heading and most, if not all, of the second sections of trains and avoid the possibility of rough handling due to limited starting capacity, all of which make for greater comfort, better service, and increased capacity of the line.

The rest of the details are relatively minor and, while they have been fully worked out, are more or less subject to change dependent on the developments of the art between now and the time each expenditure is made.

Principal Facts About Pennsylvania Railroad Electrification Between New York and Wilmington, Del., and from Philadelphia to Columbia and Atglen, Pa.

Miles of railroad to be electrified	325
Miles of track to be electrified	1300
Electric locomotives required for new electrified operation:	
Passenger	165
Freight	200
Total new electric locomotives required	365
Electric locomotives now in operation	84
Number of passenger trains:	
To be operated by electric locomotives	318
To be operated as multiple unit trains	218
Estimated cost to complete program	$100,000,000

Estimated time to complete program	6 to 7 years
Saving in number of freight trains operated	Approximately 50%
Size of freight trains to be operated	125 cars
Speed of freight trains under electrified operation	25 m.p.h.
Miles of railroad already electrified (Includes 140 miles L.I.R.R.)	333
Miles of track already electrified (Includes 418 miles L.I.R.R.)	960
Total P.R.R. line mileage which will be operated electrically on completion of new program	658
Total P.R.R. track mileage to be operated on completion of new program	2260

APPENDIX C

PART II

ELECTRIFICATION OF THE READING RAILROAD

Announcement by A. T. DICE, *President, on Nov.* 12, 1928

The Board of Directors of Reading Company has approved plans for the electrification of a major portion of the Reading Railway System in the metropolitan district of Philadelphia for the operation initially of most of the suburban trains in this area.

The following lines will be electrified: Reading Terminal to Lansdale; Glenside to Hatboro; Jenkintown to Langhorne, and the Chestnut Hill Branch. This includes the electrification of all four main tracks between Reading Terminal and Wayne Junction, and of the two tracks from Wayne Junction to Lansdale, Langhorne and Chestnut Hill.

It has been decided to use single-phase alternating current at 11,000 volts for propulsion of trains. Overhead trolley wires will be installed and the pantograph type of current collector will be used on cars and locomotives. This wiring will require steel bridges at intervals of about 300 ft. throughout the area of electrification. Active progress is now being made on the extensive detailed plans required. The erection of the catenary overhead wiring will be the first physical work undertaken, and it is planned to begin construction at outlying points. The work will then proceed toward the more congested part of the railroad system. The railroad will build a number of substations at various points for the most effective and reliable distribution of power to all parts of the system.

Type of Coaches

One hundred multiple-unit coaches of the most modern design will be placed in service, releasing 35 steam locomotives now in use and also 120 steam coaches, which will be diverted to service at other points on the system. These cars may be operated separately or combined as trains from one to ten cars each. These coaches will be propelled by their own motors, and trains will be capable of speeds as high as 70 miles per hour, which will be independent of the number of cars operated as one train. They will also be able to accelerate to full speed in very much shorter time than the present steam trains, and will maintain high speeds on heavy grades as well as on level track. It will thus be possible to maintain considerably higher average speed throughout all portions of the runs.

Probably the most important phase of the electrification to be called to the attention of the residents of this territory is the increase in frequency of service as well as speeding up of all trains in this territory. This service will give the cities and towns an average of approximately 25 per cent increase in daily train service with a 20 to 25 per cent saving in time to and from Reading Terminal. The new arrangement will provide express service to the outlying territory throughout the day, instead of providing only local trains at certain times, as at present. Better connections at junction points with through trains will also be provided. All electric and steam trains will stop at the new North Broad Street Station, which will have underground connection with the Broad Street Subway.

Aid to Community Development

It is obvious that the modernizing of service will be of the utmost importance to the territory north and northeast of Philadelphia. It has been the universal experience that following electrification of a railroad bringing with it faster and more frequent service communities multiply and grow with astonishing rapidity. Enhancement of real estate values follows, and the elimination of smoke and noise permits the development of property for home building purposes adjacent to the tracks.

At Wayne Junction a large coach storage yard and electrical repair shop will be erected on the ground between Chestnut Hill and the Tabor branches, and immediately north of Wayne Junction Station, for which ground has already been purchased by the railroad company.

At Chestnut Hill the present station will be changed for electrical operation and facilities will be enlarged to provide a storage yard for a considerable number of the new electric motor cars. At a number of other points changes will be made in station and track facilities to aid in the operation of a high type of electric service.

Coincident with the electrification the company will install modern color light signals in the entire territory, which will replace the present semaphores and "banjo" signals. These signals will not only facilitate the movement of trains, but will provide the maximum of safety that modern railroad engineering has devised.

All the equipment will be designed specially for the Reading Company and include many features never before adopted in an electrification program of this magnitude.

The First Step in the Program

According to a previous announcement of the company, plans had been made for the electrification of the Chestnut Hill Branch as the first step in the program. The revised plans, however, will place this branch last due to the fact that negotiations between the city and the railroad for the elimination of grade crossings have not been consummated.

At the same time tentative plans are being made to include electrification on the Norristown Branch when the present grade crossing elimination program is completed throughout the Manayunk section. Moreover, the plans in all sections are being developed in such a way that it will be possible to extend the service without altering the initial installation, to include through passenger and freight electrification at such time as the railroad company shall find this extension of electrification justifiable.

The total cost of the electrification program will be approximately $20,000,000. Three years will be required to complete the work.

APPENDIX C

PART III

SOME PHASES OF THE RAILROAD SITUATION

Extract from an address by P. E. CROWLEY, *President, New York Central Lines, at the Annual Dinner of The Electric Association, Chicago, Nov.* 15, 1928

While all industry is struggling with the complex questions inevitably raised by modern conditions, the one with which I am most familiar and upon which I am best qualified to speak—the railroad industry—has had and now has grave questions confronting it which call for wise solution, but which can only be solved by an understanding of those questions by those whose business is with the railroad, although not of it, and whose interests lie not only in the successful development of their own business, but in the successful maintenance and the intelligent growth of an adequate and efficient transportation system.

The fundamental need of all industry is money. With the enormous expansion that has been going on in the last decade, that need to the railroads is becoming greater. It is greater because of the enormous expenditure necessary to keep the railroads in proper condition to do the business that is offered them; to make the improvements that are necessary; to improve the state of the art and keep the standards of service so high that the public—that is, the railroads' customers—will be satisfied. To many people the railroads are to a large extent a matter of course. Their interest in them is manifested only in their desire and expectation of fast, reliable and frequent service, both freight and passenger. To meet these demands and needs, the railroads of the country have, since 1920, invested over five billions of new capital in improvements and additions. This has been done during a time when railroad freight rates, which were never high in this country, were in many instances decreasing, and when passenger rates were stabilized at a fixed level. When it is considered that while these vast amounts of money were being invested, freight rates were being decreased, passenger rates were remaining stationary, railroad wages were being pushed to higher levels, railroad materials, supplies and taxes were costing more and railroad expenses as a whole were greater, the achievement, I think, is phenomenal. The question is, can it be kept up under present conditions; and, if not, what can be done to enable this great industry to continue to furnish even more effective service in the future than it has in the past.

Enlarged passenger terminals, new and larger passenger stations, are desired by the public. Widespread demand exists for the elimination of railroad crossings, perhaps the most expensive proposition with which the railroads are confronted. The business of the country requires the enlargement of freight terminals, additional tracks and modern and efficient equipment. In the aggregate it is conservatively estimated that the capital needs of the American railroads are close to a billion dollars a year.

Revenue Increase Is Problem

The railroads have no special road to the acquisition of money. They obtain it in one of three ways: by borrowing or by selling stock, or by revenues from operations. If the revenues from operation after the payment of expenses, do not yield support for their credit, with a safe margin, this money is difficult to obtain, or at least conditions are onerous. In any case, the obligations become greater and the charges on that account increase. The economic need of the railroads is to increase their revenues, and how to do that in the face of the many difficult situations confronting them is the problem in which all of you gentlemen are as interested as are we of the railway industry.

. . . .

I have the greatest faith in the future of our railroads and in their success, but that future and that success are becoming more and more dependent upon full and frank cooperation between the people who use the railroads on the one hand and the railroads themselves on the other. I think the railroads have done, and are doing, their part; but, single-handed, they cannot accomplish the results which would be beneficial to all concerned.

I am taking advantage of the opportunity to talk to this gathering frankly; to ask if it is not possible, in your judgment, for fuller cooperation to be had on this major problem. A great step forward was made some years ago when the regional advisory boards, composed of representatives of the railroads and of users of the railroads, were organized, and much good has been accomplished in the improvement of service by the frank discussions that have taken place in those bodies. But much more remains to be done and if we are to continue to furnish the present service, or better service, if we are to continue to maintain our properties at the standard required by present day conditions, if we are to continue to make such improvements and additions as the growth of the country and the growth of business warrants and demands, then, it seems to me, the time has arrived when we should all act together, because in the ultimate result our interests are the same.

. . . .

It would not be fair for me to omit to mention another field of service in which the electrical industry fills an important sphere. That is the service by electricity in transportation. It is true that this began to be supplied many years ago in places where other means of transportation were unsatisfactory.

Take, for instance, the electrification of the trolleys in the cities. The horse had to go. It was a nuisance upon the streets. The success of electricity there and on subsequently developed interurban lines permitted the development of electric apparatus, I believe, to the point where it was suitable for the increased weights and speeds of steam railway equipment and traffic, in such places as the Baltimore and other tunnels and underground construction, where the smoke and steam of locomotives was objectionable and limited the operation as well as the service to patrons.

A Pioneer Venture

As long ago as 1899 the New York Central began to study the method of operation in and out of Grand Central Terminal, in New York, the approach to which is through a tunnel over two miles long, with an additional three miles upon an elevated structure through city streets fronted by dwellings and business buildings. It was a pioneer venture in respect of operation on the scale that had to be undertaken owing to the fact that it was not feasible to change power upon trains until the limits of New York were passed. With the aid of State Legislation, the cooperation of the state and municipal authorities and of the electrical industry, a wise plan was made and the operation has been successful, particularly from the standpoint of developing the suburban traffic, which, carried at the lowest rates afforded such traffic, so far as my knowledge pertains, in this country, is continually growing and making increased demands upon our facilities. While we do not separate our net returns from this traffic, owing to the fact that it is interwoven with long distance traffic which also comes in over the same line and to the same terminal, we can with confidence state that there is no available method by which the conditions and patronage could be satisfied with steam operation. For this solution of our problem and for its continued success, particularly from the operating standpoint, I wish to make grateful acknowledgment to the electric industry.

For many years the traffic via the Michigan Central Railroad operated by ferry across the Detroit River. This was, however, unsatisfactory, particularly in seasons when ice and fog interfered with schedules and comfort. By the construction of a tunnel under the river the railroad was made continuous; but it would have been out of the question, in my belief, to have a satisfactory result from this tunnel operation without the availability of electric power. This construction and operation has placed the service via the Michigan Central on a plane previously unknown and has increased its capacity and the satisfaction of its patrons.

We are just entering into a third major installation of electric power upon the New York Central Lines—this time in and about Cleveland. As in Detroit, the work is being done in connection with a passenger station development, which involves considerable underground operation and which, I believe, specially invites the use of electricity. On the other hand, in the new passenger terminal now nearing completion in Buffalo and in the proposed Union Station at Cincinnati there is no immediate need for electrification, as the trains will be operated entirely in the open. In other words, gentlemen, Cincinnati presents one problem, New York another and Chicago still another. Each differs from the others, as may be said of almost every city on our system. Each has problems of its own, and the local situation must be studied most carefully to develop the lines along which we should move to best serve each particular community, and not with the thought that what has been done in New York, or anywhere else, is the right thing to do at any other place. Take this great city of Chicago, where we are meeting this evening; a prime essential of the operating problem of the many railroads that enter here is the expedited interchange of freight between them. At no other point in the world is there interchange quite comparable to this. It is a problem, unique in itself. The Chicago situation must be settled and we are now engaged in studying it; and it will be solved if the railroads and the various local public bodies cooperate with the thought of arriving at a conclusion that will best serve the interests of the city and its railroads.

Experimenting with Types of Motive Power

We are also experimenting with self-contained electric types of motive power which can operate either from wayside current, or where such is not available, by electricity which is produced by a Diesel power plant on the locomotive itself. We hope these experiments will result in the availability of a satisfactory unit of power, economically reasonable in cost and obsolescence as well as operation and maintenance, with which to meet the requirements which may develop from time to time in this general field of operation, particularly industrial switching, within congested municipal limits.

We have additional experiments in progress with advanced types of steam motive power for various fields of operation so that we may obtain first hand knowledge of their relative merits and availability and economic value for our diversified service, geographical and traffic conditions.

We of the railroad industry are keenly alert as to what you gentlemen of the electrical age here in America are doing—to your brilliant and your constant progress. If we were not watching you keenly, we would hardly be worth our posts of stewardship. We are almost if not quite as interested as you in the progress of your industry, nowhere more so than in its infinitely varied and helpful relationship to the rail transport industry upon this continent—a relationship in which both industries have prospered for some years past and in which they both should continue to prosper for many years to come.

APPENDICES

1. Certified Accounts, Surplus Account, Statement of Income and Expenses of National Electric Light Association for Administrative Year Ended June 30, 1929 and List of Securities
2. Registration of Attendance at the Fifty-second Convention
3. Constitution of the National Electric Light Association
4. Organization Personnel
5. List of Member Companies
6. Presidents and Honorary Members of the Association
7. Conventions of the Association
8. Numbering of Proceedings

APPENDIX 1

CERTIFIED ACCOUNTS

NATIONAL ELECTRIC LIGHT ASSOCIATION

BALANCE SHEET, JUNE 30, 1929

ASSETS

FURNITURE AND FIXTURES	$59,837.92	
Less—Depreciation reserve	18,417.23	
		$41,420.69
INVENTORY OF PUBLICATION PAPER STOCK		2,406.75
INVESTMENT SECURITIES, AT COST		456,474.25
ACCOUNTS RECEIVABLE:		
Publications' sales accounts	$4,640.04	
Interest	5,476.18	
Miscellaneous accounts	13,707.91	
		23,824.13
CASH IN BANK OR ON HAND:		
Time certificates of deposit—Fidelity-Union Trust Co	$313,394.86	
Time certificates of deposit—Bankers Trust Co	475,000.00	
Checking account—Bankers Trust Co	10,016.32	
Cashiers' account—Bankers Trust Co	500.00	
Office cash	3,000.00	
		801,911.18
ADVANCES FOR TRAVELING EXPENSES		5,181.50
		$1,331,218.51

LIABILITIES

ACCOUNTS PAYABLE:		
Vouchers payable	$53,156.43	
Accrued expenses	79,946.23	
		$133,102.66
PREPAID DUES:		
For six months ending December 31, 1929	$757,008.55	
For subsequent years	77.00	
		757,085.55
UNADJUSTED CREDITS:		
Unapplied miscellaneous receipts		456.50
JOINT RESEARCH FUND		5,412.48
INDUSTRIAL HEATING COMMITTEE, STEEL TREATING EXPOSITION		400.00
RESERVE FOR CONTINGENT CONTRIBUTIONS		100,000.00
SURPLUS, PER ACCOMPANYING STATEMENT		334,761.32
		$1,331,218.51

We have audited the books and accounts of the National Electric Light Association for the fiscal year ending June 30, 1929, and we certify that, in our opinion, the above balance sheet and accompanying statements of income and expenses and of surplus are correctly prepared therefrom and fairly set forth the financial position of the Association at June 30, 1929, and the results of operations for the year.

PRICE, WATERHOUSE & CO.

56 Pine Street,
New York.
September 13, 1929.

NATIONAL ELECTRIC LIGHT ASSOCIATION

Statement of Income and Expenses

for the Fiscal Year Ending June 30, 1929

Income

Dues:		
Class "A" members	$1,153,274.02	
Class "B" members	44,488.03	
Class "C" members	532,50	
Class "D" members	118,594.30	
Class "E" members	9,072.00	
Class "F" members	8,228.34	
Class "G" members	2,280.50	
Class "H" members	2,510.00	
Class "I" members	310.00	
		$1,339,289.69
Gross Proceeds from Publications and Miscellaneous Sales		77,056.90
Miscellaneous Income:		
Interest on bank balances	$21,959.18	
Interest and dividends from securities owned	17,832.34	
		39,791.52
		$1,456,138.11

Expenses

Headquarters Running Expenses:		
Salaries, wages and pension	$340,155.35	
Rent, electric light and power	55,258.31	
Postage, telephone, telegrams and messenger	21,942.63	
Printing, stationery and office supplies	16,918.68	
Traveling and incidentals	50,524.63	
Newspaper clipping service	55.15	
Insurance	6,992.44	
Subscriptions to periodicals	4,382.53	
Miscellaneous	8,103.20	
Depreciation of furniture and fixtures	3,727.11	
		$508,060.03
Publications Cost		192,479.67
Talking Motion Picture		35,817.00
Geographic Division		271,213.04
National Sections:		
Accounting	$194.69	
Commercial	22,062.22	
Public relations	785.47	
Engineering	44,093.14	
		67,135.52
National Committees		869.89
Farm Electrification Activities		88,009.53
Advertising Copy Service		10,115.04
Inductive Coordination Activities		63,937.46
Convention and Exhibition		41,806.43
Dues Paid to Other Organizations		12,423.00
Federal Trade Investigation		12,827.92
Joint Committee of National Utility Associations		30,000.00
Provision for Contingent Contributions		100,000.00
Excess of Income Over Expenses for the Year Carried to Surplus Account		21,443.58
		$1,456,138.11

NATIONAL ELECTRIC LIGHT ASSOCIATION

SECURITIES ACCOUNT, JUNE 30, 1929

	MATURITY DATE	INTEREST RATE	PAR VALUE	COST
U. S. LIBERTY BONDS:				
First	1932–47	4¼%	$550.00	$550.00
Fourth	1933–38	4¼%	5,150.00	5,150.00
			$5,700.00	$5,700.00
PUBLIC UTILITY BONDS:				
New York & Queens Elec. Lt. & Pr. Co.	1930	5%	$5,000.00	$5,050.00
Minneapolis General Elec. Co.	1934	5%	5,000.00	4,920.00
Northern States Power Co.	1941	5%	5,000.00	5,041.25
Portland Railway Lt. & Pr. Co.	1942	5%	5,000.00	4,370.00
Commonwealth Edison Co.	1943	5%	5,000.00	5,143.75
Southwestern Pr. and Lt. Co.	1943	5%	20,000.00	19,690.00
Utah Lt. & Traction Co.	1944	5%	5,000.00	4,550.00
Utah Power & Light Co.	1944	5%	20,000.00	20,048.75
West Penn Power Co.	1946	5%	5,000.00	4,787.50
Great Western Power Co.	1946	5%	20,000.00	20,535.00
Tennessee Electric Power Co.	1947	6%	6,000.00	5,775.00
San Diego Consolidated Gas & Elec. Co.	1947	5%	5,000.00	5,087.50
New York Gas & Elec. Lt., Ht. & Pr. Co.	1949	4%	2,000.00	1,613.00
Penn Ohio Edison Co.	1950	6%	10,000.00	10,041.25
Ohio River Edison Co.	1951	5%	20,000.00	19,905.00
Louisville Gas & Electric Co.	1952	5%	5,000.00	5,016.25
Cities Service Pr. & Lt. Corp.	1952	5½%	5,000.00	4,925.00
Florida Power & Light Co.	1954	5%	10,000.00	9,607.50
Indiana & Michigan Electric Co.	1955	5%	20,000.00	20,440.00
Tennessee Electric Power Co.	1956	5%	5,000.00	4,910.00
Texas Power & Light Co.	1956	5%	10,000.00	9,857.50
Appalachian Electric Pr. Co.	1956	5%	10,000.00	9,895.00
Carolina Power & Light Co.	1956	5%	10,000.00	9,900.00
Continental Gas & Electric Corp.	1958	5%	5,000.00	4,762.50
Delaware Electric Power Co.	1959	5½%	20,000.00	19,277.50
Public Service Elec. & Gas Co.	1965	5%	20,000.00	19,800.00
Georgia Power Co.	1967	5%	10,000.00	9,800.00
Public Service Elec. & Gas Co.	1967	4½%	20,000.00	19,975.00
New York Power & Light Corp.	1967	4½%	10,000.00	9,512.50
Alabama Power Co.	1967	4½%	10,000.00	9,520.00
Cincinnati Gas & Elec. Company	1968	4%	5,000.00	4,553.75
Penn Central Light & Power Co.	1977	4½%	10,000.00	9,600.00
American Power & Light Co.	2016	6%	20,000.00	21,162.50
Southeastern Power & Light Co.	2025	6%	20,000.00	20,730.00
Lehigh Power Securities Corp.	2026	6%	20,000.00	20,661.25
American Gas & Electric Co.	2028	5%	5,000.00	5,010.00
			$388,000.00	$385,474.25
STOCK:				
The United Corporation 1,000 shares ($3.00) Preferred Stock.			No Par	$43,400.00
Consolidated Gas Co. 386 Shares ($3.00) Common Stock			No Par	21,900.00
193 Shares ($5.00) Preferred Stock			No Par	
				$65,300.00
TOTAL COST				$456,474.25

APPENDIX 2

NATIONAL ELECTRIC LIGHT ASSOCIATION

REGISTRATION OF ATTENDANCE AT THE FIFTY-SECOND CONVENTION AND EXHIBITION, ATLANTIC CITY, N. J.
CONVENTION AND EXHIBITION, JUNE 3RD TO 7TH (INCLUSIVE), 1929

STATES AND DIVISIONS	CLASS OF MEMBERS										GUESTS			Total Members and Guests
	A	B	C	D	E	F	G	H	I	Total Members	Ladies	Men	Total Guests	
New Jersey	6	827	....	13	155	7	36	....	....	1044	981	343	1324	2368
New York	54	848	4	78	651	43	108	....	4	1790	1045	512	1557	3347
Pennsylvania	33	1031	2	36	470	19	80	....	1	1672	1145	357	1502	3174
EASTERN DIVISION	93	2706	6	127	1276	69	224	....	5	4506	3171	1212	4383	8889
Kentucky	5	10	....	1	3	....	....	....	....	19	4	....	4	23
Ohio	14	96	....	29	208	9	11	....	....	367	120	35	155	522
West Virginia	4	30	....	3	8	....	....	....	....	45	25	3	28	73
EAST CENTRAL DIVISION	23	136	....	33	219	9	11	....	....	431	149	38	187	618
Illinois	20	162	....	21	145	11	18	....	....	377	121	36	157	534
Indiana	10	25	....	5	19	....	....	....	....	59	14	9	23	82
Michigan	6	51	....	16	73	3	9	....	....	158	58	21	79	237
Wisconsin	4	8	....	7	22	....	....	....	....	41	9	7	16	57
GREAT LAKES DIVISION	40	246	....	49	259	14	27	....	....	635	202	73	275	910
Delaware	1	31	....	....	....	2	4	....	....	38	28	5	33	71
District of Columbia	1	27	....	....	18	2	3	....	....	51	28	21	49	100
Maryland	4	80	....	2	32	1	6	....	....	125	56	22	78	203
Virginia	2	32	....	1	12	2	2	....	....	51	15	....	15	66
MIDDLE ATLANTIC DIVISION	8	170	....	3	62	7	15	....	....	265	127	48	175	440
Iowa	8	15	....	3	9	....	....	....	....	35	9	9	18	53
Kansas	5	11	....	....	....	....	....	....	....	16	5	3	8	24
Missouri	9	33	....	9	40	2	2	....	....	95	39	1	40	135
Nebraska	5	10	....	1	3	....	....	....	....	19	2	1	3	22
MIDDLE WEST DIVISION	27	69	....	13	52	2	2	....	....	165	55	14	69	234
Connecticut	10	39	....	14	86	3	3	....	....	155	39	11	50	205
Maine	4	9	....	1	5	....	....	....	....	19	1	1	2	21
Massachusetts	43	138	....	12	100	8	18	....	....	319	88	20	108	427
New Hampshire	3	3	....	....	3	....	....	....	....	9	7	2	9	18
Rhode Island	3	15	....	....	1	....	....	....	....	19	4	2	6	25
Vermont	7	4	....	....	....	....	....	....	....	11	1	....	1	12
NEW ENGLAND DIVISION	70	208	....	27	195	11	21	....	....	532	140	36	176	708
Minnesota	5	18	....	5	14	3	3	....	....	48	9	1	10	58
North Dakota	....	....	....	....	....	....	....	....	....	....	....	1	1	1
South Dakota	1	2	....	....	....	....	....	....	....	3	....	....	....	3
NORTH CENTRAL DIVISION	6	20	....	5	14	3	3	....	....	51	9	2	11	62
Alaska	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Idaho	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Montana	1	1	....	....	....	....	....	....	....	2	....	....	....	2
Oregon	4	5	....	....	....	....	....	....	....	9	4	....	4	13
Utah	1	1	....	....	....	....	....	....	....	2	....	....	....	2
Washington	2	8	....	....	3	....	....	....	....	13	1	....	1	14
NORTHWEST DIVISION	8	15	....	....	3	....	....	....	....	26	5	....	5	31

APPENDIX 2—(*Continued*)

STATES AND DIVISIONS	CLASS OF MEMBERS										GUESTS			Total Members and Guests
	A	B	C	D	E	F	G	H	I	Total Members	Ladies	Men	Total Guests	
Arizona	1	2	....	....	....	....	....	....	....	3	1	....	1	4
California	6	16	....	2	8	2	3	....	....	37	11	3	14	51
Hawaii	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Nevada	1	1	....	....	....	....	....	....	....	2	....	....	....	2
Philippine Islands	....	....	....	....	....	....	....	....	....	....	....	....	....	....
PACIFIC COAST DIVISION	8	19	....	2	8	2	3	....	....	42	12	3	15	57
Colorado	3	12	....	....	1	....	....	....	....	16	3	1	4	20
New Mexico	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Wyoming	....	....	....	....	....	....	....	....	....	....	....	....	....	....
ROCKY MOUNTAIN DIVISION	3	12	....	....	1	....	....	....	....	16	3	1	4	20
Alabama	2	12	....	1	6	....	....	....	....	21	7	1	8	29
Cuba	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Florida	4	8	....	....	....	....	....	....	....	12	2	2	4	16
Georgia	4	34	1	....	15	2	2	....	....	58	10	4	14	72
North Carolina	5	17	....	....	1	....	....	....	....	23	....	1	1	24
South Carolina	1	4	....	....	....	....	....	....	....	5	....	....	....	5
Tennessee	7	21	....	....	1	....	....	....	....	29	8	1	9	38
Porto Rico	....	....	....	....	....	....	....	....	....	....	....	....	....	....
SOUTHEASTERN DIVISION	23	96	1	1	23	2	2	....	....	148	27	9	36	184
Arkansas	2	3	....	....	....	....	....	....	....	5	1	1	2	7
Louisiana	5	9	....	....	....	....	....	....	....	14	2	1	3	17
Mississippi	2	5	....	....	....	....	....	....	....	7	1	....	1	8
Oklahoma	3	9	....	....	....	....	....	....	....	12	3	2	5	17
Texas	10	30	....	....	10	....	1	....	....	51	9	4	13	64
SOUTHWESTERN DIVISION	22	56	....	....	10	....	1	....	....	89	16	8	24	113
CANADIAN DIVISION	8	24	....	6	15	4	1	....	....	58	14	12	26	84
Mexico	1	....	....	....	....	....	....	....	....	1	....	....	....	1
Central America	....	1	....	....	....	....	....	1	....	2	1	....	1	3
Australia	....	....	....	....	1	....	....	....	2	3	1	2	3	6
Japan	....	....	....	....	1	....	....	2	4	7	1	1	2	9
Holland	....	....	....	....	....	....	....	1	....	1	....	....	....	1
Argentine	....	1	....	....	....	....	....	1	1	3	1	....	1	4
Chile	....	....	....	....	....	....	....	1	1	2	....	....	....	2
England	....	....	....	....	....	....	....	1	....	1	....	1	1	2
Switzerland	....	....	....	....	....	....	....	1	....	1	....	....	....	1
Uruguay	....	....	....	....	....	....	....	1	....	1	1	....	1	2
Brazil	....	....	....	....	....	....	....	....	1	1	3	1	4	5
France	....	....	....	....	....	....	....	....	....	....	....	2	2	2
Germany	....	....	....	....	....	....	....	....	....	....	....	1	1	1
FOREIGN COUNTRIES	1	2	....	....	2	....	....	9	9	23	8	8	16	39
GRAND TOTAL	340	3779	7	266	2139	123	310	9	14	6987	3938	1464	5402	12389

APPENDIX 3

CONSTITUTION
of the
NATIONAL ELECTRIC LIGHT ASSOCIATION

As amended and adopted at the Fifty-second Convention, Atlantic City, N. J., June 7, 1929

ARTICLE I—NAME

This Association shall be entitled the National Electric Light Association.

ARTICLE II—OBJECT

The object of this Association shall be to advance the art and science of the production, distribution and use of electrical energy for light, heat and power for public service.

In the furtherance of this object its activities shall be largely educational and for the fullest development of the electrical engineering arts and sciences in all their branches.

It shall not be engaged in business.

ARTICLE III—MEMBERSHIP

SECTION 1. Members shall be divided into ten classes—Central Station Company Members (Class A), Central Station Individual Members (Class B), Invited Members (Class C), Manufacturer Company Members (Class D), Manufacturer Individual Members (Class E), Associate Company Members (Class F), Associate Individual Members (Class G), Foreign Company Members (Class H), Foreign Individual Members (Class I), and Honorary Members.

SECTION 2. Class A members shall be regularly incorporated public service companies engaged in producing and supplying electrical energy for light, heat or power for public use. They shall be entitled, through their regularly accredited delegates, to attend all meetings of the Association, to vote and to hold any office.

SECTION 3. Class B members shall be officers or employees of Class A members, elected or continued from year to year with the written approval of the Class A members with which they are connected. They shall have the same privileges as Class A members, except the right to vote at the executive sessions of the Association.

SECTION 4. Class C members shall be officials of public service commissions, instructors, teachers or practitioners of engineering and related sciences or of other professions who are interested in the art of applied electricity. They may become or remain members only upon the invitation and approval of the National Executive Committee. They shall have the same privileges as Class B members, except the right to hold elective office.

SECTION 5. Class D members shall be companies or firms engaged in the manufacture of apparatus, machinery, equipment, supplies or material for the production or use of electrical energy. They shall be entitled, through their regularly accredited delegates, to attend all meetings of the Association, to vote and to hold offices not restricted by provisions of this Constitution to other classes (see Article V—Officers).

SECTION 6. Class E members shall be officers or employees of Class D members, elected or continued from year to year with the written approval of the Class D members with which they are connected. They shall have the same privileges as Class D members, except the right to vote at the executive sessions of the Association.

SECTION 7. Class F members shall be companies or firms of electrical wholesalers, contractors, dealers, electrical or mechanical engineers, publishers and associations—corporations or individuals—who are interested in advancing the use of electrical energy, and are not engaged in its production or distribution. They shall have the same privileges as Class D members, except the right to vote at executive sessions.

SECTION 8. Class G members shall be officers or employees of Class F members, elected or continued from year to year with the written approval of the Class F members with which they are connected. They shall have the same privileges as Class F members.

SECTION 9. Class H members shall be individuals or corporations not residents of the United States or of Canada, engaged in the central station industry, or interested in advancing the use of electrical energy, who shall ally themselves with this Association. They shall have the same privileges as Class A and Class D members, except the right to hold elective office or to vote at executive sessions.

SECTION 10. Class I members shall be officers or employees of Class H members, elected or continued from year to year with the written approval of the Class H members with which they are connected. They shall have the same privileges as Class H members.

SECTION 11. Honorary members shall be elected upon unanimous recommendation of the National Executive Committee and shall be approved by a two-thirds vote of the Association. They shall have the same privileges as Class A and Class D members, except the right to vote and to hold office.

SECTION 12. Individual members (Class B, Class C, Class E, Class G and Class I) may purchase, at member price, reports, proceedings, handbooks and other literature that may be published by the National Electric Light Association for general distribution.

ARTICLE IV—DUES

SECTION 1. The annual dues of Central Station Company Members (Class A) shall be based on the gross revenues from the sale (retail and otherwise) of electrical energy (Operating Revenue—Sales of Current) by the company during the preceding calendar year. The annual dues of a company with such revenue amounting to, but not in excess of, Fifty Thousand Dollars ($50,000), shall be at the rate of Fifty Cents (50c.) per thousand dollars of its Operating Revenue—Sales of Current. The minimum dues of any Class A member shall not be less than Ten Dollars ($10) per annum. The annual dues of a company having Operating Revenue—Sales of Current of over Fifty Thousand Dollars ($50,000) shall be one-twelfth of one per cent (1/12 of 1%) of such Operating Revenue—Sales of Current.

No syndicate, holding company or other corporation or association, controlling or managing central station companies, shall be eligible to membership as a Class A member, unless all of its controlled central station companies are Class A members of the Association in good standing, in which case such syndicate, holding company or other corporation or association may become a Class A member after being duly elected and upon payment of dues of Fifty Dollars ($50) per annum.

SECTION 2. The annual dues of Central Station Individual Members (Class B) shall be Three Dollars ($3).

SECTION 3. The annual dues of Invited Members (Class C) shall be fixed by the National Executive Committee and shall not exceed Five Dollars ($5).

SECTION 4. The annual dues of Manufacturer Company Members (Class D), manufacturing or selling apparatus, machinery, equipment, supplies or material for the production, distribution, consumption and translation of electrical energy to Class A and Class F members, or to corporations, firms or individuals eligible to Class A or Class F membership, shall be fixed annually by the National Executive Committee.

SECTION 5. The annual dues of Manufacturer Individual Members (Class E) shall be Three Dollars ($3).

SECTION 6. The annual dues of Associate Company Members (Class F) shall be based on the gross sales from the sale of electrical apparatus, equipment, appliances, publications or service by the company, firm or individual during the preceding calendar year. The rate of dues for Class F members shall be one one-hundredth of one per cent (1/100 of 1%) of such gross sales for such period. The minimum dues of any Class F member shall be Twenty-five Dollars ($25) per annum, which minimum dues apply only when the gross sales during the preceding calendar year were not greater than Two Hundred and Fifty Thousand Dollars ($250,000).

SECTION 7. The annual dues of Associate Individual Members (Class G) shall be Three Dollars ($3).

SECTION 8. The annual dues of Foreign Company Members (Class H) shall be Fifty Dollars ($50).

SECTION 9. The annual dues of Foreign Individual Members (Class I) shall be Five Dollars ($5).

SECTION 10. In the event that an applicant for Class A, Class D or Class F membership is elected after January 1, the dues for the remainder of the year, ending December 31, shall be pro-rated on a monthly basis.

SECTION 11. In the event that an applicant for Class B, Class E and Class G membership is elected after July 1, the dues for the remainder of the year shall be Two Dollars ($2), which will entitle the member to the *National Electric Light Association Bulletin* for the same period.

SECTION 12. Class A, Class D or Class F members who may elect to collect for the Association the dues of their Class B, Class E or Class G members upon an installment basis, may do so in accordance with a plan of payment approved by the National Executive Committee. In the event that a Class B, Class E or Class G member leaves the employ of the member company, the member company shall so notify the Association and shall be responsible only for the proportion of the dues of the member up to the date of such notice.

SECTION 13. The annual dues of the members of the National Electric Light Association residing or engaged in business in Canada, who are members of the Canadian Electrical Association, shall be fixed by the National Executive Committee.

SECTION 14. All dues, fixed and percentage, shall be paid directly to the Treasurer of the National Electric Light Association.

SECTION 15. All dues shall be payable in advance and shall cover the period of the calendar year. Any member in arrears for sixty (60) days shall be suspended from all privileges of membership, but may be reinstated when all outstanding dues have been paid.

SECTION 16. All dues of members (Class A, Class B, Class C, Class D, Class E, Class F, Class G, Class H and Class I) include subscription to the *National Electric Light Association Bulletin.*

ARTICLE V—OFFICERS

SECTION 1. The officers of this Association shall be a President, four Vice-Presidents, a Treasurer, a Managing Director and a Secretary.

SECTION 2. The President, four Vice-Presidents and Treasurer shall be elected from Class A or Class B members to serve one year from July 1, or until their successors shall have been elected. The President shall not be eligible for immediate reelection to the same office. The President shall preside at all meetings of the Association and of the National Executive Committee, and shall perform such other duties as may be provided for in this Constitution or by vote of the Association. In case of the absence, disability or death of the President, his office shall be filled by the Vice-Presidents, in the order of their seniority.

SECTION 3. The National Executive Committee shall consist of the President, the retiring president, the four Vice-Presidents, the Treasurer, the presiding officer or other duly accredited representative of each of the Geographic Divisions, the chairman of each of the National Sections, and eleven members at large, six of whom shall be chosen from Class A or B members, three from Class D or E members and two from Class F or G members, to be elected by Class A and D members at the annual convention. The eleven members at large shall each be elected to serve terms of three years (except the two F or G members, each of whom shall be elected for a term of one year), except at the first election, two Class A or B members shall be elected for one year, two Class A or B members for two years, and two Class A or B members for three years, and one Class D or E member for one year, one Class D or E member for two years and one Class D or E member for three years. The President of the Association shall act as Chairman of the National Executive Committee.

In case the presiding officer, or other duly accredited representative of a Geographic Division, or the chairman of a National Section, is unable to attend any meeting of the National Executive Committee, he may appoint a delegate to represent such Division or Section at such meeting.

SECTION 4. The National Executive Committee shall be the governing body of the Association, shall manage its affairs, and shall pass upon all applications for membership and upon the eligibility of representatives, subject to this Constitution and such special rules or regulations as may be adopted by the Association from time to time. Seven members of the National Executive Committee shall constitute a quorum.

SECTION 5. The Treasurer shall perform the duties assigned to him by the National Executive Committee, subject to its approval. He shall give a security bond in such sum and with such qualifications as the National Executive Committee may from time to time prescribe.

SECTION 6. The Managing Director shall be appointed by the President, and his appointment confirmed by the National Executive Committee. He shall have charge of all the work of the Association, including the appointment and direction of a Headquarters staff under the general direction of the President and National Executive Committee.

SECTION 7. The Secretary shall be appointed by the President and be confirmed by the National Executive Committee. He shall serve for one year from the first of the month next following the date of the President's election, or until his successor is appointed and confirmed. He may be a member of any class and shall be eligible for reappointment without limit, and shall perform such duties as the Managing Director may direct.

ARTICLE VI—ELECTION OF OFFICERS

SECTION 1. At the first meeting of the executive session of the annual convention there shall be chosen a Nominating Committee, to be composed of five accredited representatives from Central Station Company Members (Class A) in the following manner:

Any accredited representative of a Central Station Company Member (Class A) shall have the privilege of making nominations and, when such nominations are seconded by any other similarly accredited representative, that nominee shall be one of those to be voted for. Nominations in this manner may continue until a resolution shall be adopted to close the lists. After the lists are closed, a ballot shall then be taken. The accredited representative of any Central Station Company Member (Class A) shall have the right to vote for five of those placed in nomination in the manner described in this section. The five nominees receiving the highest number of votes shall constitute a Nominating Committee.

The Nominating Committee shall hold open meetings at times and places to be announced, and at these meetings any accredited representative of a Central Station Company Member (Class A) or a Manufacturer Company Member (Class D) may suggest nominees for any of the offices to be filled.

At a meeting of the executive session, the Nominating Committee shall bring in the names of those recommended by it for the several offices to be filled and an election shall be held.

The submission of names by the Nominating Committee shall not, however, debar any accredited representative of a Central Station Company Member (Class A) or a Manufacturer Company Member (Class D) from making nominations for any or all of the several offices to be filled. Such nominations, if seconded, shall be submitted for election at the same time and in the same manner as those of the Nominating Committee. Whenever there are more nominees than vacancies to be filled, the election shall be decided by ballot. When there is no contest for office, the secretary of the executive session may be instructed by a *viva voce* vote to cast the ballot for those recommended by the Nominating Committee.

SECTION 2. Vacancies in office may be filled by the National Executive Committee to cover unexpired terms.

ARTICLE VII—COMMITTEES

SECTION 1. The President shall appoint a Public Policy Committee, four members of which shall be selected by and from the Executive Committee of the Public Relations National Section, all subject to the approval of the National Executive Committee, and shall name such other committees as may seem to him desirable, subject to the approval of the National Executive Committee, and he shall appoint the members thereof.

SECTION 2. Unless otherwise provided, the terms of members of committees shall expire with the end of the month of June next following their appointment unless sooner terminated by the National Executive Committee.

ARTICLE VIII—NATIONAL SECTIONS

SECTION 1. The National Executive Committee may authorize the formation of National Sections, as it may deem necessary, for the consideration and treatment of certain subjects; shall define the names of such National Sections; shall specify their scope of operations, and shall approve, subject to the constitutional provisions herein, the Committee organization for each Section.

SECTION 2. There shall be a Public Relations National Section having an Executive Committee, and the membership of the Executive Committee of this Section shall be limited to executive officers of member companies. The President shall appoint four (4) members of the said Executive Committee to the Public Policy Committee, subject to the approval of the National Executive Committee and the Public Policy Committee. There shall also be an Accounting National Section, a Commercial National Section, and an Engineering National Section.

SECTION 3. Each National Section shall have an Executive Committee and such other committees as may be approved by the National Executive Committee.

SECTION 4. The Executive Committee of a National Section shall be the governing board of the Section.

SECTION 5. The Executive Committee of a National Section shall consist of a Chairman, the retiring Chairman, not more than six (6) members at large, the Chairmen of the other Committees of the Section, and the Chairmen of corresponding Sections of the Geographic Divisions. There may also be one or more Vice-Chairmen. The Chairman of each National Section shall be a member of the Executive Committee of each of the other National Sections.

SECTION 6. Each of the National Sections' Executive Committees shall appoint a Nominating Committee consisting of five (5) members, and the Chairman shall announce the names of the members so appointed at the first executive sessions of the annual meetings of the Sections. These Nominating Committees, at subsequent executive sessions of the Sections, shall submit the names of fifteen (15) members of the Association. The submission of names by the Nominating Committees shall not, however, debar any accredited representative of a Central Station Company Member (Class A) or a Manufacturer Company Member (Class D) from making nomination for any or all of the several offices to be filled. Such nomination, if seconded, shall be submitted with the fifteen (15) names presented by the Nominating Committee. From this list the President Elect shall select and appoint the Chairman, Vice-Chairmen and members at large of each National Section for the administrative year beginning July 1 next, as herein provided.

SECTION 7. The terms of office of the Chairman and Vice-Chairmen shall be one year each. The terms of office of the six (6) members at large shall be two years each, except, at the first appointment, three of such members shall be appointed for terms of one year and three for two years each. The officers and six members at large shall be eligible to immediate reappointment to the same offices.

SECTION 8. The Chairman of a National Section shall be the Chairman of the Section's Executive Committee and shall *ipso facto* become a member of the National Executive Committee. If he be unable to attend any meeting of the National Executive Committee, he may appoint a delegate to represent him, such delegate being a Class B or Class E member of the Association.

SECTION 9. Vacancies, exclusive of the Chairmen of the corresponding Sections of the Geographic Divisions, occurring in the Executive Committee of a National Section shall be filled by the President, subject to the approval of the Executive Committee.

SECTION 10. Except as prescribed in Section 2 of Article VIII, other Committees of a National Section shall consist of a Chairman and members at large appointed by the Chairmen of the Section, subject to the approval of the President, and the Chairmen of the corresponding Committees of the Geographic Divisions.

SECTION 11. The National Executive Committee may authorize a National Section to create, or continue, one or more special committees, the personnel of which may consist solely of members at large, who shall be appointed by the Section Chairman, subject to the approval of the President.

SECTION 12. Meetings of the Executive Committee of a National Section shall be held upon call of its Chairman; meetings of other committees of a National Section may be held upon call by their respective Chairmen subject to the approval of the Section Chairman.

SECTION 13. Not later than August 15th of each year, the Executive Committee of each National Section shall prepare and present, through its Chairman, to the President, a detailed budget of its estimated expenses for the year beginning July 1st, immediately preceding, and shall also file with the President a detailed statement of the actual expenses of the Section incurred during the preceding administrative year.

SECTION 14. The National Executive Committee, after consideration and approval of the budget of a National Section submitted to it by the President, shall, upon certification of the Chairman of the Section, authorize the Treasurer of the Association to pay the indebtedness incurred by the Section. The expenses of a National Section must be limited to the appropriations authorized by the National Executive Committee.

SECTION 15. The Constitutions of the Accounting National Section, the Commercial National Section, the Engineering National Section (prior to May 21, 1926, Technical National Section) and the Public Relations National Section are annulled, and the Constitution of the National Electric Light Association shall govern the organization and operations of any and all National Sections authorized bv the National Executive Committee.

SECTION 16. No person not a member of the National Electric Light Association shall be eligible to membership in any National Section of the Association.

ARTICLE IX—GEOGRAPHIC DIVISIONS

SECTION 1. A Geographic Division shall be a sectional organization embracing two or more adjacent states, which states shall be represented in the Division by state electrical central station associations or central station branches of state public utility associations, and where there are no such existing state organizations the membership of the National Electric Light Association within such state or states shall constitute the representation of the state or states within the Geographic Division.

SECTION 2. There shall be thirteen Geographic Divisions, designated and defined as follows:

Eastern—New Jersey, New York, Pennsylvania.
East Central—Kentucky, Ohio, West Virginia.
Great Lakes—Illinois, Indiana, Michigan, Wisconsin.
Middle Atlantic—Delaware, District of Columbia, Maryland, Virginia.
Middle West—Iowa, Kansas, Missouri, Nebraska.
New England—Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont.
North Central—Minnesota, North Dakota, South Dakota.
Northwest—Idaho, Montana, Oregon, Utah, Washington, Alaska.
Pacific Coast—Arizona, California, Nevada, Hawaii, Philippine Islands.
Rocky Mountain—Colorado, New Mexico, Wyoming.
Southeastern—Alabama, Cuba, Florida, Georgia, North Carolina, South Carolina, Tennessee, Porto Rico.
Southwest—Arkansas, Louisiana, Mississippi, Oklahoma, Texas.
Canadian—Canada; represented by the Canadian Electrical Association.

SECTION 3. The National Executive Committee may, on its own motion or upon the application of the Executive Committee of one or more adjacent Geographic Divisions, modify the boundaries of the territory of any of the thirteen Geographic Divisions or add to or subtract from the existing number of Geographic Divisions.

SECTION 4. The presiding officer, or other duly accredited representative, selected by and from the Executive Committee of each of the Geographic Divisions, shall represent the Division as a member of the National Executive Committee. Such presiding officer, or other duly accredited representative, shall be a Class A or Class B member of the Association.

SECTION 5. The form of organization of each Geographic Division shall be in conformity with the Constitution of the National Electric Light Association, subject to ratification by the National Executive Committee and subject to amendment by those members of the Geographic Division qualified to vote. All proposed changes in and amendments to the organization of a Geographic Division shall be submitted to the National Executive Committee for approval before adoption.

SECTION 6. Not later than August 15th each year the Executive Committee of each Geographic Division shall prepare and present to the National Executive Committee a detailed budget of the estimated expenses of its Geographic Division for the year beginning July 1st immediately preceding, and shall also file with the National Executive Committee a detailed statement of the actual expenses of its Geographic Division during the preceding administrative year.

SECTION 7. The National Executive Committee, after consideration and approval of the detailed budget submitted by a Geographic Division, shall authorize the Treasurer of the Association to pay to the proper officer of the Geographic Division an amount which, in the judgment of the National Executive Committee, is necessary to finance the Geographic Division properly, but the amount in no case shall exceed 50 per cent (50%) of the yearly dues received from Classes A [Class A dues, for this purpose, to be figured at the rate of one-fifteenth of one per cent (1/15 of 1%) where "Operating Revenue—Sales of Current" is over Fifty Thousand Dollars ($50,000)], B, E, F and G members of such Geographic Division.

The expenditures of a Geographic Division, in so far as the responsibility of the National Electric Light Association is concerned, must not exceed appropriations authorized by the National Executive Committee.

ARTICLE X—STATE ASSOCIATIONS

SECTION 1. State Associations may be organized as unit sections of the thirteen Geographic Divisions.

SECTION 2. The presiding officer, or other duly accredited representative, selected by and from the Executive Committee of a State Association, shall represent such State Association in its Geographic Division as a member of the Geographic Division's Executive Committee. Such presiding officer, or other duly accredited representative, shall be a Class A or Class B member of the National Electric Light Association.

SECTION 3. The form of organization of each State Association shall be in conformity with the Constitution of the National Electric Light Association.

ARTICLE XI—COMPANY SECTIONS

SECTION 1. Upon the application to it by any Class A member, having in its employ not less than ten Class B members, the National Executive Committee may authorize the organization of any or all of the officers and employees of said Class A member into a Company Section, club, or other similar organization, of the National Electric Light Association, the officers, executive committee and committee chairmen of which shall be elected from Class B membership.

SECTION 2. A Company Section, club or other similar organization may include as Limited Members those employees of Class A members who desire to participate in the local organization's activities, but who are not yet qualified for Class B membership. The dues from such Limited Members shall go into the local treasury.

ARTICLE XII—LOCAL CLUBS

SECTION 1. Upon the application to it by ten members of any class, the National Executive Committee may, with the approval of the State Association or Geographic Division concerned, authorize the formation of a local club, or other similar organization, to which all classes of Association members residing or engaged in business in such community shall be eligible to membership.

SECTION 2. The form of organization of each local club shall be in conformity with the Constitution of the National Electric Light Association.

ARTICLE XIII—MEETINGS

SECTION 1. An annual convention shall be held in May or June of each year, unless otherwise directed by the National Executive Committee, and in such places and on such dates as the National Executive Committee may designate.

SECTION 2. A member company shall not be permitted to entertain any convention of any national conference, but all expenses pertaining thereto shall be paid out of the treasury of the Association, subject to the approval of the National Executive Committee.

ARTICLE XIV—NATIONAL CONFERENCES

SECTION 1. Upon application to it of at least twenty members, the National Executive Committee may call a National Conference upon any designated subject or subjects affecting the industry as represented by the National Electric Light Association, due notice of which Conference shall be sent to each member of the Association.

SECTION 2. The expenses of National Conferences may be met by appropriations made by the National Executive Committee from the general funds of the Association or by special contribution.

ARTICLE XV—QUORUM

SECTION 1. Twenty members, of which not less than fifteen shall be Class A members of the Association, shall constitute a quorum for the transaction of business.

ARTICLE XVI—VOTING AND PROXIES

SECTION 1. A roll call shall be ordered on the demand of any ten Class A or Class D members on any question before the Association. Where it is not otherwise specified in this Constitution, the authorized delegates shall cast their votes by rising.

SECTION 2. Voting by proxy shall not be allowed at any meeting of the Association, or of any of its committees.

ARTICLE XVII—PARLIAMENTARY RULES

SECTION 1. Roberts' Rules of Order shall be the governing parliamentary law of the Association in all cases not definitely provided for by its Constitution or its own rules.

ARTICLE XVIII—EXHIBITIONS

SECTION 1. The National Executive Committee, upon application to it by one or more members of Class A, Class D or Class F, may authorize the holding of such exhibitions and of such contest at such times and places as it may designate and assign. Such exhibitions and such contests held under the auspices of the National Electric Light Association shall be governed by such rules and regulations as the National Executive Committee, or its delegates, shall prescribe and may be financially supported by the National Electric Light Association at the discretion of the National Executive Committee.

ARTICLE XIX—ASSOCIATION MAGAZINE

SECTION 1. The National Electric Light Association shall publish a monthly bulletin which shall be under the direction of the Managing Director, subject to the approval of the National Executive Committee as to the policy and scope thereof and the expenditures therefor. The annual subscription price of the *National Electric Light Association Bulletin* shall be Three Dollars ($3), and is included in the annual dues of all classes of members.

ARTICLE XX—PERMANENT OFFICE

SECTION 1. The permanent office of the Association shall be maintained in the City of New York, and shall be located, furnished and governed in such manner as the National Executive Committee may from time to time direct.

ARTICLE XXI—AMENDMENTS

SECTION 1. Amendments to this Constitution shall be offered in writing and shall be referred, before being acted upon, to a committee to be elected by the Association. A two-thirds vote of all Class A and D members present shall be necessary for their adoption.

APPENDIX 4

Organization Personnel

of the

National Electric Light Association

for the

Administrative Year
July 1, 1928—June 30, 1929

National Executive Committee

Officers

President, P S Arkwright, Georgia Power Co, Atlanta, Ga
Vice-President, M S Sloan, The New York Edison Co, New York, N Y
Vice-President, W A Jones, Henry L Doherty & Co, New York, N Y
Vice-President, J F Owens, Oklahoma Gas & Electric Co, Oklahoma City, Okla
Vice-President, Marshall E Sampsell, Central Illinois Public Service Co, Chicago, Ill
Treasurer, P S Young, Public Service Electric & Gas Co, Newark, N J
Managing Director, Paul S Clapp, National Electric Light Association, New York, N Y
Secretary, A Jackson Marshall, National Electric Light Association, New York, N Y

Members at Large

(Terms expiring June 30th, 1929)

H T Sands, *ex-officio,* Electric Bond & Share Co, New York, N Y
C L Collens, Reliance Electric & Manufacturing Co, Cleveland, Ohio
G E Cullinan, Graybar Electric Co, Inc, New York, N Y
E W Lloyd, Commonwealth Edison Co, Chicago, Ill
Harry Reid, National Electric Power Co, New York, N Y
James R Strong, Tucker Electrical Construction Co, New York, N Y

(Terms expiring June 30th, 1930)

D C Barnes, Stone & Webster, Inc, Boston, Mass
H P Liversidge, The Philadelphia Electric Co, Philadelphia, Pa
Gerard Swope, General Electric Co, New York, N Y

(Terms expiring June 30th, 1931)

John P Coghlan, Pacific Gas & Electric Co, San Francisco, Cal
H M Edwards, The New York Edison Co, New York, N Y
E M Herr, Westinghouse Electric & Manufacturing Co, New York, N Y

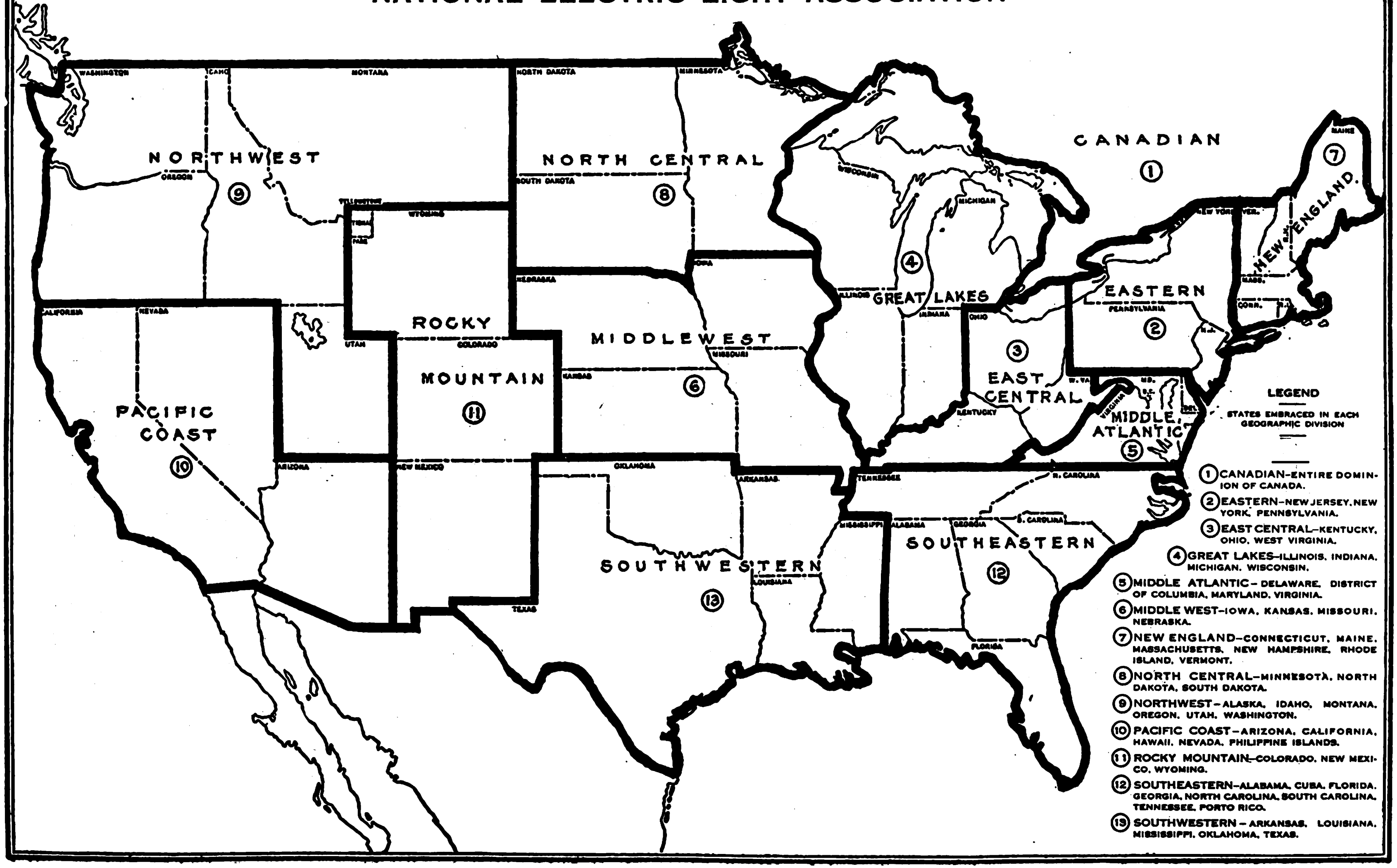
National Section Chairmen

Accounting—J F Ford, The Philadelphia Electric Co, Philadelphia, Pa
Commercial—Marshall E Sampsell, Central Illinois Public Service Co, Chicago, Ill
Engineering—E C Stone, Duquesne Light Co, Pittsburgh, Pa
Public Relations—J F Owens, Oklahoma Gas & Electric Co, Oklahoma City, Okla

Geographic Division Presidents

Canadian—P S Gregory, The Shawinigan Water & Power Co, Montreal, Can
Eastern—F R Phillips, Duquesne Light Co, Pittsburgh, Pa
East Central—C S MacCalla, Pennsylvania-Ohio Power & Light Co, Youngstown, Ohio
Great Lakes—J E Johnson, Illinois Power & Light Corp, Chicago, Ill
Middle West—Ralph T Smalley, Kansas Electric Power Co, Lawrence, Kans
New England—Irvin W Day, The Connecticut Light & Power Co, Waterbury, Conn
North Central—L M Pharis, Minnesota Power & Light Co, Duluth, Minn
Northwest—R M Boykin, Puget Sound Power & Light Co, Seattle, Wash
Pacific Coast—Paul M Downing, Pacific Gas & Electric Co, San Francisco, Cal
Rocky Mountain—Clare N Stannard, Public Service Co of Colorado, Denver, Colo
Southeastern—C A Collier, Georgia Power Co, Atlanta, Ga
Southwestern—J G Holtzclaw, Gulf States Utilities Co, Beaumont, Texas

GEOGRAPHIC DIVISIONS
OF THE
NATIONAL ELECTRIC LIGHT ASSOCIATION


CANADIAN ①
NEW ENGLAND ⑦
EASTERN ②
EAST CENTRAL ③
MIDDLE ATLANTIC ⑤
GREAT LAKES ④
NORTH CENTRAL ⑧
MIDDLEWEST ⑥
NORTHWEST ⑨
ROCKY MOUNTAIN ⑪
PACIFIC COAST ⑩
SOUTHWESTERN ⑬
SOUTHEASTERN ⑫
WASHINGTON
IDAHO
MONTANA
OREGON
WYOMING
UTAH
NEVADA
CALIFORNIA
COLORADO
ARIZONA
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
MINNESOTA
IOWA
MISSOURI
ARKANSAS
LOUISIANA
WISCONSIN
ILLINOIS
MICHIGAN
INDIANA
OHIO
KENTUCKY
TENNESSEE
MISSISSIPPI
ALABAMA
GEORGIA
FLORIDA
S. CAROLINA
N. CAROLINA
VIRGINIA
W. VA.
MD.
DEL.
PENNSYLVANIA
N.J.
NEW YORK
VER.
MASS.
CONN.
MAINE

LEGEND

STATES EMBRACED IN EACH GEOGRAPHIC DIVISION

① CANADIAN—ENTIRE DOMINION OF CANADA.
② EASTERN—NEW JERSEY, NEW YORK, PENNSYLVANIA.
③ EAST CENTRAL—KENTUCKY, OHIO, WEST VIRGINIA.
④ GREAT LAKES—ILLINOIS, INDIANA, MICHIGAN, WISCONSIN.
⑤ MIDDLE ATLANTIC—DELAWARE, DISTRICT OF COLUMBIA, MARYLAND, VIRGINIA.
⑥ MIDDLE WEST—IOWA, KANSAS, MISSOURI, NEBRASKA.
⑦ NEW ENGLAND—CONNECTICUT, MAINE, MASSACHUSETTS, NEW HAMPSHIRE, RHODE ISLAND, VERMONT.
⑧ NORTH CENTRAL—MINNESOTA, NORTH DAKOTA, SOUTH DAKOTA.
⑨ NORTHWEST—ALASKA, IDAHO, MONTANA, OREGON, UTAH, WASHINGTON.
⑩ PACIFIC COAST—ARIZONA, CALIFORNIA, HAWAII, NEVADA, PHILIPPINE ISLANDS.
⑪ ROCKY MOUNTAIN—COLORADO, NEW MEXICO, WYOMING.
⑫ SOUTHEASTERN—ALABAMA, CUBA, FLORIDA, GEORGIA, NORTH CAROLINA, SOUTH CAROLINA, TENNESSEE, PORTO RICO.
⑬ SOUTHWESTERN—ARKANSAS, LOUISIANA, MISSISSIPPI, OKLAHOMA, TEXAS.

Geographic Divisions

CANADIAN DIVISION

(Entire Dominion of Canada)

Canadian Electrical Association

President, P S Gregory, The Shawinigan Water & Power Co, Montreal, Can; *Secretary,* H M Lysier, Room 712, Power Bldg, Montreal, Can

(This Division Has No State [Provincial] Section)

* EASTERN DIVISION

(New Jersey, New York, Pennsylvania)

President, F R Phillips, Duquesne Light Co, Pittsburgh, Pa; *Managing Director,* A B Millar, Telegraph Bldg, Harrisburg, Pa

Empire State Gas and Electric Association

President, Charles S Ruffner, Mohawk-Hudson Power Corp, Albany, N Y; *Secretary,* Charles H B Chapin, 5618 Grand Central Terminal Bldg, New York, N Y

New Jersey Electric Association

President, C H Howell, Atlantic City Electric Co, Atlantic City, N J; *Secretary,* S F Delany, Atlantic City Electric Co, Atlantic City, N J

Pennsylvania Electric Association

President, F R Phillips, Duquesne Light Co, Pittsburgh, Pa; *Managing Director,* A B Millar, Telegraph Bldg, Harrisburg, Pa

EAST CENTRAL DIVISION

(Kentucky, Ohio, West Virginia)

President, C S MacCalla, Pennsylvania-Ohio Power & Light Co, Youngstown, Pa; *Secretary-Treasurer,* D L Gaskill, 603½ Broadway, Greenville, Ohio

Kentucky Association of Public Utilities

President, Samuel Riddle, Louisville Railway Co, Louisville, Ky; *Secretary,* E F Kelly, Louisville Railway Co, Louisville, Ky

Public Utilities Association of West Virginia

President, A C Spurr, Wheeling Traction Co, Wheeling, W Va; *Secretary,* A Bliss McCrum, Box 1483, Charleston, W Va

GREAT LAKES DIVISION

(Illinois, Indiana, Michigan, Wisconsin)

President, J E Johnson, Illinois Power & Light Corp, Chicago, Ill; *Secretary,* Tom C Polk, 910 Marquette Bldg, Chicago, Ill

Illinois State Electric Association

President, Julius L Hecht, Public Service Co of Northern Illinois, Chicago, Ill; *Secretary-Treasurer,* Tom C Polk, 910 Marquette Bldg, Chicago, Ill

Indiana Electric Light Association

President, Norman A Perry, Indianapolis Power & Light Co, Indianapolis, Ind; *Secretary-Treasurer,* William Stokes, 1548 Consolidated Building, Indianapolis, Ind

Michigan Electric Light Association

President, Howard Pett, Consumers Power Co, Jackson, Mich; *Secretary-Treasurer,* Herbert Sylvester, The Detroit Edison Co, Ann Arbor, Mich

Wisconsin Utilities Association

President, C R Phenicie, Wisconsin Public Service Corp, Green Bay, Wis; *Executive Secretary,* John N Cadby, Room 203, University Bldg, 432 Broadway, Milwaukee, Wis

* MIDDLE ATLANTIC DIVISION

(To Consist of Delaware, District of Columbia, Maryland, Virginia)

Maryland Utilities Association

President, H T Connolly, Washington, Baltimore & Annapolis Electric Railroad Co, Baltimore, Md; *Secretary,* D E Kinnear, United Railways & Electric Co, Baltimore, Md.

Public Utilities Association of Virginia

President, A W Higgins, Virginia Public Service Co, Charlottesville, Va; *Secretary,* A B Tunis, 301 East Grace Street, Richmond, Va

MIDDLE WEST DIVISION

(Iowa, Kansas, Missouri, Nebraska)

President, Ralph T Smalley, Kansas Electric Power Co, Lawrence, Kan; *Managing Director,* Thorne Browne, 1527 Sharp Bldg, Lincoln, Neb

Iowa Section

President, C S Macy, Iowa Power & Light Co, Adel, Iowa; *Secretary-Treasurer,* H E Weeks, Tri-City Railway & Light Co, Davenport, Iowa

Kansas Section

President, Frank M Stone, Kansas Utilities Co, Fort Scott, Kan; *Secretary,* H Lee Jones, Kansas Gas & Electric Co, Wichita, Kan

Missouri Association of Public Utilities

President, A E Reynolds, Springfield Gas & Electric Co, Springfield, Mo; *Secretary-Treasurer,* F D Beardslee, 315 N Twelfth St, St Louis, Mo

Nebraska Section

President, C W Amidon, Central Power Co, Grand Island, Neb; *Managing Director,* Thorne Browne, 1527 Sharp Bldg, Lincoln, Neb

NEW ENGLAND DIVISION

(Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont)

President Irvin W Day, The Connecticut Light & Power Co, Waterbury, Conn; *Secretary,* Miss O A Bursiel, Room 1113 Statler Bldg, 20 Providence St, Boston, Mass

(This Division Has No State Sections)

NORTH CENTRAL DIVISION

(Minnesota, North Dakota, South Dakota)

North Central Electric Association

President, L M Pharis, Minnesota Power & Light Co, Duluth, Minn; *Secretary,* John W Lapham, 803-804 Plymouth Bldg, Minneapolis, Minn

(This Division Has No State Sections)

NORTHWEST DIVISION

(Alaska, Idaho, Montana, Oregon, Utah, Washington)

Northwest Electric Light & Power Association

President, R M Boykin, Puget Sound Power & Light Co, Seattle, Wash; *Secretary,* Berkeley Snow, Room 1206, Spaulding Bldg, Portland, Ore

(This Division Has No State Sections)

PACIFIC COAST DIVISION

(Arizona, California, Hawaii, Nevada, Philippine Islands)

Pacific Coast Electrical Association

President, Paul M Downing, Pacific Gas & Electric Co, San Francisco, Cal; *Secretary,* Samuel H Taylor, Suite 729-730, 447 Sutter St, San Francisco, Cal

Arizona Utilities Association

President, M A Pooler, Tucson Gas, Electric Light & Power Co, Tucson, Ariz; *Secretary,* L C McCullough, 134 South Central Ave, Phoenix, Ariz

ROCKY MOUNTAIN DIVISION

(Colorado, New Mexico, Wyoming)

President, Clare N Stannard, Public Service Co of Colorado, Denver, Colo; *Secretary,* O A Weller, Public Service Co of Colorado, Denver, Colo

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*Note: This Division is in process of formation.

The Colorado Utilities Association

President, V L BOARD, Public Service Co of Colorado, Denver, Colo; *Secretary,* O A WELLER, Public Service Co of Colorado, Denver, Colo

New Mexico Utilities Association

President, W W NIELSEN, New Mexico Power Co, Santa Fe, N M; *Secretary-Treasurer,* BERNARD L WILES, Albuquerque Gas & Electric Co, Albuquerque, N M

Wyoming Utilities Association

President, W D JOHNSTONE, Mountain States Power Co, Casper, Wyo; *Secretary,* F A PROBST, Mountain States Telephone & Telegraph Co, Casper, Wyo

SOUTHEASTERN DIVISION

(*Alabama, Cuba, Florida, Georgia, North Carolina, South Carolina, Tennessee, Porto Rico*)

President, C A COLLIER, Georgia Power Co, Atlanta, Ga; *Secretary,* C M KILIAN, 207-8 Bona Allen Bldg, Atlanta, Ga

SOUTHWESTERN DIVISION

(*Arkansas, Louisiana, Mississippi, Oklahoma, Texas*)

President, J G HOLTZCLAW, Gulf States Utilities Co, Beaumont, Tex; *Secretary,* S J BALLINGER, San Antonio Public Service Co, San Antonio, Tex

Arkansas Utilities Association

President, W E BANN, Southwestern Gas & Electric Co, Texarkana, Tex; *Secretary,* R I BROWN, Arkansas Central Power Co, Little Rock, Ark

Mississippi Electric League

President, A H JONES, Jones-Johnson Co, McComb, Miss; *Secretary,* A R RIDDICK, A G Riddick, Inc, Jackson, Miss

Oklahoma Utilities Association

President, L W SCHERER, United Telephone Corp, Watonga, Okla; *Secretary,* EDWARD F MCKAY, 1020 Petroleum Bldg, Oklahoma City, Okla

Southwestern Public Service Association

President, W H BURKE, Stone & Webster, Inc, Houston, Tex; *Secretary,* E N WILLIS, 403 Slaughter Bldg, Dallas Tex

Special National Committees

ADVERTISING COMMITTEE

To endeavor to improve, increase the efficiency of, and to coordinate as far as practicable, all advertising and information activities of the electric light and power industry

Chairman, Frank LeRoy Blanchard, Henry L Doherty & Co, New York, N Y
J F Ford, The Philadelphia Electric Co, Philadelphia, Pa
E Frank Gardiner, Midland Utilities Co, Chicago, Ill
Louis D Gibbs, The Edison Electric Illuminating Co, Boston, Mass
G R Hilty, Florida Power & Light Co, Miami, Fla
W H Hodge, Byllesby Engineering & Management Corp, Chicago, Ill
A C Joy, Great Western Power Co, San Francisco, Cal
Donald M Mackie, Allied Power & Light Corp, Jackson, Mich
Dempster MacMurphy, Middle West Utilities Co, Chicago, Ill
J F Owens, Oklahoma Gas & Electric Co, Oklahoma City, Okla
Stanley J Quinn, Electric Bond & Share Co, New York, N Y
Marshall E Sampsell, Central Illinois Public Service Co, Chicago, Ill
Richard E Smith, Southern California Edison Co, Los Angeles, Cal
L K Starr, Georgia Power Co, Atlanta, Ga
E C Stone, Duquesne Light Co, Pittsburgh, Pa
E R Treverton, The Ohio Public Service Co, Cleveland, Ohio
A C Watt, Allied Power & Light Corp, New York, N Y
Miss Clara Zillessen, The Philadelphia Electric Co, Philadelphia, Pa

CHARLES A COFFIN PRIZE COMMITTEE

By action of its Board of Directors, the General Electric Company has set aside a fund of $400,000 to be known as the "Charles A Coffin Foundation," the income from which, amounting to approximately $20,000 a year, will be available for encouraging and rewarding service in the electrical field by giving prizes to its employees, recognition to lighting, power and railway companies, for improvements in service to the public and fellowships to graduate students and funds for research work at technical schools and colleges

The Foundation will be controlled and administered by a Foundation Committee appointed by the Board. This Committee, within the limits of the purposes for which the Foundation is created, will have power to change the conditions applicable to the distribution of the fund and the amounts for each particular purpose

A gold medal, to be known as the "Charles A Coffin Medal," will be awarded annually to the public utility operating company within the United States which, during the year, has made the greatest contribution toward increasing the advantages of the use of electric light and power for the convenience and well-being of the public and the benefit of the industry. The company receiving the medal will also receive one thousand dollars ($1,000) for its employees' benefit or similar fund

A Committee to be named by the National Electric Light Association and known as the "Charles A Coffin Prize Committee of the National Electric Light Association," which shall consist of its President, Chairman of its Public Policy Committee and a third member nominated by them, will award this medal, acting with the advice and cooperation of a committee appointed by the Foundation Committee. The expenses of the Committee are to be paid out of the income of the Foundation

Chairman, P S Arkwright, *President, National Electric Light Association,* Georgia Power Co, Atlanta, Ga
R H Ballard, *Chairman, Public Policy Committee,* Southern California Edison Co, Los Angeles, Cal
Samuel W Stratton, *President,* Massachusetts Institute of Technology, Boston, Mass
William W Trench, *Secretary,* Charles A Coffin Foundation, Schenectady, N Y

CODES AND STANDARDS COMMITTEE

Determination of broad policies with respect to codes and standards to serve as a guide for the committees handling such matters

To establish rules and instructions of procedure for representatives of the power industry

To assist in broad coordination of the activities of the power industry with those of other interests in taking an active part in the establishment of codes and standards

Chairman, Irvin W Day, The Connecticut Light & Power Co, Waterbury, Conn
W S Finlay, Jr, West Penn Electric Co, Pittsburgh, Pa
G H Harries, H M Byllesby & Co, Chicago, Ill
C A Pratt, Electric Bond & Share Co, New York, N Y
Marshall E Sampsell, Central Illinois Public Service Co, Chicago, Ill
Frank W Smith, The United Electric Light & Power Co, New York, N Y
W G Vincent, Jr, Pacific Gas & Electric Co, San Francisco, Cal

CONSTITUTION AND BY-LAWS COMMITTEE

To investigate on behalf of the President and National Executive Committee any proposed changes in the National Association's Constitution and By-Laws; to investigate and standardize all provisions of the Constitution and By-Laws by Geographic, Company or any other Divisions or Sections of the Association

Chairman, R F Pack, Northern States Power Co, Minneapolis, Minn
P S Arkwright, *ex-officio,* Georgia Power Co, Atlanta, Ga
W A Jones, Henry L Doherty & Co, New York, N Y
J F Owens, Oklahoma Gas & Electric Co, Oklahoma City, Okla
Marshall E Sampsell, Central Illinois Public Service Co, Chicago Ill
M S Sloan, The New York Edison Co, New York, N Y

ELECTRIFICATION OF STEAM RAILROADS COMMITTEE

To study all steam railroad electrifications in a general way, developing the fundamental reasons for, and the results of, these electrifications; to promote cooperation between the executives of railway and power companies for the mutual understanding of each other's problems

Officers

Chairman, Britton I Budd, Public Service Co of Northern Illino Chicago, Ill
Secretary, Horace H Field, Public Service Co of Northern Illinoi Chicago, Ill

Steam Railroads

Reinier Beeuwkes, Chicago, Milwaukee, St Paul & Pacific Railroad Co, Seattle, Wash
E P Bracken, Chicago, Burlington & Quincy Railroad Co, Chicago, Ill
D J Brumley, Illinois Central Railroad Co, Chicago, Ill
Ralph Budd, Great Northern Railway Co, St Paul, Minn
H A Currie, New York Central Railroad Co, New York, N Y
G W Hand, Chicago & NorthWestern Railway Co, Chicago, Ill
H A Johnson, Chicago Rapid Transit Co, Chicago, Ill
W L Ross, The New York, Chicago & St Louis Railroad Co, Cleveland, Ohio
J W Sasser, The Virginian Railway Co, Princeton, W Va
J T Wallis, The Pennsylvania Railroad Co, Philadelphia, Pa
Sidney Withington, The New York, New Haven & Hartford Railroad Co, New Haven, Conn

Power Companies

H C Cummins, Standard Gas & Electric Co, Chicago, Ill
F W Doolittle, The North American Co, New York, N Y
L E Fischer, Illinois Power & Light Corp, Chicago, Ill
C E Groesbeck, Electric Bond & Share Co, New York, N Y
J T Hutchings, The United Gas Improvement Co, Philadelphia, Pa
J W Lieb, The New York Edison Co, New York, N Y
H P Liversidge, The Philadelphia Electric Co, Philadelphia, Pa
E W Lloyd, Commonwealth Edison Co, Chicago, Ill
W H McGrath, Puget Sound Power & Light Co, Seattle, Wash
R F Schuchardt, Commonwealth Edison Co, Chicago, Ill

Consulting Engineers

W S Murray, Murray & Flood, New York, N Y
James Walker, Bankers Building, Chicago, Ill

Electrical Manufacturers

A H Armstrong, General Electric Co, Schenectady, N Y
C L Bardo, American Brown Boveri Electric Corp, Camden, N J
F H Shepard, Westinghouse Electric & Manufacturing Co, New York, N Y

Special Membership of Subcommittees

C P Billings, Electric Bond & Share Co, New York, N Y
H J Dunbaugh, Isham, Lincoln & Beale, Chicago, Ill
R B Grove, United Electric Light & Power Co, New York, N Y
L Wylie, Chicago, Milwaukee, St Paul & Pacific Railroad Co, Seattle, Wash

Subcommittee on Electrification in Europe

Chairman, H A Johnson; *Secretary,* Horace H Field; Reinier Beeuwkes, L E Fischer

Subcommittee on Form of Contract

Chairman, E W Lloyd; *Secretary,* Horace H Field; C P Billings, D J Brumley, H J Dunbaugh, R B Grove, J T Wallis, L Wylie

EXHIBITION COMMITTEE

To take charge of exhibitions held in connection with conventions of the Association. This Committee is elected annually by Class "D" members

Chairman, E W Goldschmidt, Wagner Electric Corp, New York N Y

Secretary-Treasurer, Frank H Gale, General Electric Co, Schenectady, N Y
Edwin L Andrew, Rome Wire Co, Rome, N Y
S E Doane, National Lamp Works of G E Co, Cleveland, Ohio
E D Doty, Frigidaire Corp, Dayton, Ohio
J J Greene, Johns-Manville Corp, New York, N Y
George A Hughes, Edison Electric Appliance Co, Inc, Chicago, Ill
J C McQuiston, Westinghouse Electric & Manufacturing Co, East Pittsburgh, Pa
C L Peirce, Jr, Hubbard & Co, Pittsburgh, Pa

FINANCE COMMITTEE

To supervise the finances of the Association, reporting to the President and National Executive Committee

Chairman, Sidney Z Mitchell, Electric Bond & Share Co, New York, N Y
N F Brady, The New York Edison Co, New York, N Y
Henry L Doherty, Henry L Doherty & Co, New York, N Y
Charles L Edgar, The Edison Electric Illuminating Co, Boston, Mass
Samuel Insull, Commonwealth Edison Co, Chicago, Ill
J J O'Brien, H M Byllesby & Co, Chicago, Ill
P S Young, Public Service Electric & Gas Co, Newark, N J

LAMP COMMITTEE

To report to members current developments in the manufacture, the characteristics and utilization of incandescent, arc lamps and other electric illuminants and equipment in connection therewith; to secure the adoption of suitable standard lamp voltages; to report the current practices of the Member Companies with respect to the handling of incandescent lamps

Chairman, Frank W Smith, The United Electric Light & Power Co, New York, N Y
Secretary, Robert B Grove, The United Electric Light & Power Co, New York, N Y
W H Atkins, The Edison Electric Illuminating Company of Boston, Boston, Mass
Douglass Burnett, Consolidated Gas, Electric Light & Power Co, Baltimore, Md
Walter Cary, Westinghouse Lamp Co, New York, N Y
S E Doane, National Lamp Works of G E Co, Cleveland, Ohio
S Ferguson, The Hartford Electric Light Co, Hartford, Conn
W W Freeman, Columbia Gas & Electric Corp, New York, N Y
E W Lloyd, Commonwealth Edison Co, Chicago, Ill
George F Morrison, General Electric Co, New York, N Y
F W Patterson, Canadian General Electric Co, Ltd, Montreal, Can
Charles J Russell, The Philadelphia Electric Co, Philadelphia, Pa

Special Membership of Subcommittees

M D Cooper, National Lamp Works of G E Co, Cleveland, Ohio
Samuel G Hibben, Westinghouse Lamp Co, Bloomfield, N J
G S Merrill, National Lamp Works of G E Co, Cleveland, Ohio
Preston S Millar, Electrical Testing Laboratories, Inc, New York, N Y
Henry Schroeder, Edison Lamp Works of G E Co, Harrison, N J

Carbon Lamps and Their Uses Subcommittee

Chairman, S E Doane; S Ferguson, C J Russell

Preparation of Articles for N E L A Bulletin Subcommittee

Chairman, Preston S Millar; Samuel G Hibben, G S Merrill, Henry Schroeder

Standardization of Lamp Voltages Subcommittee

Chairman, S E Doane; M D Cooper, Samuel G Hibben, Preston S Millar, Henry Schroeder

PRIZE AWARDS COMMITTEE

This Committee shall be in charge of all the prize awards offered by the Association, with the exception of the Charles A Coffin Prize. It shall prepare the necessary leaflets and other means of notification to the Association's membership. It shall receive the reports and papers on the various awards and will make recommendations to the National Executive Committee covering its decision as to the winners in the various contests. With the exception of the Charles A Coffin Prize and the Insull Medals, the Committee will announce these awards at the Annual Convention

Chairman, W H Onken, Jr, *Electrical World,* New York, N Y
B C Forbes, *Forbes Magazine,* New York, N Y
John T Madden, New York University, New York, N Y
W S Murray, Murray & Flood, New York, N Y
Miss Clara Zillessen, The Philadelphia Electric Co, Philadelphia, Pa

PUBLIC POLICY COMMITTEE

To determine the policy of the Association on all questions of broad public import, to recommend to member companies such attitude and action in relation to specific questions as will best promote the welfare of the industry in the public service. Included in the personnel of the Committee are the President and four Vice-Presidents of the Association and four representatives from the Executive Committee of the Public Relations National Section

Chairman, R H Ballard, Southern California Edison Co, Los Angeles, Cal
Vice-Chairman, W W Freeman, Columbia Gas & Electric Corp, New York, N Y
P S Arkwright, Georgia Power Co, Atlanta, Ga
Henry G Bradlee, Stone & Webster, Inc, Boston, Mass
N F Brady, The New York Edison Co, New York, N Y
B C Cobb, Allied Power & Light Corp, New York, N Y
Frank L Dame, The North American Co, New York, N Y
J E Davidson, Nebraska Power Co, Omaha, Neb
Henry L Doherty, Henry L Doherty & Co, New York, N Y
Alex Dow, The Detroit Edison Co, Detroit, Mich
Charles L Edgar, The Edison Electric Illuminating Co, Boston, Mass
Halford Erickson, Byllesby Engineering & Management Corp, Chicago, Ill
P G Gossler, Columbia Gas & Electric Corp, New York, N Y
A R Graustein, International Paper Co, New York, N Y
Franklin T Griffith, Portland Electric Power Co, Portland, Ore
C E Groesbeck, Electric Bond & Share Co, New York, N Y
Edwin Gruhl, The North American Co, New York, N Y
A F Hockenbeamer, Pacific Gas & Electric Co, San Francisco, Cal
Martin J Insull, Middle West Utilities Co, Chicago, Ill
Samuel Insull, Commonwealth Edison Co, Chicago, Ill
W A Jones, Henry L Doherty & Co, New York, N Y
John W Lieb, The New York Edison Co, New York, N Y
Thomas W Martin, Alabama Power Co, Birmingham, Ala
Thomas N McCarter, Public Service Electric & Gas Co, Newark, N J
John B Miller, Southern California Edison Co, Los Angeles, Cal
Sidney Z Mitchell, Electric Bond & Share Co, New York, N Y
J J O'Brien, H M Byllesby & Co, Chicago, Ill
J F Owens, Oklahoma Gas & Electric Co, Oklahoma City, Okla
R F Pack, Northern States Power Co, Minneapolis, Minn
A W Robertson, Westinghouse Electric & Manufacturing Co, Pittsburgh, Pa
Marshall E Sampsell, Central Illinois Public Service Co, Chicago, Ill
H T Sands, Electric Bond & Share Co, New York, N Y
Paul A Schoellkopf, The Niagara Falls Power Co, Niagara Falls, N Y
M S Sloan, The New York Edison Co, New York, N Y
Frank W Smith, The United Electric Light & Power Co, New York, N Y
R P Stevens, Allied Power & Light Corp, New York, N Y
Frank M Tait, The Dayton Power & Light Co, Dayton, Ohio
George N Tidd, American Gas & Electric Co, New York, N Y
Herbert A Wagner, Consolidated Gas, Electric Light & Power Co, Baltimore, Md
Owen D Young, General Electric Co, New York, N Y
John E Zimmermann, The United Gas Improvement Co, Philadelphia, Pa

Public Relations National Section Representatives

John F Gilchrist, Commonwealth Edison Co, Chicago, Ill
T A Kenney, Allied Power & Light Corp, New York, N Y
Guy W Talbott, Pacific Power & Light Co, Portland, Ore

RATE RESEARCH COMMITTEE

To publish information as to current rates and decisions bearing upon rates—in other words, the supervision of the publication of Rate Research and the Rate Book

To study and report to the Executive Committee (or Public Policy Committee) at intervals all new rate methods; rate methods being defined as the theory and construction of practical rate schedules

The coordination of work of other bureaus and committees of the Engineering, Commercial and Accounting Sections along lines which lead into questions of rate theory, this function to be developed to the elimination of duplicated work and the avoidance of inconsistent conclusions by committees of Sections working separately

Chairman, L R Nash, Stone & Webster, Inc, Boston, Mass
Secretary, C E Neil, The North American Co, New York, N Y
H H Agee, Public Service Electric & Gas Co, Newark, N J
E J Fowler, Commonwealth Edison Co, Chicago, Ill
John W Lieb, The New York Edison Co, New York, N Y
E N Strait, Byllesby Engineering & Management Corp, Chicago, Ill
W G Vincent, Jr, Pacific Gas & Electric Co, San Francisco, Cal
W R Waggoner, Alabama Power Co, Birmingham, Ala
Ralph P Wagner, Henry L Doherty & Co, New York, N Y

WATER POWER DEVELOPMENT COMMITTEE

To investigate and report upon the water power possibilities of the country, both developed and undeveloped, and suggest a broad policy for future development and interconnection of water-power systems

Chairman, PAUL A SCHOELLKOPF, The Niagara Falls Power Co, Niagara Falls, N Y
R H BALLARD, Southern California Edison Co, Los Angeles, Cal
H T EDGAR, Stone & Webster, Inc, Boston, Mass
H W FULLER, Byllesby Engineering & Management Corp, Chicago, Ill
D C GREEN, Utah Power & Light Co, Salt Lake City, Utah
H I HARRIMAN, New England Power Co, Boston, Mass
A W LEONARD, Puget Sound Power & Light Co, Seattle, Wash
CHARLES S RUFFNER, Mohawk Hudson Power Corp, Albany, N Y
GUY W TALBOT, Pacific Power & Light Co, Portland, Ore
O G THURLOW, Alabama Power Co, Birmingham, Ala
A B WEST, The Southern Sierras Power Co, Riverside, Cal
A G WISHON, San Joaquin Light & Power Corp, Fresno, Cal
E A YATES, Alabama Power Co, Birmingham, Ala

WIRING POLICY COMMITTEE

To determine policies with respect to wiring to serve as a guide for the Association and its Codes and Standards Committee

Chairman, J E DAVIDSON, Nebraska Power Co, Omaha, Neb
ALEX DOW, The Detroit Edison Co, Detroit, Mich
W A JONES, Henry L Doherty & Co, New York, N Y
E W LLOYD, Commonwealth Edison Co, Chicago, Ill
J F OWENS, Oklahoma Gas & Electric Co, Oklahoma City, Okla
R F PACK, Northern States Power Co, Minneapolis, Minn

General National Committees

CIVIC DEVELOPMENT COMMITTEE

To cooperate with local organizations in the industrial and civic development of communities served by electric light and power companies

Chairman, John B Reynolds, Middle West Utilities Co, Chicago, Ill
James M Bennett, The Philadelphia Electric Co, Philadelphia, Pa
H C Couch, Arkansas Power & Light Co, Pine Bluff, Ark
J E Davidson, Nebraska Power Co, Omaha, Neb
Leavitt L Edgar, The Edison Electric Illuminating Co, Boston, Mass
Louis H Egan, Union Electric Light & Power Co, St Louis, Mo
Ralph B Feagin, Electric Bond & Share Co, New York, N Y
Frank A Leach, Jr, Pacific Gas & Electric Co, San Francisco, Cal
John G Learned, Public Service Co of Northern Illinois, Chicago, Ill
A W Leonard, Puget Sound Power & Light Co, Seattle, Wash
Charles J Russell, The Philadelphia Electric Co, Philadelphia, Pa
Miss Sarah Sheridan, The Detroit Edison Co, Detroit, Mich
Herbert A Wagner, Consolidated Gas, Electric Light & Power Co, Baltimore, Md
Arthur Williams, The New York Edison Co, New York, N Y

Geographic Division Representatives

Canadian—W H Winter, Bell Telephone Co, Montreal, Can
Eastern—D A Elias, Harrisburg Light & Power Co, Harrisburg, Pa
East Central—C G Eichelberger, The Union Gas & Electric Co, Cincinnati, Ohio
Great Lakes—J Paul Clayton, Central Illinois Public Service Co, Springfield, Ill
Middle West—L A Pettit, Jr, Missouri Power & Light Co, Kansas City, Mo
New England—R W Perkins, Eastern Connecticut Power Co, Norwich, Conn
North Central—John W Lapham, 803 Plymouth Building, Minneapolis, Minn
Northwest—
Pacific Coast—
Rocky Mountain—V L Board, Public Service Co of Colorado, Denver, Colo
Southeastern—Tom D Johnson, Alabama Power Co, Birmingham, Ala
Southwestern—J C Kennedy, Central & South West Utilities, Dallas, Texas

EDUCATIONAL COMMITTEE

To prepare fundamental and specialized courses for the education of employees of member companies and others who desire to subscribe; to conduct these courses among the member companies and allied industries; to work closely and advise with all companies interested in the education of employees, and to cooperate with all Sections and Committees in the matters of education

Chairman, Fred R Jenkins, Commonwealth Edison Co, Chicago, Ill
E A Davis, Middle West Utilities Co, Chicago, Ill
W S R Dickinson, Public Service Electric & Gas Co, Newark, N J
Miss May Fletemeyer, Northern Indiana Public Service Co, Hammond, Ind
Carl D Jackson, 36 West 44th St, New York, N Y
E A LeFever, Buffalo General Electric Co, Buffalo, N Y
Wirt S Scott, Westinghouse Electric & Manufacturing Co, Mansfield, Ohio
Howell Van Blarcom, Westinghouse Electric & Manufacturing Co, East Pittsburgh, Pa
W S Vivian, Middle West Utilities Co, Chicago, Ill

Geographic Division Representatives

Canadian—Fraser S Keith, Shawinigan Water & Power Co, Montreal, Can
Eastern—
East Central—A Bliss McCrum, Box 1483, Charleston, W Va
Great Lakes—
Middle West—Elliott Belden, United Power & Light Co, Abilene, Kan
New England—E S Mansfield, The Edison Electric Illuminating Co, Boston, Mass
North Central—Fred R Rice, Northwestern Public Service Co, Huron, S D
Northwest—Berkeley Snow, 1206 Spaulding Bldg, Portland, Ore
Pacific Coast—Don C Ray, Pacific Gas & Electric Co, San Francisco, Cal
Rocky Mountain—R A Faris, Mountain States Power Co, Casper, Wyo
Southeastern—C M Kilian, 207-8 Bona-Allen Bldg, Atlanta, Ga
Southwestern—Hugh M Blain, 1426 Hibernia Bldg, New Orleans La

INSURANCE COMMITTEE

To form closer contact with executives of insurance companies so that their problems and those of the industry may be discussed with mutual benefit

To investigate and report on proper forms for all kinds of insurance, including fire, compensation, liability, life and others, and to assist member companies in obtaining proper protection

To devise educational means for informing member companies in connection with insurance and preventive measures; to act as an insurance service bureau for the Association and its members

Chairman, W H Sawyer, Stevens & Wood, Inc, New York, N Y
Vice-Chairman, G H Bourne, Allied Power & Light Corp, New York, N Y
George Barker, Public Service Corp of New Jersey, Newark, N J
H C Blackwell, The Union Gas & Electric Co, Cincinnati, Ohio
W H Blood, Jr, Stone & Webster, Inc, Boston, Mass
C L Campbell, The Connecticut Light & Power Co, Waterbury, Conn
Ralph S Child, Bonbright & Co, Inc, New York, N Y
A V R Coe, The Philadelphia Electric Co, Philadelphia, Pa
J E Davidson, Nebraska Power Co, Omaha, Neb
J J Dougherty, Duquesne Light Co, Pittsburgh, Pa
John F Gilchrist, Commonwealth Edison Co, Chicago, Ill
F C Gordon, Byllesby Engineering & Management Corp, Chicago, Ill
Franklin T Griffith, Portland Electric Power Co, Portland, Ore
H T Hughes, Public Service Co of Colorado, Denver, Colo
Carlton W Pierce, The Niagara Falls Power Co, Niagara Falls, N Y
J G Reese, Consolidated Gas, Electric Light & Power Co, Baltimore, Md
A W Reid, American Gas & Electric Co, New York, N Y

Geographic Division Representatives

Canadian—Wills Maclachlan, 2 Bloor St East, Toronto 5, Can
Eastern—J H Nickell, The Philadelphia Electric Co, Philadelphia, Pa
East Central—E G Dunlap, Pennsylvania-Ohio Power & Light Co, Youngstown, Ohio
Great Lakes—Robert Davey, Consumers Power Co, Jackson, Mich
Middle West—L R King, United Light & Power Engineering & Construction Co, Davenport, Iowa
New England—H P Hood, The Edison Electric Illuminating Co, Boston, Mass
North Central—A H Savage, Union Public Service Co, St Paul, Minn
Northwest—L A McArthur, Pacific Power & Light Co, Portland, Ore
Pacific Coast—Herbert Dewes, Southern Sierras Power Co, Riverside, Cal
Rocky Mountain—J E Loiseau, Public Service Co of Colorado, Denver, Colo
Southeastern—
Southwestern—M T Walker, Southwestern Gas & Electric Co, Shreveport, La

Special Membership of Subcommittee

C F Hirshfeld, The Detroit Edison Co, Detroit, Mich

Electrical Apparatus Subcommittee

Chairman, G H Bourne; George Barker, C L Campbell, C F Hirshfeld, H P Hood, J G Reese

Association's Insurance Expert

W H Blood, Jr, Stone & Webster, Inc, Boston, Mass

MEMBERSHIP COMMITTEE

To obtain new members in all classes; to prepare and distribute information regarding the advantages of membership in the Association; to coordinate and develop the membership campaigns of the various Geographic Divisions and State Sections of the Association

Chairman, Howard K Mohr, The Philadelphia Electric Co, Philadelphia, Pa
G E Cullinan, Graybar Electric Co, Inc, New York, N Y
Frank H Gale, General Electric Co, Schenectady, N Y
W H Onken, Jr, *Electrical World*, New York, N Y

Geographic Division Representatives

Canadian—H M Lyster, 712 Power Bldg, Montreal, Can
Eastern—A B Millar, Telegraph Bldg, Harrisburg, Pa
East Central—D L Gaskill, 603 Broadway, Greenville, Ohio
Great Lakes—Tom C Polk, 910 Marquette Bldg, Chicago, Ill
Middle West—Thorne Browne, 1527 Sharp Bldg, Lincoln, Neb
New England—Miss O A Bursiel, 20 Providence St, Boston, Mass
North Central—John W Lapham, 803 Plymouth Bldg, Minneapolis, Minn
Northwest—Berkeley Snow, 1206 Spaulding Bldg, Portland, Ore
Pacific Coast—Samuel H Taylor, 447 Sutter St, San Francisco, Cal
Rocky Mountain—O A Weller, Public Service Co of Colorado, Denver, Colo
Southeastern—C M Kilian, 207-08 Bona-Allen Bldg, Atlanta, Ga
Southwestern—S J Ballinger, San Antonio Public Service Co, San Antonio, Tex

RURAL ELECTRIC SERVICE COMMITTEE

To make a study of the problems connected with rural electric service, to collect accurate information on the cost of this service to the utility; to determine the value of this service to the rural customers; to analyze the various rules, methods of financing and forms of rural rates now being used; to assist in the development of farm equipment suitable for electric drive; to assist in determining the proper standards of rural line construction and to assist the Committee on the Relation of Electricity to Agriculture in carrying on this work; to assist in the development of rural service departments in public utility organizations; to assist in the building of electric power load on the farm

Chairman, Charles F Stuart, Northern States Power Co, Minneapolis, Minn
Vice-Chairman, Eugene Holcomb, Consumers Power Co, Jackson, Mich
F A Belden, The Edison Electric Illuminating Co, Boston, Mass
D E Blandy, New York Power & Light Corp, Albany, N Y
Richard Boonstra, Public Service Co of Northern Illinois, Chicago, Ill
C H Churchill, New York Power & Light Corp, Schenectady, N Y
John M Costello, Niagara, Lockport & Ontario Co, Batavia, N Y
Arthur Huntington, Iowa Railway & Light Co, Cedar Rapids, Iowa
E F Kelly, Central Illinois Public Service Co, Springfield, Ill
J W Leland, Central Maine Power Co, Augusta, Me
L A McArthur, Pacific Power & Light Co, Portland, Ore
W T McCaskey, Middle West Utilities Co, Chicago, Ill
G C Neff, Wisconsin Power & Light Co, Madison, Wis
J F Owens, Oklahoma Gas & Electric Co, Oklahoma City, Okla
H A Pendergraph, Georgia Power Co, Atlanta, Ga
C V Sorenson, Northern Indiana Power Co, Indianapolis, Ind
Philip B Shaw, National Electric Power Co, New York, N Y
E N Strait, Byllesby Engineering & Management Corp, Chicago, Ill
Norman E Sutherland, Pacific Gas & Electric Co, San Francisco, Cal
Stanley Taber, Iowa-Nebraska Light & Power Co, Lincoln, Neb
E A White, 58 East Washington St, Chicago, Ill
John S Wise, Jr, Pennsylvania Power & Light Co, Allentown, Pa

Geographic Division Representatives

Canadian—H O Wilkins, Electric Service Corp, Montreal, Can
Eastern—C E Oakes, Pennsylvania Power & Light Co, Allentown, Pa
East Central—C I Weaver, Ohio Edison Co, Springfield, Ohio
Great Lakes—Eugene Holcomb, Consumers Power Co, Jackson, Mich
Middle West—W R McGeachin, Iowa-Nebraska Light & Power Co, Lincoln, Neb
New England—R H Alton, Worcester Suburban Electric Co, Uxbridge, Mass
North Central—C P Wagner, Northern States Power Co, Minneapolis, Minn
Northwest—J C Scott, Puget Sound Power & Light Co, Seattle, Wash
Pacific Coast—
Rocky Mountain—J A Clay, Western Colorado Power Co, Durango, Colo
Southeastern—H M Weathers, Alabama Power Co, Birmingham, Ala
Southwestern—O A Jennings, Oklahoma Gas & Electric Co, Oklahoma City, Okla

Accounting National Section

Scope of Activity

The object of the Accounting National Section shall be to bring together those engaged in the fiscal, accounting, statistical, purchasing and store room accounting departments of member companies, for the interchange of ideas, to promote the adoption and dissemination of sound financial and accounting theories and methods, and to work for the establishment of a single uniform system of accounts and reports.

EXECUTIVE COMMITTEE

Officers

Chairman, J F Ford, The Philadelphia Electric Co, Philadelphia, Pa
Vice-Chairman, W R Emerson, Oklahoma Gas & Electric Co, Oklahoma City, Okla
Vice-Chairman, Franklyn Heydecke, Public Service Electric & Gas Co, Newark, N J
Vice-Chairman, J H Lobban, The Detroit Edison Co, Detroit, Mich

Members at Large

(Terms expiring June 30, 1929)

E A Davis, *ex-officio*, Middle West Utilities Co, Chicago, Ill
B F Brahaney, H M Byllesby & Co, Chicago, Ill
B F McGuire, Commonwealth Edison Co, Chicago, Ill
J A Rockwood, Portland Electric Power Co, Portland, Ore

(Terms expiring June 30, 1930)

Walter C Lang, Electric Bond & Share Co, New York, N Y
W Paxton Little, The Niagara Falls Power Co, Niagara Falls, N Y
J E Loiseau, Public Service Co of Colorado, Denver, Colo

Geographic Division Representatives

Canadian—
Eastern—R A Freeman, Pennsylvania Power & Light Co, Allentown, Pa
East Central—F J Pfeiffer, Louisville Gas & Electric Co, Louisville, Ky
Great Lakes—J E Gray, Wisconsin Power & Light Co, Madison, Wis
Middle West—W J Goldsworthy, Community Power & Light Co, St Louis, Mo
New England—J W Lester, The Edison Electric Illuminating Co, Boston, Mass
North Central—W S Hodgson, Minnesota Power & Light Co, Duluth, Minn
Northwest—A E Janssen, Idaho Power Co, Boise, Idaho
Pacific Coast—H T Terry, Pacific Gas & Electric Co, San Francisco, Cal
Rocky Mountain—W D Virtue, Public Service Co of Colorado, Denver, Colo
Southeastern—C J Curry, Carolina Power & Light Co, Raleigh, N C
Southwestern—E E Ehret, Public Service Co of Oklahoma, Tulsa, Okla

Committee Chairmen

Budget Committee
B S Rodey, Jr, The United Electric Light & Power Co, New York, N Y

Classification of Accounts
H C Hasbrouck, H C Hopson & Co, New York, N Y

Corporate Finance Committee
O E McCormick, Middle West Utilities Co, Chicago, Ill

Customers' Records Committee
Douglas Brown, New York & Queens Electric Light & Power Co, Long Island City, N Y

Fixed Capital Committee
J A Rockwood, Portland Electric Power Co, Portland, Ore

General Records Committee
K B Crumb, American Gas & Electric Co, New York, N Y

Purchasing and Storeroom Committee
W G Young, New York & Queens Electric Light & Power Co, Long Island City, N Y

Statistics Committee
Harry A Snow, The Detroit Edison Co, Detroit, Mich

Accounting Director

Fred W Herbert, N E L A Headquarters, New York, N Y

BUDGET COMMITTEE

(Scope of activities to be determined)

Chairman, B S Rodey, Jr, The United Electric Light & Power Co, New York, N Y
Vice-Chairman, C E Weger, Henry L Doherty & Co, New York, N Y
Secretary, C A Keller, Commonwealth Edison Co, Chicago, Ill
Howard Duryea, Alabama Power Co, Birmingham, Ala
F W Funk, Pennsylvania-Ohio Power & Light Co, Youngstown, Ohio (representing Engineering National Section)
W S Hodgson, Minnesota Power & Light Co, Duluth, Minn
T O Kennedy, Ohio Public Service Co, Cleveland, Ohio (representing Commercial National Section)
C R Lammert, Westchester Lighting Co, New York, N Y
J P Maguire, The Philadelphia Electric Co, Philadelphia, Pa
Alex Morgan, Toledo Edison Co, Toledo, Ohio
Louis Teitelbaum, Public Service Electric & Gas Co, Newark, N J
O A Weller, Public Service Co of Colorado, Denver, Colo
C V Woolsey, Brooklyn Edison Co, Inc, Brooklyn, N Y

CLASSIFICATION OF ACCOUNTS COMMITTEE

To endeavor to secure the adoption of the Uniform Classification of Accounts and standard form of annual reports by all member companies and by regulatory commissions, having jurisdiction over accounting procedure and to assist in their interpretation and application

Chairman, H C Hasbrouck, C H Hopson & Co, New York, N Y
R E Cuthbertson, The Ohio Public Service Co, Cleveland, Ohio
John B Everett, New England Public Service Co, Augusta, Me
P O Johnson, Northern States Power Co, Minneapolis, Minn
A J Mayotte, Consumers Power Co, Jackson, Mich
C P Zimmerer, Electric Bond & Share Co, New York, N Y

Geographic Division Representatives

Canadian—
Eastern—H R Kern, The Philadelphia Electric Co, Philadelphia, Pa
East Central—G B Moir, Appalachian Electric Power Co, Charleston, W Va
Great Lakes—Douglas Shaw, Wisconsin Power & Light Co, Madison, Wis
Middle West—F M Bucher, Missouri Power & Light Co, Kansas City, Mo
New England—J M Ahern, Concord Electric Co, Concord, N H
North Central—W L Hatch, Otter Tail Power Co, Fergus Falls, Minn
Northwest—W F Miller, Washington Water Power Co, Spokane, Wash
Pacific Coast—C P Staal, Southern California Edison Co, Los Angeles, Cal
Rocky Mountain—W J Benning, Southern Colorado Power Co, Pueblo, Colo
Southeastern—C J Curry, Carolina Power & Light Co, Raleigh, N C
Southwestern—Thomas P McDonnell, Southwestern Light & Power Co, Oklahoma City, Okla

Special Membership of Subcommittees

Robert Davey, Consumers Power Co, Jackson, Mich
E J Fowler, Commonwealth Edison Co, Chicago, Ill
Isaac S Hall, Charles H Tenney & Co, Boston, Mass
W B S Winans, Henry L Doherty & Co, New York, N Y

Interconnection Accounting Subcommittee

Chairman, E J Fowler; Robert Davey, Franklyn Heydecke

Merchandise and Jobbing Accounting Subcommittee

Chairman, H C Hasbrouck; Isaac S Hall, A J Mayotte, W B S Winans

CORPORATE FINANCE COMMITTEE

To study electric utility companies' financial matters

Chairman, Oliver E McCormick, Middle West Utilities Co, Chicago, Ill
Vice-Chairman, C M Breitinger, The Philadelphia Electric Co, Philadelphia, Pa
F L Blackburn, Henry L Doherty & Co, New York, N Y
H M Edwards, The New York Edison Co, New York, N Y
Frank C Gordon, New York & Queens Electric Light & Power Co, Long Island City, N Y
E G Kellett, Northern States Power Co, Minneapolis, Minn
Walter C Lang, Electric Bond & Share Co, New York, N Y
R O Launey, Brooklyn Edison Co, Inc, Brooklyn, N Y
W Paxton Little, The Niagara Falls Power Co, Niagara Falls, N Y

Mortgages Subcommittee

Chairman, C M Breitinger; F L Blackburn, Walter C Lang, W Paxton Little

CUSTOMERS' RECORDS COMMITTEE

To study and report on methods applicable to customers' records and billing, customers' deposit practices, meter reading record, policies relating to credits and collections, merchandise sales, billing and collections, machine billing and allied subjects, including consideration of customer relations

Chairman, Douglas Brown, New York & Queens Electric Light & Power Co, Long Island City, N Y
Vice-Chairman, E W Korsmeyer, Henry L Doherty & Co, New York, N Y
P F Gow, Kansas Gas & Electric Co, Wichita, Kan
J D Jacobus, The Detroit Edison Co, Detroit, Mich
B F McGuire, Commonwealth Edison Co, Chicago, Ill

Geographic Division Representatives

Canadian—
Eastern—M H Parkinson, Penn Central Light & Power Co, Altoona, Pa
East Central—A W Isenhart, The Dayton Power & Light Co, Dayton, Ohio
Great Lakes—Paul Stark, Central Indiana Power Co, Indianapolis, Ind
Middle West—F J Moylan, Nebraska Power Co, Omaha, Neb
New England—H O Wendte, Salem Electric Lighting Co, Salem, Mass
North Central—W G Brownell, Northern States Power Co, Minneapolis, Minn
Northwest—B H Parkinson, Pacific Power & Light Co, Portland, Ore
Pacific Coast—J A Cannon, San Diego Consolidated Gas & Electric Co, San Diego, Cal
Rocky Mountain—C C Baker, Colorado Central Power Co, Golden, Colo
Southeastern—C A H Raymond, Tampa Electric Co, Tampa, Fla
Southwestern—Dan Ryan, Fort Smith Light & Traction Co, Fort Smith, Ark

FIXED CAPITAL COMMITTEE

To study and report on methods for preparation and maintenance of fixed capital records, work order systems, estimates for construction requirements, distribution of capital expenditures and overhead expenses on construction

Chairman, J A Rockwood, Portland Electric Power Co, Portland, Ore
Vice-Chairman, Thomas M Ford, The Philadelphia Electric Co, Philadelphia, Pa
E J Armbruster, New Orleans Public Service Inc, New Orleans, La
S L Ferguson, The Detroit Edison Co, Detroit, Mich
George A Hausenbauer, New York & Queens Electric Light & Power Co, Long Island City, N Y
D Leaf, Staten Island Edison Co, St George, N Y
J W Lester, The Edison Electric Illuminating Co, Boston, Mass
C E Olwine, Public Service Electric & Gas Co, Newark, N J
Maurice R Scharff, Farmers Bank Building, Pittsburgh, Pa
F J Stanwood, 150 Congress St, Boston, Mass
H B Utter, Commonwealth Edison Co, Chicago, Ill

Geographic Division Representatives

Canadian—
Eastern—E C Story, Pennsylvania Power & Light Co, Allentown, Pa
East Central—Earl Ruby, Pennsylvania-Ohio Power & Light Co, Youngstown, Ohio
Great Lakes—R L Stiles, The Milwaukee Electric Railway & Light Co, Milwaukee, Wis
Middle West—George F Myers, Sioux City Gas & Electric Co, Sioux City, Iowa
New England—B O Marston, Central Maine Power Co, Augusta, Me
North Central—C L Sanstedt, Northwestern Public Service Co, Huron, S D
Northwest—L E Hinman, Portland Electric Power Co, Portland, Ore
Pacific Coast—A S Walthall, San Joaquin Light & Power Corp, Fresno, Cal
Rocky Mountain—P F Parkinson, Western Colorado Power Co, Durango, Colo
Southeastern—C J Curry, Carolina Power & Light Co, Raleigh, N C
Southwestern—F D Schaefer, Oklahoma Gas & Electric Co, Oklahoma City, Okla

GENERAL RECORDS COMMITTEE

To study and report on methods applicable to accounts payable, practices for general ledger and subsidiary records; other than customers' records; payroll, tax, insurance and interest records; internal auditing, filing systems, preservation of records; automotive equipment accounting and records

Chairman, K B Crumb, American Gas & Electric Co, New York, N Y
Vice-Chairman, C E McBride, Electric Bond & Share Co, New York, N Y
C J Allen, The Connecticut Light & Power Co, Hartford, Conn
W Bergmann, The New York Edison Co, New York, N Y
R B Boyle, Fort Worth Power & Light Co, Fort Worth, Tex
F P Dexter, Stone & Webster, Inc, Boston, Mass
E W Jahn, Consolidated Gas, Electric Light & Power Co, Baltimore, Md
C E Kohlhepp, Wisconsin Public Service Corp, Milwaukee, Wis
R S Pruyn, Westchester Lighting Co, Mt Vernon, N Y
H J Roth, Commonwealth Edison Co, Chicago, Ill

E M Sheehan, New York & Queens Electric Light & Power Co, Long Island City, N Y
W J Vega, The New York Edison Co, New York, N Y

Geographic Division Representatives

Canadian—
Eastern—Valentine Pfromm, Pennsylvania Power & Light Co, Allentown, Pa
East Central—W A Marshall, Toledo Edison Co, Toledo, Ohio
Great Lakes—J H McIsaac, The Detroit Edison Co, Detroit, Mich
Middle West—A G Beisenherz, Missouri Gas & Electric Co, Lexington, Mo
New England—
North Central—Fred R Gamble, Minnesota Northern Power Co, Minneapolis, Minn
Northwest—O W Bennett, Puget Sound Power & Light Co, Seattle, Wash
Pacific Coast—A B Carpenter, San Joaquin Light & Power Corp, Fresno, Cal
Rocky Mountain—H A Mitchell, Public Service Co of Colorado, Denver, Colo
Southeastern—
Southwestern—H B Parris, Dallas Power & Light Co, Dallas, Tex

PURCHASING AND STOREROOM COMMITTEE

To study and report on systems of purchasing, storing and accounting for and issuing materials and supplies, purchasing agents records requirements, methods and allied functions

Chairman, W G Young, New York & Queens Electric Light & Power Co, Long Island City, N Y
E S Brock, Public Service Electric & Gas Co, Newark, N J
K C Campbell, The Detroit Edison Co, Detroit, Mich
Lewis A Jones, New York Power & Light Corp, Schenectady, N Y
F A Jordan, Georgia Power Co, Atlanta, Ga
W P McArdle, Electric Bond & Share Co, New York, N Y
S W Smallpage, New Orleans Public Service Inc, New Orleans, La
D R Truax, Central Illinois Public Service Co, Springfield, Ill

Geographic Division Representatives

Canadian—
Eastern—F F Fullerton, Pennsylvania Electric Co, Johnstown, Pa
East Central—A C Moorhaus, The Union Gas & Electric Co, Cincinnati, Ohio
Great Lakes—L L Colvert, Public Service Co of Northern Illinois, Chicago, Ill
Middle West—F J Larsh, Des Moines Electric Co, Des Moines, Iowa
New England—W F Stevens, The Edison Electric Illuminating Co, Boston, Mass
North Central—E G Kellett, Northern States Power Co, Minneapolis, Minn
Northwest—R H Jones, Utah Power & Light Co, Salt Lake City, Utah
Pacific Coast—
Rocky Mountain—H P Tewksbury, Public Service Co of Colorado, Denver, Colo
Southeastern—Thomas E Bartlett, Florida Power Corp, St Petersburg, Fla
Southwestern—H C Loehr, Central Power & Light Co, San Antonio, Tex

STATISTICS COMMITTEE

To study and report on statistical methods, both company and national, including standards in terminology, reporting forms and graphic presentation; to assist in the preparation and collection of national statistics for the electric light and power industry

Chairman, Harry A Snow, The Detroit Edison Co, Detroit, Mich
Vice-Chairman, E J Fowler, Commonwealth Edison Co, Chicago, Ill
F A Brown, Northern States Power Co, Minneapolis, Minn
Howard Duryea, South Eastern Engineering Co, Birmingham, Ala
L S Goodman, The Edison Electric Illuminating Co, Boston, Mass
Loren Imlay, Buffalo, Niagara & Eastern Power Corp, Buffalo, N Y
E B Lee, Electric Bond & Share Co, New York, N Y
Lyle McDonald, Public Service Electric & Gas Co, Newark, N J
R G Smith, The North American Co, New York, N Y
G U Stewart, The Philadelphia Electric Co, Philadelphia, Pa

Geographic Division Representatives

Canadian—
Eastern—H M Cobb, The Philadelphia Electric Co, Philadelphia, Pa
East Central—W A Patterson, Kentucky Utilities Co, Louisville, Ky
Great Lakes—C A Turner, Middle West Utilities Co, Chicago, Ill
Middle West—A G Beisenherz, Missouri Gas & Electric Co, Lexington, Mo
New England—W J Ray, Narragansett Electric Co, Providence, R I
North Central—L L Benedict, Interstate Power Co, Dubuque, Iowa
Northwest—B Gadeholt, Northwestern Electric Co, Portland, Ore
Pacific Coast—W C F West, Los Angeles Gas & Electric Corp, Los Angeles, Cal
Rocky Mountain—C Jacobson, Mountain States Power Co, Casper, Wyo
Southeastern—C J Curry, Carolina Power & Light Co, Raleigh, N C
Southwestern—N A Easter, Central & South West Utilities Co, Dallas, Tex

Commercial National Section

Scope of Activity

The scope of activities of the Commercial National Section shall be to encourage commercial progress through teamwork between the branches of our industry and groups directly interested with the National Electric Light Association in electrical development; to analyze the commercial needs of the industry; to make surveys and plans for sales development, and to advance by all constructive means the use of electrical energy for light, heat and power for public service.

EXECUTIVE COMMITTEE

Officers

Chairman, Marshall E Sampsell, Central Illinois Public Service Co, Chicago, Ill

Vice-Chairman, Frank D Pembleton, Public Service Electric & Gas Co, Newark, N J

Vice-Chairman, T O Kennedy, The Ohio Public Service Co, Cleveland, Ohio

Vice-Chairman, V M F Tallman, Charles H Tenney & Co, Boston, Mass

Members at Large

(Terms expiring June 30, 1929)

J E Davidson, *ex-officio,* Nebraska Power Co, Omaha, Neb
A K Baylor, General Electric Co, New York, N Y
W L Frost, Southern California Edison Co, Los Angeles, Cal
S L Nicholson, Westinghouse Electric & Manufacturing Co, New York, N Y

(Terms expiring June 30, 1930)

C L Harold, Brooklyn Edison Co, Inc, Brooklyn, N Y
A C McMicken, Portland Electric Power Co, Portland, Ore
M E Skinner, Mohawk Hudson Power Corp, Albany, N Y

Geographic Division Representatives

Canadian—L W Pratt, Dominion Power & Transmission Co, Hamilton, Can
Eastern—H C Thuerk, Associated Gas & Electric Systems, New York, N Y
East Central—M W Arthur, Northern Ohio Power & Light Co, Akron, Ohio
Great Lakes—W H Sammis, Consumers Power Co, Jackson, Mich
Middle West—C A Nash, United Power & Light Corp, Davenport, Ia
New England—A S Moore, The Edison Electric Illuminating Co, Brockton, Mass
North Central—C J Strike, Northwestern Public Service Co, Huron, S D
Northwest—Lewis A Lewis, The Washington Water Power Co, Spokane, Wash
Pacific Coast—James J Pollard, Pacific Gas & Electric Co, Salinas, Cal
Rocky Mountain—Fred Norcross, Home Gas & Electric Co, Greeley, Colo
Southeastern—Charles R Preston, Florida Power & Light Co, Miami, Fla
Southwestern—G B Richardson, Texas Power & Light Co, Dallas, Tex

Bureau and Related Committee Chairmen

Commercial and Industrial Power and Heating Bureau
V M F Tallman, Charles H Tenney & Co, Boston, Mass

Commercial Cooking Committee
O Wilhelmy, The Union Gas & Electric Co, Cincinnati, Ohio

General Power Committee
H C Thuerk, Erie Lighting Co, Erie, Pa

Industrial Heating Committee
J L Faden, The Edison Electric Illuminating Co, Boston, Mass

Lighting Bureau
T O Kennedy, The Ohio Public Service Co, Cleveland, Ohio

Commercial and Industrial Lighting Committee
J Daniels, The Edison Electric Illuminating Co, Boston, Mass

Electrical Advertising Committee
C J Eaton, Middle West Utilities Co, Chicago, Ill

Home Lighting Committee
W T Blackwell, Public Service Electric & Gas Co, Newark, N J

Street Lighting Committee
R J Malcomson, Public Service Co of Northern Illinois, Chicago, Ill

Merchandising Bureau
Frank D Pembleton, Public Service Electric & Gas Co, Newark, N J

Domestic Electric Range Committee
Frank A Coupal, Buffalo, Niagara & Eastern Power Corp, Buffalo, N Y

Merchandise Sales Committee
C L Harold, Brooklyn Edison Co, Inc, Brooklyn, N Y

Refrigeration Committee
C L Dunn, The Ohio Public Service Co, Cleveland, Ohio

Water Heating Committee
Norman T Wilcox, Stone & Webster, Inc, Boston, Mass

Committee Chairmen

Customer Relations Committee
H T East, Public Service Co of Northern Illinois, Chicago, Ill

Promotional Rates Committee
E W Lloyd, Commonwealth Edison Co, Chicago, Ill

Wiring Sales Committee
A P Good, Commonwealth Edison Co, Chicago, Ill

Commercial Director

C E Greenwood, N E L A Headquarters, New York, N Y

COMMERCIAL AND INDUSTRIAL POWER AND HEATING BUREAU

Chairman, V M F Tallman, Charles H Tenney & Co, Boston, Mass
Vice-Chairman, W H Sammis, Consumers Power Corp, Jackson, Mich

Committee Chairmen

Commercial Cooking
O Wilhelmy, The Union Gas & Electric Co, Cincinnati, Ohio

General Power
H C Thuerk, Associated Gas & Electric Systems, New York, N Y

Industrial Heating
J L Faden, The Edison Electric Illuminating Co, Boston, Mass

Geographic Division Representatives

Canadian—D M Gall, Montreal Light, Heat & Power Construction Co, Montreal, Can
Eastern—F T Brook, Philadelphia Suburban-Counties Gas & Electric Co, Philadelphia, Pa
East Central—S A Wills, Appalachian Electric Power Co, Huntington, W Va
Great Lakes—A S McLay, The Detroit Edison Co, Detroit, Mich
Middle West—George Ahlborn, Kansas Power & Light Co, Topeka, Kan
New England—A W Milliken, New Bedford Gas & Edison Light Co, New Bedford, Mass
North Central—Carl J Johnson, Otter Tail Power Co, Fergus Falls, Minn
Northwest—E E Scofield, The Washington Water Power Co, Spokane, Wash
Pacific Coast—P P Pine, San Diego Consolidated Gas & Electric Co, San Diego, Cal
Rocky Mountain—E L Siekmann, Public Service Co of Colorado, Leadville, Colo
Southeastern—C P Mills, Southern Georgia Power Co, Albany, Ga
Southwestern—J R McCoy, Central Power & Light Co, San Antonio, Tex

COMMERCIAL COOKING COMMITTEE

To analyze results now being secured with electric heat in commercial cooking, and secure data on energy consumption; to analyze the value of electric baking as a load builder, and by operation of schools, and the preparation of articles on the subject, to train men for selling and promote the development of commercial cooking; to cooperate with Bakery Associations and other contacts which will be of value in development work

Chairman, O Wilhelmy, The Union Gas & Electric Co, Cincinnati, Ohio
Vice-Chairman, Delton T Waby, Public Service Co of Northern Illinois, Chicago, Ill
Ell C Bennett, Bennett, Watts, Haywood Co, Chicago, Ill
Grant Call, Edison Electric Appliance Co, Inc, Chicago, Ill
Frank A Coupal, Buffalo, Niagara & Eastern Power Corp, Buffalo, N Y
J L Faden, The Edison Electric Illuminating Co, Boston, Mass
W D Gentry, Consolidated Gas, Electric Light & Power Co, Baltimore, Md
E J Hoelscher, Cleveland Electric Illuminating Co, Cleveland, Ohio
F B Jacoby, Philadelphia Electric Co, Philadelphia, Pa
A M Lloyd, Commonwealth Edison Co, Chicago, Ill
R H McGillivray, Westinghouse Electric & Manufacturing Co, Mansfield, Ohio
Frank Moore, Erie County Electric Co, Erie, Pa
Burton Ricker, Rockland Power & Light Co, Nyack, N Y
C J Russell, The Philadelphia Electric Co, Philadelphia, Pa
Wirt S Scott, Westinghouse Electric & Manufacturing Co, Mansfield, Ohio
D Senour, Edison Electric Appliance Co, Inc, Chicago, Ill
A C Shepherd, The Cleveland Electric Illuminating Co, Cleveland, Ohio
E A Speer, Alabama Power Co, Birmingham, Ala

Special Membership of Subcommittees

R M Crawford, Crawford Oven Co, New Haven, Conn
G B Eggert, Baker-Perkins Co, Saginaw, Mich
A N Otis, General Electric Co, Schenectady, N Y

GENERAL POWER COMMITTEE

To act as a clearing house for competitive power problems, to obtain data on power costs in isolated steam, gas and oil engine plants, and to study new applications of electric power

Chairman, H C Thuerk, Associated Gas & Electric System, New York, N Y
Vice-Chairman, L J Lamberger, Duquesne Light Co, Pittsburgh, Pa
E A Armstrong, Public Service Co of Northern Illinois, Chicago, Ill
L L Bailey, Monongahela West Penn Public Service Co., Fairmont, W. Va.
H W Derry, Pennsylvania Power & Light Co, Allentown, Pa
C T Gilliam, Central Power & Light Co, San Antonio, Tex
R A Graves, Kansas City Power & Light Co, Kansas City, Mo
E H Hillock, New York & Queens Electric Light & Power Co, Long Island City, N Y
E G Stahl, San Joaquin Light & Power Corp, Fresno, Cal
J W Wattles, The Edison Electric Illuminating Co, Boston, Mass

INDUSTRIAL HEATING COMMITTEE

To promote the greater use of electric heat in industry through assignment of specialists for this work by Central Stations, and the organization of industrial heating divisions (methods of organization are fully covered in Serial Report No. 276-13); to cooperate with trade and technical associations through participation in technical programs and exhibits; to conduct national and geographic industrial heating schools for the education of Central Station commercial salesmen; to prepare reports covering recent developments in the industrial heating field; to promote through the Industrial Heating Film and general publicity the use of electricity for industrial heating applications

Chairman, J L Faden, The Edison Electric Illuminating Co, Boston, Mass
Vice-Chairman, Robert M Keeney, The Connecticut Light & Power Co, Hartford, Conn
Secretary, R T Kaighin, Public Service Electric & Gas Co, Newark, N J
W E Benninghof, The Cleveland Electric Illuminating Co, Cleveland, Ohio
S Bennis, The United Electric Light & Power Co, New York, N Y
Grant Call, The Edison Electric Appliance Co, Inc, Chicago, Ill
D St Pierre DuBose, Consolidated Gas, Electric Light & Power Co, Baltimore, Md
J H Faulkner, Commonwealth Edison Co, Chicago, Ill
Harold Fulwider, General Electric Co, Schenectady, N Y
H J Hall, The Detroit Edison Co, Detroit, Mich
J D Haynesworth, Public Service Co of Northern Illinois, Chicago, Ill
R W Heller, Duquesne Light Co, Pittsburgh, Pa
R H Mather, The Shawinigan Water & Power Co, Montreal, Can
A H Rick, Electric Bond & Share Co, New York, N Y
B M Riker, Charles H Tenney & Co, Boston, Mass
E A Roeser, The Rochester Gas & Electric Corp, Rochester, N Y
Charles J Russell, The Philadelphia Electric Co, Philadelphia, Pa
W H Sammis, Consumers Power Co, Jackson, Mich
Wirt S Scott, Westinghouse Electric & Manufacturing Co, Mansfield, Ohio
E A Steinbuehler, Brooklyn Edison Co, Inc, Brooklyn, N Y
O Wilhelmy, The Union Gas & Electric Co, Cincinnati, Ohio
C P Yoder, Erie County Electric Co, Erie, Pa

LIGHTING BUREAU

Chairman, T O Kennedy, The Ohio Public Service Co, Cleveland, Ohio
Vice-Chairman, Julius Daniels, The Edison Electric Illuminating Co, Boston, Mass

Members-at-Large

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F C Eteson, Virginia Electric & Power Co, Richmond, Va
Ward Harrison, National Lamp Works of G E Co, Cleveland, Ohio
S G Hibben, Westinghouse Lamp Co, Bloomfield, N J
M Luckiesh, National Lamp Works of G E Co, Cleveland, Ohio

Committee Chairmen

Commercial and Industrial Lighting Committee
J Daniels, The Edison Electric Illuminating Co, Boston, Mass

Electrical Advertising
C J Eaton, Middle West Utilities Co, Chicago, Ill

Home Lighting
W T Blackwell, Public Service Electric & Gas Co, Newark, N J

Street Lighting
R J Malcomson, Public Service Co of Northern Illinois, Chicago, Ill

Geographic Division Representatives

Canadian—P R Labelle, The Shawinigan Water & Power Co, Montreal, Can
Eastern—H L Johnston, Duquesne Light Co, Pittsburgh, Pa
East Central—H S Nonneman, The Dayton Power & Light Co, Dayton, Ohio
Great Lakes—J M Shute, Allied Power & Light Co, Peoria, Ill
Middle West—W J Krug, Nebraska Power Co, Omaha, Neb
New England—R B Brown, Jr, The Edison Electric Illuminating Co, Boston, Mass
North Central—John Hogan, Northern States Power Co, Minneapolis, Minn
Northwest—Fred Zaugg, Northwestern Electric Co, Portland, Ore
Pacific Coast—W E Carlson, Edison Lamp Works of G E Co, San Francisco, Cal
Rocky Mountain—H T Rankin, Public Service Co of Colorado, Denver, Colo
Southeastern—B H Martin, Tennessee Electric Power Co, Chattanooga, Tenn
Southwestern—R F Judd, Mississippi Power & Light Co, Jackson, Miss

COMMERCIAL AND INDUSTRIAL LIGHTING COMMITTEE

To develop plans for promoting better lighting in commercial and industrial establishments, using valuable data secured during the Industrial Lighting Contest; to promote more adequate wiring in commercial buildings and create better contact between our industry and the architects; to direct attention to the need of industrial lighting specialists in the power company commercial departments and encourage cooperative promotion in this field

Chairman, J Daniels, The Edison Electric Illuminating Co, Boston, Mass
Secretary, J M Shute, Allied Power & Light Corp, Peoria, Ill
Willard Allphin, Fall River Electric Co, Fall River, Mass
H H Balkam, Brooklyn Edison Co, Inc, Brooklyn, N Y
H F Barnes, Edison Lamp Works, Harrison, N J
E N Beach, Westinghouse Lamp Co, Bloomfield, N J
A E Brainerd, The Philadelphia Electric Co, Philadelphia, Pa
E A Brand, New York Power & Light Corp, Albany, N Y
Scott Button, General Electric Co, Schenectady, N Y
H A Cook, The Detroit Edison Co, Detroit, Mich
C L Dunn, The Ohio Public Service Co, Cleveland, Ohio
F C Eteson, Virginia Electric & Power Co, Richmond, Va
J C Fisher, Consolidated Gas, Electric Light & Power Co, Baltimore, Md
L K Franke, The Rochester Gas & Electric Corp, Rochester, N Y
Ward Harrison, National Lamp Works of G E Co, Cleveland, Ohio
H V Hartman, The New York Edison Co, New York, N Y
S G Hibben, Westinghouse Lamp Co, Bloomfield, N J
W H Horton, Jr, West Penn Power Co, Pittsburgh, Pa
H L Johnston, Duquesne Light Co, Pittsburgh, Pa
L C Kent, National Lamp Works of G E Co, Cleveland, Ohio
A L Powell, Edison Lamp Works, Harrison, N J
W F Rooney, The Edison Electric Illuminating Co, Boston, Mass
George H Stickney, Edison Lamp Works, Harrison, N J
E Stryker, National Lamp Works of G E Co, Cleveland, Ohio
Walter Sturrock, National Lamp Works of G E Co, Cleveland, Ohio
A H Thayer, The Cleveland Electric Illuminating Co, Cleveland, Ohio
S W Thompson, Commonwealth Edison Co, Chicago, Ill

Society for Electrical Development Representatives

D C Birdsell, Decorative Lamp & Shade Co, Philadelphia, Pa
R Bourke Corcoran, The Electric Association, Chicago, Ill

Reports Subcommittee

Chairman, A L Powell; S G Hibben, L C Kent

Schools Subcommittee

Chairman, E D Stryker; A E Brainerd, Scott Button, H A Cook, R Bourke Corcoran, S G Hibben, W H Horton, Jr, W F Rooney, George H Stickney, Walter Sturrock

Standards Subcommittee

Chairman, George H Stickney; E A Brand, H A Cook, J C Fisher, Ward Harrison, S G Hibben, W H Horton, Jr

ELECTRICAL ADVERTISING COMMITTEE

Shall through every means possible promote widespread interest in all the benefits accruing from electrical advertising; program shall embrace a thorough study of all pertinent factors pertaining to this subject. Concluding results shall be incorporated in serial reports and such other manner or form as would be consistent and most profitable to our industry

Chairman, C J Eaton, Middle West Utilities Co, Chicago, Ill
Vice-Chairman, L W McLellen, Kentucky Utilities Co, Louisville, Ky
E M Beach, Westinghouse Lamp Co, New York, N Y
W T Blackwell, Public Service Electric & Gas Co, Newark, N J
W C Brown, National Lamp Works of G E Co, Cleveland, Ohio
C O Dunten, Central & South West Utilities Co, Dallas, Tex
E B Fox, Edison Lamp Works of G E Co, Harrison, N J
James M Gilchrist, Federal Electric Co, Chicago, Ill
W H Horton, Jr, West Penn Power Co, Pittsburgh, Pa
D W Howard, Commonwealth Edison Co, Chicago, Ill
W D Krupke, Federal Electric Co, Chicago, Ill
Donald Mackie, Allied Power & Light Corp, Jackson, Mich
E A Mills, The New York Edison Co, New York, N Y
W J Moore, Society for Electrical Development, New York, N Y
E E Potter, Edison Lamp Works of G E Co, Harrison, N J
T E Roach, National Electric Power Co, New York, N Y
M R Rodger, Central Illinois Public Service Co, Springfield, Ill
H G Russell, Opalume Sign System, Battle Creek, Mich
J M Stafford, Jr, Georgia Power Co, Atlanta, Ga
R R Wiley, Flexlume Corp, Buffalo, N Y
H N Wood, Pennsylvania-Ohio Power & Light Co, Youngstown, Ohio
O D Ziegler, Reynolds Electric Co, Chicago, Ill

To Submit Report for Committee as a Whole as a Basis for Outline of Activities Subcommittee

Chairman, Donald M Mackie; W C Brown, W H Horton, Jr, Walter Krupke, L W McLellen

Accounting Matters Subcommittee

Chairman, T E Roach

Electric Sign Week Subcommittee

Chairman, J M Stafford, Jr; W C Brown

Exhibition Subcommitee

Chairman, W J Moore

Federal Award Subcommittee

Chairman, W D Krupke

Model Sign Ordinances Subcommittee

Chairman, W T Blackwell

Preparation of Model Sign Maintenance Plans Subcommittee

Chairman, H N Wood

Training Schools. Cooperation With National Window Display Advertising Association Subcommittee

Chairman, E E Potter; W C Brown

HOME LIGHTING COMMITTEE

To undertake analysis of residential campaigns as a basis for planning new ones; to prepare recommendations for Central Stations to secure trained women in Home Lighting Service; to investigate sources of literature on Home Lighting; to sponsor competitive fixture extibit in connection with the Annual Convention, and to promote more effective lighting service work in power companies

Chairman, W T Blackwell, Public Service Electric & Gas Co, Newark, N J
D W Atwater, Westinghouse Lamp Co, Bloomfield, N J
Mrs Bernice Bowser, Bowser Lamp Service, New York, N Y
Miss Florence Clauss, *Electrical Merchandising,* New York, N Y
E W Comery, National Lamp Works of G E Co, Cleveland, Ohio
C L Dunn, The Ohio Public Service Co, Cleveland, Ohio
Mrs Phyllis Dunning, Society for Electrical Development, New York, N Y
Mrs Mariquita Dygert, The Detroit Edison Co, Detroit, Mich
C H Ferris, Illuminating Glassware Guild, New York, N Y
J Carl Fisher, Consolidated Gas, Electric Light & Power Co, Baltimore, Md
Miss Helen W Hardy, Public Service Electric & Gas Co, Newark, N J
Ward Harrison, National Lamp Works of G E Co, Cleveland, Ohio
H V Hartman, The New York Edison Co, New York, N Y
J M Hickerson, Miller Co, Meriden, Conn
F V Loomis, Consolidated Lamp & Glass Co, Coraopolis, Pa
M Luckiesh, National Lamp Works of G E Co, Cleveland, Ohio
Miss Helen G McKinlay, Edison Lamp Works, Harrison, N J
P S Millar, Electrical Testing Laboratories, Inc, New York, N Y
E E Potter, Edison Lamp Works, Harrison, N J
A L Powell, Edison Lamp Works, Harrison, N J
G P Rogers, Artistic Lighting Equipment Association, New York, N Y
Mrs Sarai C Waugh, Westchester Lighting Co, Mt Vernon, N Y
Miss Mary Webber, National Lamp Works of G E Co, Cleveland, Ohio

Special Membership of Subcommittees

L C Kent, National Lamp Works of G E Co, Cleveland, Ohio
W F Little, Electrical Testing Laboratories, Inc, New York, N Y
R E Swift, Atlantic City Electric Co, Atlantic City, N J

Competitive Lighting Exhibit Subcommittee

Chairman, P S Millar; H V Hartman, L C Kent, W F Little, R E Swift

Critical Analysis of Residential Campaigns Subcommittee

Chairman, E W Comery

Home Lighting Literature Subcommittee

Chairman, Miss Helen W Hardy; Mrs. Bernice Bowser, Miss Florence Clauss, Mrs Phyllis Dunning, Mrs Mariquita Dygert, Miss Helen McKinlay, Mrs Sarai Waugh, Miss Mary Webber

Lighting Service Subcommittee

Chairman, J Carl Fisher

Promotion of Home Lighting Service Subcommittee

Chairman, Mrs Sarai Waugh; Mrs Bernice Bowser, Miss Florence Clauss, Mrs Phyllis Dunning, Mrs Mariquita Dygert, Miss Helen W Hardy, Miss Helen McKinlay, Miss Mary Webber

STREET LIGHTING COMMITTEE

To place street lighting before the commercial executives of the central stations as a sales responsibility; to develop a street lighting sales plan to present to commercial managers so that this activity will receive the same aggressive sales efforts as other more familiar load building activities receive

Street lighting will be shown as key to development of entire lighting program of the central station. Study and survey will be made regarding street lighting practices in the various parts of the country with view in mind of presenting actual conditions in the various central stations so as to provide a guide to any utility contemplating street lighting promotion

Study will be made of highway lighting, reviewing what has been done and what should be done in future to develop this rural lighting program. Cooperation with other lighting committees to include street lighting in all lighting sales programs will be kept before the committee at all times

Chairman, R J Malcomson, Public Service Co of Northern Illinois, Chicago, Ill
Vice-Chairman, M R Rodger, Central Illinois Public Service Co, Springfield, Ill
H S Beagle, New York Power & Light Corp, Albany, N Y
William P Bear, Pacific Gas & Electric Co, San Francisco, Cal
W T Blackwell, Public Service Electric & Gas Co, Newark, N J
J P Campbell, The Cleveland Electric Illuminating Co, Cleveland, Ohio
J A Cook, Lynn Gas & Electric Co, Lynn, Mass
J Carl Fisher, Consolidated Gas, Electric Light & Power Co, Baltimore, Md
Samuel G Hibben, Westinghouse Lamp Co, Bloomfield, N J
James E Ingram, Jr, Welsbach Electric Street Lighting Co Philadelphia, Pa
Preston S Millar, Electrical Testing Laboratories, Inc, New York, N Y
R B Patterson, Potomac Electric Power Co, Washington, D C
W A Porterfield, The Union Metal Manufacturing Co, Canton, Ohio
T W Rolph, Holophane Company, Inc, Newark, Ohio
G H Stickney, Edison Lamp Works, Harrison, N J
S W Thompson, Commonwealth Edison Co, Chicago, Ill
F H Winkley, General Electric Co, Schenectady, N Y
L A S Wood, Westinghouse Electric & Manufacturing Co, South Bend, Ind

Highway Lighting Subcommittee

Chairman, W A Porterfield; W T Blackwell, M R Rodger, F H Winkley

Street Lighting Practice Subcommittee

Chairman, T W Rolph; S G Hibben, Preston S Millar, G H Stickney, L A S Wood

Street Lighting Sales Plans Subcommittee

Chairman, L A S Wood; J Carl Fisher, Preston S Millar, M R Rodger, F H Winkley

MERCHANDISING BUREAU

Chairman Frank D Pembleton, Public Service Electric & Gas Co, Newark, N J
Vice-Chairman, Norman T Wilcox, Stone & Webster, Inc, Boston, Mass

Members-at-Large

L J Montgomery, New York & Queens Electric Light & Power Co, Long Island City, N Y

Committee Chairmen

Domestic Electric Range

Frank A Coupal, Buffalo, Niagara & Eastern Power Corp, Buffalo, N Y

Merchandise Sales

C L Harold, Brooklyn Edison Co, Inc, Brooklyn N Y

Refrigeration

C L Dunn, The Ohio Public Service Co, Cleveland, Ohio

Water Heating

Norman T Wilcox, Stone & Webster, Inc, Boston, Mass

Geographic Division Representatives

Canadian—
Eastern—William Geiger, The Philadelphia Electric Co, Philadelphia, Pa
East Central—E T Schmidt, Toledo Edison Co, Toledo, Ohio
Great Lakes—E L Hinchcliff, Middle West Utilities Co, Chicago, Ill
Middle West—Stanley Taber, Iowa-Nebraska Light & Power Co, Lincoln, Neb
New England—D M DeBard, Stone & Webster, Inc, Boston, Mass
North Central—C M Baldwin, Minnesota Power & Light Co, Duluth, Minn
Northwest—V H Moon, Pacific Power & Light Co, Portland, Ore
Pacific Coast—H C Rice, Southern California Edison Co, Los Angeles, Cal
Rocky Mountain—E F Stone, Southern Colorado Power Co, Pueblo, Colo
Southeastern—J F Derge, Florida Power & Light Co, Miami, Fla
Southwestern—W J Aicklen, Houston Lighting & Power Co, Houston, Tex

DOMESTIC ELECTRIC RANGE COMMITTEE

To stimulate sales plans for promoting electric cookery not only through electric companies, but through combination companies; to further the education of sales people for electric range selling; to compile helpful statistics in connection with exploitation of electric cookery; to formulate a program designed to interest non-electrical dealers in handling electric ranges cooperatively with their local utilities; to consider the advisability of simplifying wiring methods to reduce initial installation cost to the consumer

Chairman, Frank A Coupal, Buffalo, Niagara & Eastern Power Corp, Buffalo, N Y
Ell C Bennett, Bennett, Watts, Haywood Co, Chicago, Ill
H M Camp, The Tennessee Electric Power Co, Chattanooga, Tenn
H P Dilkes, The Philadelphia Electric Co, Philadelphia, Pa
A J Lindermann, Lindermann & Haversan, Milwaukee, Wis
A V Lindsley, The Connecticut Light & Power Co, Hartford, Conn
P L Miles, Edison Electric Appliance Co, Inc, Chicago, Ill
Reese Mills, Westinghouse Electric & Manufacturing Co, Mansfield, Ohio
L W Pratt, Dominion Power & Transmission Co, Hamilton, Can
Mrs Eva Hawkins Shanks, Public Service Co of Northern Illinois, Chicago, Ill
R W Staud, Benjamin Electric Manufacturing Co, Chicago, Ill
Earl Whitehorne, *Electrical World,* New York, N Y

Education of Sales People Subcommittee

Chairman, R W Staud; Mrs Eva Hawkins Shanks

Market Survey Subcommittee

Chairman, P L Miles; Reese Mills

Range Wiring Subcommittee

Chairman, H P Dilkes; A V Lindsley, L W Pratt

Sales Analysis Subcommittee

Chairman; Ell C Bennett; Earl Whitehorne

MERCHANDISE SALES COMMITTEE

To develop broader marketing plans and better trade relations; to analyze the market for load building appliances; to stimulate appliance sales through advertising and through cooperative marketing plans; to stimulate the sale of more kilowatt-hours; to study new fields of appliance selling, especially appliances for the farm, and power radio

Chairman, C L Harold, Brooklyn Edison Co, Inc, Brooklyn, N Y
A K Baylor, General Electric Co, New York, N Y
C O Dunton, Central & South West Utilities Co, Dallas, Tex
Harry C Hahn, Electric Vacuum Cleaner Co, Cleveland, Ohio
Thomas F Kelley, The Hoover Vacuum Cleaner Co, North Canton, Ohio
Harvey R Keys, Duquesne Light Co, Pittsburgh, Pa
C K Magers, The Union Gas & Electric Co, Cincinnati, Ohio
H J Mauger, Edison Electric Appliance Co, Chicago, Ill
M C Morrow, Westinghouse Electric & Manufacturing Co, Mansfield, Ohio
Grover C Neff, Wisconsin Power & Light Co, Madison, Miss
Ralph Neumuller, The United Electric Light & Power Co, New York, N Y
C E Nichols, The New York Edison Co, New York, N Y
G Ostlund, Westchester Lighting Co, Mt Vernon, N Y
H A Pendergraph, Georgia Power Co, Atlanta, Ga
Dorsey Smith, Consolidated Gas, Electric Light & Power Co, Baltimore, Md
C V Sorensen, Attica Electric Co, Attica, Ind
J S Sutherland, Alabama Power Co, Birmingham, Ala
Stanley Taber, Iowa-Nebraska Light & Power Co, Lincoln, Neb
H D Valentine, Central Hudson Gas & Electric Co, Poughkeepsie, N Y
J H Van Aernam, New York Power & Light Corp, Albany, N Y
C P Wagner, Northern States Power Co, Minneapolis, Minn
Frank W Watts, *Electric Light & Power,* New York, N Y
Earl Whitehorne, *Electrical World,* New York, N Y
H E Young, Northern States Power Co, Minneapolis, Minn
Miss Clara H Zillessen, The Philadelphia Electric Co, Philadelphia, Pa

Advertising Subcommittee

Chairman, Earl Whitehorne; C K Magers, H J Mauger, Ralph Neumuller, H D Valentine, Miss Clara H Zillessen

Atlantic City Exhibit Subcommittee

Chairman, H D Valentine; A K Baylor, Ralph Neumuller, Earl Whitehorne

Farm Equipment Sales Subcommittee

Chairman, Grove C Neff; H A Pendergraph, C V Sorensen, Stanley Taber, C P Wagner

Oil Burners Subcommittee

Chairman, A K Baylor; C E Nichols, H D Valentine, H E Young

K.W.H. Contest Prizes Subcommittee

Chairman, C L Harold; A K Baylor, M C Morrow, Earl Whitehorne

Quality Standards Subcommittee

Chairman, H D Valentine

Radio Subcommittee

Chairman, J H Van Aernam; C O Dunton, Harvey R Keys, Dorsey Smith, J S Sutherland

REFRIGERATION COMMITTEE

To develop plans for promoting the electric refrigeration load, and to devise sales plans; to cooperate with the manufacturers of refrigeration equipment in broad plans to sell the need of food preservation for health and economy, culminating this effort in national educational activity

Chairman, C L Dunn, The Ohio Public Service Co, Cleveland, Ohio
Cyrus Barnes, Charles H Tenney & Co, Boston, Mass
G B Buck, Public Service Co of Colorado, Denver, Colo
W E Clement, New Orleans Public Service Inc, New Orleans, La
J A Corcoran, Kelvinator Detroit Co, Detroit, Mich
Mrs Cecil Harvey, Westchester Lighting Co, Mt Vernon, N Y
Henry W Hennig, Public Service Co of New Jersey, Newark, N J
T P Kindig, *Electrical World* New York, N Y
P Lorch, The New York Edison Co, New York, N Y
J E North, Electrical League, Cleveland, Ohio
George A Stewart, Interstate Public Service Co, Indianapolis, Ind
Stanley Taber, Iowa-Nebraska Light & Power Co, Lincoln, Neb
M C Terry, Westinghouse Electric & Manufacturing Co, Mansfield, Ohio
J Hall Truman, Stevens & Wood, Inc, New York, N Y
Earl Whitehorne, *Electrical World,* New York, N Y
W R Winans, Frigidaire Corp, New York, N Y
H E Young, Northern States Power Co, Minneapolis, Minn
P B Zimmerman, General Electric Co, Cleveland, Ohio

Educational Plan Subcommittee

Chairman, J Hall Truman; J A Corcoran, Earl Whitehorne

WATER HEATING COMMITTEE

To conduct a comprehensive survey of apparatus available; to make field tests of the many practices of water heating methods now in use with the idea of determining the best methods of water heating installations; to study load characteristics of electric water heating, and to ascertain and recommend practical methods of developing potential load

Chairman, Norman T Wilcox, Stone & Webster, Inc, Boston, Mass
M T Crawford, Puget Sound Power & Light Co, Seattle, Wash
J F Derge, Florida Power & Light Co, Miami, Fla
C J Eaton, Middle West Utilities Co, Chicago, Ill
W E Goring, Dominion Power & Transmission Co, Ltd, Hamilton, Can
R S Hale, Edison Electric Illuminating Company of Boston, Boston, Mass
A V Jones, Buffalo General Electric Co, Buffalo, N Y
J C Langdell, Consumers Power Co, Jackson, Mich
W H McInnis, Columbus Power & Light Co, Columbus, Ga
W C McWhinney, Southern California Edison Co, Los Angeles, Cal
Earl Nichols, Iowa Railway & Light Co, Cedar Rapids, Iowa
George D Nutting, Edison Electric Illuminating Co, Detroit, Mich
H C Wilder, Rome Wire Co, Rome, N Y

CUSTOMER RELATIONS COMMITTEE

To promote good-will and improve the relationship between electric light and power companies and their customers by formulating efficient methods for handling customer contacts. The Committee's work covers all practices and policies which influence the attitude of the customer toward the company, such as application procedures, simplification of methods, improvement of forms, development of routines, handling of inquiries and complaints, meter reading, collections and credits, telephone and correspondence communications and general improvement of service

To prepare monthly reports on customer relations subjects for publication in the N E L A Monthly Bulletin under the title "Service Suggestions"

To cooperate with all other Committees in the promotion of good-will

Chairman, H T East, Public Service Co of Northern Illinois, Chicago, Ill
Vice-Chairman, J G Ross, The Rochester Gas & Electric Corp, Rochester, N Y

Members at Large

R F Bonsall, Consolidated Gas, Electric Light & Power Co, Baltimore, Md
Miss Marguerite Butler, Portland Electric Power Co, Portland, Ore
J W De Maine, Northern States Power Co, Minneapolis, Minn
G J Leibman, Brooklyn Edison Co, Inc, Brooklyn, N Y
C E Michel, Union Electric Light & Power Co, St Louis, Mo
X J Montreuil, New York & Queens Electric Light & Power Co, Long Island City, N Y
H L Nickerson, Southwestern Gas & Electric Co, Shreveport, La
H L Oulliber, New Orleans Public Service Co, Inc, New Orleans, La
H M Pace, South Carolina Power Co, Charleston, S C
Paul Renshaw, Memphis Power & Light Co, Memphis, Tenn
Louis Stoecker, Public Service Electric & Gas Co, Newark, N J
P G Vondersmith, The Union Gas & Electric Co, Cincinnati, Ohio
Harold Wright, Commonwealth Edison Co, Chicago, Ill

Geographic Division Representatives

Canadian—
Eastern—H W Ewald, Electrical League of Pittsburgh, Pittsburgh, Pa
East Central—H N Wood, Pennsylvania-Ohio Power & Light Co, Youngstown, Ohio
Great Lakes—L M LaPorte, Milwaukee Electric Railway & Light Co, Milwaukee, Wis
Middle West—E J Otterbein, Peoples Light Co, Davenport, Iowa
New England—Ralph H Wheelock, Narragansett Electric Co, Providence, R I
North Central—R A Bearnes, Interstate Power Co, Albert Lea, Minn
Northwest—W A Schoel, Puget Sound Power & Light Co, Everett, Wash
Pacific Coast—Ward C Schafer, Pacific Gas & Electric Co, Stockton, Cal
Rocky Mountain—Ralph W Booze, Colorado Central Power Co, Golden, Colo
Southeastern—Frank R Mitchell, Georgia Power Co, Atlanta, Ga
Southwestern—T H Williams, Texas Power & Light Co, Waco, Tex

PROMOTIONAL RATES COMMITTEE

To review rate forms that may be developed in different power companies established for domestic service, and to urge the adoption of "promotional" forms which will be of benefit to the public and the company in selling greater electric service

Chairman, E W Lloyd, Commonwealth Edison Co, Chicago, Ill
A K Baylor, General Electric Co, New York, N Y
Robert S Hale, The Edison Electric Illuminating Co, Boston, Mass
Thomas F Kennedy, Henry L Doherty & Co, New York, N Y
F E Kruesi, Middle West Utilities Co, Chicago, Ill
Miss Sarah Sheridan, The Detroit Edison Co, Detroit, Mich

WIRING SALES COMMITTEE

To promote sales activity directed toward adequate wiring installations; to develop wiring materials and methods of wiring; to watch wiring developments for needed revisions of the National Electrical Code

Chairman, A P Good, Commonwealth Edison Co, Chicago, Ill
Vice-Chairman, J D Noyes, The Detroit Edison Co, Detroit, Mich
L L Bailey, West Penn Power Co, Pittsburgh, Pa
E A Brand, New York Power & Light Corp, Albany, N Y
J W Cowles, The Edison Electric Illuminating Co, Boston, Mass
M C Huse, The Philadelphia Electric Co, Philadelphia, Pa
G E Miller, The Cleveland Electric Illuminating Co, Cleveland, Ohio
Ralph Neumueller, The United Electric Light & Power Co, New York, N Y
Walter Sturrock, National Lamp Works of G E Co, Nela Park, Cleveland, Ohio

Geographic Division Representatives

Canadian—J K Wilson, The Shawinigan Water & Power Co, Montreal, Can
Eastern—L L Bailey, West Penn Power Co, Pittsburgh, Pa
East Central—G E Miller, The Cleveland Electric Illuminating Co, Cleveland, Ohio
Great Lakes—J D Noyes, The Detroit Edison Co, Detroit, Mich
Middle West—
New England—R J Forsyth, Greenfield Electric Light & Power Co, Greenfield, Mass
North Central—C R Perkins, Eastern Minnesota Power Co, Pine City, Minn
Northwest—Rome C Saunders, Puget Sound Power & Light Co, Tacoma, Wash
Pacific Coast—W A Cyr, McGraw-Hill Co, San Francisco, Cal
Rocky Mountain—Luke Storey, Home Gas & Electric Co, Greeley, Colo
Southeastern—W W Barr, Georgia Power Co, Dublin, Ga
Southwestern—J O Bannahan, Houston Lighting & Power Co, Houston, Tex

Contact Member for Commercial National Section

L B Bonnett, Brooklyn Edison Co, Brooklyn, N Y

Contact Member for Commercial and Industrial Lighting Committee

E A Brand, New York Power and Light Corp, Albany, N Y

Contact Member for Merchandise Sales Committee

Earl Whitehorne, *Electrical World,* New York, N Y

Metropolitan Area, New York City, Member-at-Large

L A Scofield, The United Electric Light and Power Co, New York, N Y

Revision of National Electrical Code Subcommittee

To study the Code for needed changes; to compile data which would support definite proposals to change the Code; to examine proposals of other organizations for changes in the Code and to prepare in advance data supporting or opposing such proposed changes according as they prove to be for or against the Subcommittee's conception of the interest of the electrical industry

Chairman, A P Good

Wiring Sales Promotion Subcommittee

To promote sales activity directed toward adequate wiring installations

Chairman, E A Brand; L L Bailey, Ralph Neumueller, Walter Sturrock

Wiring Materials and Methods Subcommittee

To develop methods of wiring; to study, develop and test wiring materials, flexible cords, etc

Chairman, John D Noyes; J W Cowles, A P Good, M C Huse, G E Miller

Engineering National Section

Scope of Activity

The Section deals with all engineering matters. Its major purposes are:

(a) To accelerate the development of the art through studies of important engineering problems and interchange of ideas. (b) To keep engineers informed as to the latest and best developments and operating practices in power system engineering by providing opportunity for discussion of their problems and by the compiling and distribution of serial reports of important engineering developments and practices. (c) To set up authoritative engineering policies for the industry in matters dealing with codes and standards, joint construction with other utilities and all subjects in which engineering contact is had with other interests.

The work of the Section is handled by Committees whose activities include the following:

To investigate and report tendencies and developments in design, installation and operation of and experience with electric power systems and the apparatus and equipment used in connection therewith. To study intensively the problems of electric power generation, transmission and distribution to encourage constructive efforts by member companies in the form of investigations, tests and other suitable means to better understand the conditions to which power systems and their apparatus are subjected in service. To ascertain the requirements of the industry concerning apparatus to be used and to see that the manufacturers are thoroughly informed as to such requirements. To follow through appropriate cross-representation the work of other committees of this Association which is of interest to the Section, with a view to coordinating such work. To follow codification and standardization work particularly with the bodies engaged in the actual formulation of standards; to maintain a suitable committee policy for dealing with the technical subject matter of standards, and when appropriate, to initiate activities in connection with such subjects when these are deemed necessary to properly protect and promote the best interests of the industry. To provide representation as deemed desirable and proper from time to time on committees of other organizations working within the field of this Section, in order to properly protect the interests of the industry.

At the present time the work of the Section is directed toward the following major objectives:

More kilowatts of system capacity per dollar of investment. Definite advance planning of system development, and coordination of adjacent systems. Comprehensive research in fundamental engineering problems of the industry, coordinated through the committees. Recruiting and training of adequate engineering personnel. Better content and wider distribution of serial reports. Study of and, when desirable, reports on national engineering issues affecting our industry. Constructive cooperation in the national movement for standardization. Greater engineering service to the industry through closer cooperation with other Sections and Committees.

EXECUTIVE COMMITTEE

Officers

Chairman, E C Stone, Duquesne Light Co, Pittsburgh, Pa
Vice-Chairman, Thomas Sproule, Public Service Electric & Gas Co, Newark, N J
Vice-Chairman, A D Bailey, Commonwealth Edison Co, Chicago, Ill
Vice-Chairman, Nicholas Stahl, Pennsylvania Power & Light Co, Allentown, Pa

Members at Large

(Terms expiring June 30, 1929)

C F Hirshfeld, *Ex-officio,* The Detroit Edison Co, Detroit, Mich
H L Doolittle, Southern California Edison Co, Los Angeles, Cal
K R MacKinnon, Nebraska Power Co, Omaha, Neb
W E Mitchell, Georgia Power Co, Atlanta, Ga

(Terms expiring June 30, 1930)

C M Allen, Worcester Polytechnic Institute, Worcester, Mass
C L Lefever, Northwestern Electric Co, Portland, Ore
H R Woodrow, Brooklyn Edison Co, Inc, Brooklyn, N Y

Geographic Division Representatives

Canadian—C V Christie, McGill University, Montreal, Can
Eastern—C H Frick, Pennsylvania Power & Light Co, Allentown, Pa
East Central—Wm Shuler, The Dayton Power & Light Co, Dayton, Ohio
Great Lakes—F E Andrews, Public Service Co of Northern Illinois, Chicago, Ill
Middle West—C L Karr, Kansas Gas & Electric Co, Wichita, Kan
New England—C A Mayo, Malden Electric Co, Malden, Mass
North Central—J A Colvin, Northern States Power Co, Minneapolis, Minn
Northwest—D W Proebstel, Portland Electric Power Co, Portland, Ore
Pacific Coast—N B Hinson, Southern California Edison Co, Los Angeles, Cal
Rocky Mountain—P S Schools, Western Colorado Power Co, Durango, Colo
Southeastern—H J Scholz, Alabama Power Co, Birmingham, Ala
Southwestern—R F Danner, Oklahoma Gas & Electric Co, Oklahoma City, Okla

Committee Chairmen

Accident Prevention Committee
C R Beardsley, Brooklyn Edison Co, Inc, Brooklyn, N Y

Electrical Apparatus Committee
J A Johnson, The Niagara Falls Power Co, Niagara Falls, N Y

Engineering Administration Committee
H P Liversidge, The Philadelphia Electric Co, Philadelphia, Pa

Hydraulic Power Committee
Byron E White, Utica Gas & Electric Co, Utica, N Y

Inductive Coordination Committee
H L Wills, Georgia Power Co, Atlanta, Ga

Meter Committee
E E Hill, The New York Edison Co, New York, N Y

Overhead Systems Committee
Harold Cole, The Detroit Edison Co, Detroit, Mich

Power System Engineering Committee
L W W Morrow, *Electrical World,* New York, N Y

Prime Movers Committee
E B Ricketts, The New York Edison Co, New York, N Y

Special Engineering Research Committee
C F Hirshfeld, The Detroit Edison Co, Detroit, Mich

Underground Systems Committee
J W Sylvester, The Philadelphia Electric Co, Philadelphia, Pa

Engineering Director

H S Bennion, N E L A Headquarters, New York, N Y

ACCIDENT PREVENTION COMMITTEE

The major functions of this Committee are: To promote accident prevention throughout the electric light and power industry; to study accident occurrence, cause and results; to develop and promote safe methods and practices; to promote resuscitation and first aid; to administer the Insull award for the N E L A; to vise of safety codes; to study fire prevention in its relation to human safety

Officers

Chairman, C R Beardsley, Brooklyn Edison Co, Inc, Brooklyn, N Y
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Middle West—A A Rall, Kansas City Power & Light Co, Kansas City, Mo
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North Central—W H Brown, Northern States Power Co, Minneapolis, Minn
Northwest—J B Fisken, Washington Water Power Co, Spokane, Wash
Pacific Coast—F S Thomas, Coast Counties Gas & Electric Co, Gilroy, Cal
Rocky Mountain—Charles F Dwyer, Public Service Co of Colorado, Denver, Colo
Southeastern—R B Grove, Florida Power & Light Co, Miami, Fla
Southwestern—H E Braunig, Gulf States Utilities Co, Beaumont, Tex

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Overhead Systems Committee
W C Wagner, The Philadelphia Electric Co, Philadelphia, Pa

Underground Systems Committee
E W Oesterreich, Duquesne Light Co, Pittsburgh, Pa

Automobile Accidents Subcommittee

To investigate causes and results of automobile accidents to employees and cars of member companies. To recommend methods of selection and training of drivers

Chairman, W E Sanford; George S Diehl, J R Grant, A J Van Brunt

Codes Subcommittee

To scan proposed codes with reference to accident prevention provisions, and report such provisions in advance of their adoption

Chairman, W C Wagner; Dennis L Boyle, H D Freitag, M L Wilkins

Construction Subcommittee

To study construction methods and develop safe practices

Chairman, M R Sumner; W H Brown, A G Butler, M O Howle, A W Lee, W R Loyd, K R MacKinnon, C C Steck

Contests Subcommittee

To study contests and prepare recommendations for rules, scope, methods of judgment and award

Chairman, F A Belden; M H Bowman, Jr, R B Grove, P L G Hasskarl, P R Kuhn, Buford McCulloch

Cooperation with National Safety Council Subcommittee

To study division of work; to effect mutual cooperation and exchange of information; to prevent duplication of effort

Chairman, C J Rutland; M H Bowman, Jr, W A Buchanan, W R Loyd, K R MacKinnon, Buford McCulloch, H F Webb

Cost of Accidents Subcommittee

To study overall costs of accidents

Chairman, F S Thomas; M H Bowman, Jr, J B Fisken, M F Treadwell, F T Wendell

Fire Prevention and Extinguishment Subcommittee

(Personnel being determined)

Geographic Divisions Subcommittee

To stimulate work in all Geographic Divisions; prepare bibliography of divisions' reports; distribute important reports; promote use of all Accident Prevention Committee, N E L A publications

Chairman, W A Buchanan; J R Grant, Perry Mellon, R M Moore, I L Scott

Grounding Subcommittee

To review Accident Prevention Committee Report, "Temporary Grounding" No 278-4

Chairman, P L G Hasskarl; Charles F Dwyer, P R Kuhn, R M Moore, M F Treadwell

Handbook on Safety Training Subcommittee

To outline essential features of selecting and training employees for safety

Chairman, C J Rutland; M H Bowman, Jr, W H Brown, J R Grant, H H Judson, H M Keller, Miss Elizabeth Lee, H F Lovering, R M Moore

High Voltage Testing Subcommittee

To study high voltage testing and develop safe practices

Chairman, C C Steck; J R Grant, H H Judson, George Opp

Hot Line Tools Subcommittee

To study hot line tools; to develop safe practices; to secure preparation of purchase and test specifications for tools; to prepare recommendations for working rules (conferring with related committees)

Chairman, H E Braunig; W A Buchanan, Paul A Carnahan, Charles F Dwyer, P L G Hasskarl, A W Lee, H F Lovering, K R MacKinnon, H E Shedd

Low Voltage Hazards Subcommittee

To study low voltage hazards and accidents and prepare educational matter

Chairman, E W Gorry; F A Belden, Miss Elizabeth Lee, Miss Helen Smith, R C Sogge

Resuscitation and First Aid Subcommittee

To study resuscitation and first aid; prepare educational matter

Chairman, Wills Maclachlan; J B Fisken, E W Gorry, J P Jackson, A J Van Brunt

Insull Medal Award Sub Subcommittee

To administer Insull Medal Award for N E L A

Chairman, Wills Maclachlan; E W Gorry, A J Van Brunt

Rubber Gloves and Goods Subcommittee

To report on manufacture, shipment and storage, purchase specifications, retests, field use of rubber gloves and goods

Chairman, K R MacKinnon; A J Allen, E W Oesterreich, A H Sweetnam, W C Wagner

Safety Provisions, Devices and Appliances Subcommittee

To review safety features of devices referred to Accident Prevention Committee; to list safety features, designs and apparatus; to promote their use

Chairman, C C Steck; C B Auel, M Eldredge, R B Grove, Buford McCulloch, G E Sanford, F S Thomas, A J Van Brunt, F T Wendell

Statistics Subcommittee

To supervise collection of accident statistics; to make annual analysis and report

Chairman, W R Loyd; M H Bowman, Jr, J P Jackson, H F Lovering, Mrs Grace D Thweatt

Suggestion Systems Subcommittee

To study suggestion systems

Chairman, C B Auel; H H Judson, H M Keller, George Opp, M F Treadwell

Unusual Accidents Subcommittee

To study unusual accidents and recommend protection against new hazards

Chairman, I L Scott; H F Lovering, F T Wendell

ELECTRICAL APPARATUS COMMITTEE

The scope of this Committee includes consideration of the design, characteristics, disposition, use or operation, and maintenance of all electrical generation, transformation, conversion, utilization, control, protective and communication apparatus required or used in connection with electric power systems when located in power stations, in substations or on users' premises, from the coupling of the prime mover in the generating station to the point of utilization of the power, including the design of generating station and substation buildings, structures, circuits and devices for the housing, support, connection, operation and manipulation of such apparatus

Officers

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ENGINEERING ADMINISTRATION COMMITTEE

The scope of this Committee includes consideration of matters overlapping the field of existing subject Committees, and particularly matters in which the executive point of view is needed in addition to the technical

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W E Mitchell, Georgia Power Co, Atlanta, Ga
I E Moultrop, The Edison Electric Illuminating Co, Boston, Mass
R F Pack, Northern States Power Co, Minneapolis, Minn
Thomas Sproule, Public Service Electric & Gas Co, Newark, N J

HYDRAULIC POWER COMMITTEE

The scope of this Committee includes consideration of the design, characteristics, disposition, use or operation, and maintenance of all hydraulic and mechanical apparatus, and equipment required or used in hydro-electric generating plants, from the sources of water supply to the coupling of the electric generating unit, and of reservoirs, dams, buildings, structures and devices required or used in connection therewith

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P O Crawford, California-Oregon Power Co, Medford, Ore
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E A Crellin, Pacific Gas & Electric Co, San Francisco, Cal
H L Doolittle, Southern California Edison Co, Los Angeles, Cal
E A Dow, New England Power Construction Co, Boston, Mass
Walter Dreyer, Pacific Gas & Electric Co, San Francisco, Cal
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J P Growdon, The Aluminum Co of America, Pittsburgh, Pa
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J S Riddile, Laurentide Power Co, Ltd, Grand Mere, Quebec, Can
H G Roby, Byllesby Engineering & Management Corp, Chicago, Ill
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R G Walter, Wisconsin Power & Light Co, Madison, Wis

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East Central—
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Middle West—George A Neal, Iowa Public Service Co, Sioux City, Iowa
New England—F H Mason, Central Maine Power Co, Augusta, Me
North Central—G E Loughland, Northern States Power Co, Minneapolis, Minn
Northwest—E H Collins, Washington Water Power Co, Spokane Wash
Pacific Coast—Harold K Fox, San Joaquin Light & Power Corp, Fresno, Cal
Rocky Mountain—W D Hardaway, Public Service Co of Colorado, Denver, Colo
Southeastern—J H White, Florida Power & Light Co, Miami, Fla
Southwestern—

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Draft Tube Tests Subcommittee

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Chairman, J W Jourdan; Clinton DeWitt, H A Hageman, F Newell, S O Schamberger

Water Wheel Tests Subcommittee

Chairman, J S Riddile; C M Allen, J W Andree, E B Strowger

INDUCTIVE COORDINATION COMMITTEE

The major functions of this Committee are. To study conditions and current practices, both foreign and domestic, relating to the inductive coordination of power and signal systems; to further a better understanding of inductive coordination and encouraging cooperative planning for the coordination of facilities; to formulate principles and preferred practices as guides for the inductive coordination of power and signal systems; to consult with member N E L A companies for the purpose of rendering assistance in their inductive coordination problems; to keep in touch with and advise in the matter of local activities affecting or liable to affect the inductive coordination situation through legislation, commission regulations or rulings, contractual relations, or intercompany practices; to aid in joint studies with other interests concerned with, or aimed toward, the formation of working rules and specifications to govern the installation and coordination of the respective services; to prepare educational courses for the information and training of power system engineers in the principles and practices of inductive coordination

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Vice-Chairman, M D Hooven, Public Service Electric & Gas Co, Newark, N J

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Howard S Phelps, The Philadelphia Electric Co, Philadelphia, Pa
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W G Kelley, Commonwealth Edison Co, Chicago, Ill
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H H Schomburg, Columbus Electric & Power Co, Columbus, Ga
H H Schoolfield, Pacific Power & Light Co, Portland, Ore
A E Silver, Electric Bond & Share Co, New York, N Y
J J Smith, General Electric Co, Schenectady, N Y
E D Tanzer, Day & Zimmermann Engineering & Construction Co, Philadelphia, Pa
L A Terven, West Penn Power Co, Pittsburgh, Pa
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Systems Grounding Subcommittee

(Personnel being determined)

METER COMMITTEE

The scope of this Committee includes consideration of the design, installation, test, operation and maintenance of electrical metering and measuring devices as used on customers' premises, in industrial substations and in company generating and substations and of electrical and time measuring instruments and devices as used in the laboratory or in the field, including indicating, recording and graphic meters, primary and secondary electrical standards, standard clocks, timing relays, stop watches and other laboratory instruments used for standardization

Special functions of this Committee include: Analysis of existing rules and regulations of Federal, State or local regulatory bodies and the preparation and consideration of new rules and methods of procedure for the maintenance of meters and meter installations; preparation of educational courses for the training and development of men for service in the meter departments of operating companies

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OVERHEAD SYSTEMS COMMITTEE

The scope of this Committee includes consideration of the design, characteristics, disposition, use or operation, and maintenance of overhead lines, of the apparatus immediately connected therewith, such as pole-mounted transformers, fuses, air break switches and line type lightning arresters, and of the structures, materials and devices required or used in connection therewith

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Ray Ingham, Iowa Electric Co, Cedar Rapids, Iowa

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POWER SYSTEMS ENGINEERING COMMITTEE

To study the coordination of the fundamental elements in a power system in order to provide a guide for building and operating a system on the best and most economical basis

To study trends in system design and operation in order to afford guides for developing the existing systems along the best possible lines

All the work of the Committee is approached from the system point of view and is directed toward tangible guides that executives may use. An economic basis of evaluation of all developments is used and principles are accented rather than details. Specified studies under way are load surveys and load forecasts, distribution for high load density areas, principles of interconnection, utility energy supply to electrification projects, system layout principles and the formulation of a fundamental system building plan

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G Sutherland, New York & Queens Electric Light & Power Co, Long Island City, N Y
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PRIME MOVERS COMMITTEE

The scope of this Committee includes consideration of the design, characteristics, disposition, use or operation, and maintenance of all mechanical apparatus and equipment required or used in the production of steam from coal or any other source of energy than water from the fuel receiving plant to the coupling with the electric generator, and of buildings, structures and auxiliary apparatus and devices required or used in connection therewith. It also includes consideration of the fuels used and their characteristics

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Scope of Activity

The Public Relations National Section is organized for and devoted to the purpose of encouraging member companies to disseminate information that will give their employes and the public an understanding of the problems involved in the financing of electric light and power companies, and the furnishing, at fair rates, of continuous, dependable electric service. Its major purposes are:

To encourage member companies in so developing and training members of their organizations that employes will be able to interpret the industry to its customers and the public;
To act as a clearing house through which such ideas and practices as are found helpful in one company or section of the country may be made available to all;

To bring about and maintain a ready acceptance by the public of sound securities issued by the industry:

To be prepared, through study and research, to furnish accurate information on national problems mutually affecting the industry and the public;

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Great Lakes—H H Adams, Northern Indiana Public Service Co, Hammond, Ind
Middle West—Glen Morris, Kansas City Power & Light Co, Kansas City, Mo
New England—H U Greene, Cambridge Electric Light Co, Cambridge, Mass
North Central—T T Parker, Northwest Public Service Co, Huron, S D
Northwest—E C Kiersted, Idaho Power Co, Boise, Idaho

Pacific Coast—Eugene McCann, Pacific Gas & Electric Co, San Francisco, Cal
Rocky Mountain—F F McCammon, Public Service Co of Colorado, Denver, Colo
Southeastern—Frank R Mitchell, Georgia Power Co, Atlanta, Ga
Southwestern—R C Coffy, Fort Smith Light & Traction Co, Fort Smith, Ark

MANUFACTURERS' ADVERTISING COMMITTEE

To formulate and put into practice a campaign whereby manufacturers of electrical machinery equipment and supplies shall devote a portion of their advertising space in popular and trade magazines to the publication of "good-will" advertising

This committee will work in close cooperation with the Publicity Department

Chairman, T J McManis, General Electric Co, Schenectady, N Y
E M Beach, Westinghouse Lamp Co, New York, N Y
Frank LeRoy Blanchard, Henry L Doherty & Co, New York, N Y
A S Fromm, The Union Metal Manufacturing Co, Canton, Ohio
H H Green, National Lamp Works of G E Co, Cleveland, Ohio
W A Grove, Edison Electric Appliance Co, Inc, Chicago, Ill
Earl Hoover, The Hoover Co, Chicago, Ill
J S Kennedy, Landers, Frary & Clark, New Britain, Conn
J W McIver, Edison Lamp Works, Harrison, N J
J C McQuiston, Westinghouse Electric & Manufacturing Co, Pittsburgh, Pa
Herbert Metz, Graybar Electric Co, Inc, New York, N Y
G A Powers, Jr, M S Wright Co, Worcester, Mass
P L Thomson, Western Electric Co, New York, N Y
F U Webster, The Cutler-Hammer Manufacturing Co, Milwaukee, Wis

PUBLIC SPEAKING COMMITTEE

To organize through the Geographic Divisions a bureau of public speakers, national in its scope, and dealing with subjects pertaining to the electric light and power industry

Chairman, W S Vivian, Middle West Utilities Co, Chicago, Ill
R V Bozell, Bonbright & Co, New York, N Y
Thorne Browne, 1527 Sharp Building, Lincoln, Neb
Mrs Elsie Carter, Oklahoma Gas & Electric Co, Oklahoma City, Okla
J Paul Clayton, Central Illinois Public Service Co, Springfield, Ill
C W Davis, Dallas Power & Light Co, Dallas, Tex
R E Haas, Columbia Engineering & Management Corp, New York, N Y
Miss Sara Harris, Utica Gas & Electric Co, Utica, N Y
Carl D Jackson, 36 West 44th Street, New York, N Y
Fred R Jenkins, Commonwealth Edison Co, Chicago, Ill
Clarence L Law, The New York Edison Co, New York, N Y
Homer Niesz, Commonwealth Edison Co, Chicago, Ill
Tom C Polk, 910 Marquette Bldg, Chicago, Ill
Mrs Jane Pratt, Alabama Power Co, Birmingham, Ala
Paul Renshaw, Memphis Power & Light Co, Memphis, Tenn
E H Sniffen, Westinghouse Electric & Manufacturing Co, New York, N Y
W P Strandborg, Portland Electric Power Co, Portland, Ore

Geographic Division Representatives

Canadian—A Monro Grier, Canadian Niagara Power Co, Niagara Falls, Can
Eastern—H S Metcalfe, West Penn Power Co, Pittsburgh, Pa
East Central—D L Gaskill, 603 Broadway, Greenville, Ohio
Great Lakes—A E Scott, Interstate Public Service Co, Indianapolis, Ind
Middle West—Worth Bates, Missouri Gas & Electric Service Co, Lexington, Mo.
New England—Louis D Gibbs, The Edison Electric Illuminating Co, Boston, Mass
North Central—G O House, Northern States Power Co, St Paul, Minn
Northwest—S E Skelley, Pacific Power & Light Co, Portland, Ore
Pacific Coast—M H Schnapp, General Electric Co, San Francisco, Cal
Rocky Mountain—C H Elliott, Public Service Co of Colorado, Denver, Colo
Southeastern—Guy P Newbern, 502 Cotton States Building, Nashville, Tenn
Southwestern—E E Armstrong, Mississippi Power Co, Gulfport, Miss

RELATIONS WITH FINANCIAL INSTITUTIONS COMMITTEE

To cooperate with bankers and others interested in developing a broader outlet for sound securities of the electric light and power industry, to the end that such securities shall be generally accepted as legal investments for savings banks and trust funds;

To encourage member company executives to keep all investment agencies informed as to plans, problems and policies of the industry

Chairman, A W Robertson, Westinghouse Electric & Manufacturing Co, Pittsburgh, Pa
R H Ballard, Southern California Edison Co, Los Angeles, Cal
Henry G Bradlee, Stone & Webster, Inc, Boston, Mass
J H Briggs, H M Byllesby & Co, Chicago, Ill
Charles L Edgar, The Edison Electric Illuminating Co, Boston, Mass
Philip G Gossler, Columbia Gas & Electric Corp, New York, N Y
Martin J Insull, Middle West Utilities Co, Chicago, Ill
W A Jones, Henry L Doherty & Co, New York, N Y
John M McMillan, Henry L Doherty & Co, New York, N Y
M S Sloan, The New York Edison Co, New York, N Y

Geographic Division Representatives

Canadian—
Eastern—R E Norton, W H Newbold's Son & Co, Philadelphia, Pa
East Central—
Great Lakes—John F Gilchrist, Commonwealth Edison Co, Chicago, Ill
Middle West—C C Smith, Kansas City Power & Light Co, Kansas City, Mo
New England—W T Crawford, Stone & Webster, Inc, Boston, Mass
North Central—R F Pack, Northern States Power Co, Minneapolis, Minn
Northwest—W H Lines, Portland Electric Power Co, Portland, Ore
Pacific Coast—A F Hockenbeamer, Pacific Gas & Electric Co, San Francisco, Cal
Rocky Mountain—Harry Hughes, Public Service Co of Colorado, Denver, Colo
Southeastern—Joe H Gill, Florida Power & Light Co, Miami, Fla
Southwestern—H C Couch, Arkansas Power & Light Co, Pine Bluff, Ark

WOMEN'S COMMITTEE

To formulate and put into effect plans for the education of women of the industry on the fundamental economic principles of the electric light and power business, and the interdependence of the public and industry

Chairman, Miss Sophia Malicki, Middle West Utilities Co, Chicago, Ill
Secretary, Miss Isabell Davie, National Electric Light Association, New York, N Y

Members at Large

Miss Marguerite Butler, Portland Electric Power Co, Portland, Ore
Mrs Pearl Evans, National Electric Power Co, New York, N Y
Miss May Fletemeyer, Northern Indiana Public Service Co, Hammond, Ind
Miss Sara Harris, Utica Gas & Electric Co, Utica, N Y
Miss Elizabeth Lee, Alabama Power Co, Birmingham, Ala
Miss Mildred Nichols, Graybar Electric Co, Inc, New York, N Y
Miss Helen Norris, Commonwealth Edison Co, Chicago, Ill
Mrs Frances Rosenberg, Commonwealth Edison Co, Chicago, Ill
Mrs A C Taggart, The New York Edison Co, New York, N Y
Mrs Florence Tate, Central & South West Utilities Co, Dallas, Tex
Mrs Thelma Van Ness, Consumers Power Co, Jackson, Mich
Miss Mary K Walsh, The Washington Water Power Co, Spokane, Wash

Geographic Division Representatives

Canadian—Miss Florence Donkin, The Shawinigan Water & Power Co, Montreal, Can
Eastern—Miss Iva B Sellers, Pennsylvania Electric Co, Johnstown, Pa
East Central—Miss Esther Rockey, The Dayton Power & Light Co, Dayton, Ohio
Great Lakes—Miss Theresa Carroll, Central Illinois Public Service Co, Springfield, Ill
Middle West—Miss Betty Ewing, Kansas Power & Light Co, Topeka, Kan
New England—Miss Alice Baker, The Hartford Electric Light Co, Hartford, Conn
North Central—Mrs Mabel Wilson, Northern States Power Co, Minneapolis, Minn
Northwest—Mrs Nell Laws, Puget Sound Power & Light Co, Seattle, Wash
Pacific Coast—Mrs Ruth Creveling, San Diego Consolidated Gas & Electric Co, San Diego, Cal
Rocky Mountain—Miss Frances Ryder, Southern Colorado Power Co, Pueblo, Colo
Southeastern—Mrs Jane Pratt, Alabama Power Co, Birmingham, Ala
Southwestern—Miss Julie Pailet, New Orleans Public Service Inc, New Orleans, La

Home Service Subcommittee

To develop programs of home service activities; to assist in establishing home service departments

Chairman, Miss Ada Bessie Swann, Public Service Electric & Gas Co, Newark, N J

Manufacturers' Subcommittee

To develop cooperation between women of electric serving companies and of manufacturer companies toward accomplishment of the purpose of the program of the general Women's Committee

Chairman, Miss Frances Weedman, Edison Electric Appliance Co, Inc, Chicago, Ill

Principles and Practices in Codes and Standards Operations

Of Concern to N.E.L.A. Committees

The Codes and Standards Committee, with the approval of the National Executive Committee, has adopted for the guidance of all individuals representing the Association upon committees of standardizing bodies, or upon committees engaged in the actual formulation of standards or codes, the following general principles:

1. Codes and other collections of rules or regulations, when offered for promulgation as standards, may enunciate principles to which assent is given. They should contain a minimum of quantitative requirements. Detailed specifications are highly objectionable.
2. Pure engineering standards, whether for dimensions, quality or performance, are necessarily quantitative, but even these should preferably stress the principles involved and tend to avoid restrictive detail.
3. Due regard should be had for economy. The burden of representation is heavy in time and money, and in order to keep this within bounds effort should be made to guide standardizing activities into the smallest number of channels practicable, and otherwise to condense such activities.

The committee has also adopted certain practices stated in Serial Report No. 267-52 entitled "Principles and Practices in Codes and Standards Operations," dated April, 1927. The following statements are extracted from this report:

> "Representation to standardizing bodies shall be official and responsible to the Committee on Codes and Standards.
>
> "Representation to technical committees engaged in the actual preparation of codes and standards shall be official and responsible to the appropriate national technical or other committees of the N. E. L. A., these, in turn, being responsible to the Codes and Standards Committee for such activities.
>
> "Appointments of all official representatives shall be made by, and recorded in, Headquarters, N. E. L. A. They shall be made by the Secretary of the Association upon the recommendation of the Codes and Standards Committee, on behalf of the President of the Association. Reappointments, replacements and reliefs shall be effected in the same manner.
>
> "Representatives of all classes shall report actions taken by them, the status of their projects and recommendations, to the Codes and Standards Committee, and to their N. E. L. A. committee principals. It may be desirable to require routine periodical reports from certain classes of representatives."

Related Activities—Organizations Concerned

(Follows list of Representatives and Alternates [*Alternates shown in italics*] of the National Electric Light Association, serving on the unit of the organization indicated.)

AMERICAN COMMITTEE ON INDUCTIVE COORDINATION

R F Pack, Northern States Power Co, Minneapolis, Minn
H S Bennion, National Electric Light Association, New York, N Y
H L Wills, Georgia Power Co, Atlanta, Ga
J O'R Coleman, National Electric Light Association, New York, N Y
A E Silver, Electric Bond & Share Co, New York, N Y
J G Hemstreet, Consumers Power Co, Jackson, Mich
H S Phelps, The Philadelphia Electric Co, Philadelphia, Pa
R N Conwell, Public Service Electric & Gas Co, Newark, N J
H B Gear, Commonwealth Edison Co, Chicago, Ill
Alexander Maxwell, National Electric Light Association, New York, N Y

Executive Committee

R F Pack, Northern States Power Co, Minneapolis, Minn
H S Bennion, National Electric Light Association, New York, N Y

Program Committee

R N Conwell, Public Service Electric & Gas Co, Newark, N J

1—Technical Data Subcommittee

R N Conwell, Public Service Electric & Gas Co, Newark, N J
Alexander, Maxwell, National Electric Light Association, New York, N Y

2—Principles and Practices Subcommittee

H L Wills, Georgia Power Co, Atlanta, Ga
J O'R Coleman, National Electric Light Association, New York, N Y

3—Field Problems Subcommittee

A E Silver, Electric Bond & Share Co, New York, N Y
J O'R Coleman, National Electric Light Association, New York, N Y

4—Present Status Subcommittee

H B Gear, Commonwealth Edison Co, Chicago, Ill
Alexander, Maxwell, National Electric Light Association, New York, N Y

AMERICAN ELECTRIC RAILWAY ASSOCIATION

Committee on Power Rectifiers

A M Garrett, Commonwealth Edison Co, Chicago, Ill

Committee on Wood Preservation

John S Ware, Public Service Electric & Gas Co, Newark, N J

AMERICAN GAS ASSOCIATION

Joint Committee A G A and N E L A on Resuscitation Appliances

E C Stone, Duquesne Light Co, Pittsburgh, Pa
J P Jackson, The New York Edison Co, New York, N Y
H W Moses, The Edison Electric Illuminating Co, Boston, Mass

AMERICAN SOCIETY OF MECHANICAL ENGINEERS

Joint Committee on Boiler Feed Water

C W DeForest, The Union Gas & Electric Co, Cincinnati, Ohio
H Farmer, The Philadelphia Electric Co, Philadelphia, Pa
V M Frost, Public Service Electric & Gas Co, Newark, N J
Max Hecht, Duquesne Light Co, Pittsburgh, Pa
A L Penniman, Jr, Consolidated Gas, Electric Light & Power Co, Baltimore, Md

Mechanical Standards Advisory Council

C F Hirshfeld, The Detroit Edison Co, Detroit, Mich
Alexander Maxwell, National Electric Light Association, New York, N Y

AMERICAN SOCIETY FOR TESTING MATERIALS

Committee B-4 on High Temperature and Electrical Resistance Alloys

Norman T Wilcox, Stone & Webster, Inc, Boston, Mass
A B Morgan, National Electric Light Association, New York, N Y

AMERICAN STANDARDS ASSOCIATION

Light and Power Group

Standards Council

C F Hirshfeld, The Detroit Edison Co, Detroit, Mich
I E Moultrop, The Edison Electric Illuminating Co, Boston, Mass
W C Wagner, The Philadelphia Electric Co, Philadelphia, Pa
H S Bennion, National Electric Light Association, New York, N Y
Alexander Maxwell, National Electric Light Association, New York, N Y
W T Morrison, The New York Edison Co, New York, N Y

Sectional Committees

Alternators, Synchronous Motors and Synchronous Machines in General

L L Elden, The Edison Electric Illuminating Co, Boston, Mass
J A Johnson, The Niagara Falls Power Co, Niagara Falls, N Y
L G Smith, Consolidated Gas, Electric Light & Power Co, Baltimore, Md
R H Tapscott, The New York Edison Co, New York, N Y
Alexander Maxwell, National Electric Light Association, New York, N Y

Aluminum Conductors, Hard Drawn Standards for

R J C Wood, Southern California Edison Co, Los Angeles, Cal
A B Campbell, National Electric Light Association, New York, N Y

Automobile Brakes and Brake Testing, Safety Code for

Charles R Skinner, Jr, The New York Edison Co, New York, N Y
A B Morgan, National Electric Light Association, New York, N Y

Code for Lighting Buildings

Ward Harrison, National Lamp Works of G E Co, Cleveland, Ohio
Alexander Maxwell, National Electric Light Association, New York, N Y

Code for Pressure Piping

E B Ricketts, The New York Edison Co, New York, N Y
A L Penniman, Jr, Consolidated Gas, Electric Light & Power Co, Baltimore, Md
Alexander Maxwell, National Electric Light Association, New York, N Y

Code for Lighting Factories, Mills and Other Work Places

Clarence L Law, The New York Edison Co, New York, N Y
A B Morgan, National Electric Light Association, New York, N Y

Code for Electricity Meters

D J Bushnell, Commonwealth Edison Co, Chicago, Ill
B Currier, The Philadelphia Electric Co, Philadelphia, Pa
W L Wadsworth, The Minneapolis General Electric Co, Minneapolis, Minn
Alexander Maxwell, National Electric Light Association, New York, N Y

Colors for Traffic Signals, Safety Code for

Alexander Maxwell, National Electric Light Association, New York, N Y

Conveyors and Conveying Machinery, Safety Code for

C R Beardsley, Brooklyn Edison Co, Inc, Brooklyn, N Y
Alexander Maxwell, National Electric Light Association, New York, N Y

Copper Wire, Hard Drawn, Specifications for

E A Holden, Electric Bond & Share Co, New York, N Y
A B Campbell, National Electric Light Association, New York, N Y

Copper Wire, Medium Hard Drawn

E A Holden, Electric Bond & Share Co, New York, N Y
A B Campbell, National Electric Light Association, New York, N Y

Copper Wire, Tinned Soft or Annealed, for Rubber Insulation, Specifications for

E A Holden, Electric Bond & Share Co, New York, N Y
A B Campbell, National Electric Light Association, New York, N Y

Direct and Alternating Current Fractional Horsepower Motors

L L Elden, The Edison Electric Illuminating Co, Boston, Mass
J A Johnson, The Niagara Falls Power Co, Niagara Falls, N Y
L G Smith, Consolidated Gas, Electric Light & Power Co, Baltimore, Md
R H Tapscott, The New York Edison Co, New York, N Y
Alexander Maxwell, National Electric Light Association, New York, N Y

Direct Current Rotating Machines, Generators and Motors

L L Elden, The Edison Electric Illuminating Co, Boston, Mass

J A Johnson, The Niagara Falls Power Co, Niagara Falls, N Y
L G Smith, Consolidated Gas, Electric Light & Power Co, Baltimore, Md
R H Tapscott, The New York Edison Co, New York, N Y
Alexander Maxwell, National Electric Light Association, New York, N Y

Speeds for Driven Machines, Standardization of

N L Pollard, Public Service Production Co, Newark, N J
A B Morgan, National Electric Light Association, New York, N Y

Gas Safety Code

J C Parker, Brooklyn Edison Co, Inc, Brooklyn, N Y
Alexander Maxwell, National Electric Light Association, New York, N Y

Gears

Alexander Maxwell, National Electric Light Association, New York, N Y

Identification of Piping System, Safety Code for

A L Penniman, Jr, Consolidated Gas, Electric Light & Power Co, Baltimore, Md
Alexander Maxwell, National Electric Light Association, New York, N Y

Illuminating Engineering Nomenclature and Photometric Standards

Clayton H Sharp, Electrical Testing Laboratories, Inc, New York, N Y

Induction Motors and Induction Machines in General

L L Elden, The Edison Electric Illuminating Co, Boston, Mass
J A Johnson, The Niagara Falls Power Co, Niagara Falls, N Y
L G Smith, Consolidated Gas, Electric Light & Power Co, Baltimore, Md
R H Tapscott, The New York Edison Co, New York, N Y
Alexander Maxwell, National Electric Light Association, New York, N Y

Industrial Control Apparatus (Electrical)

E A Hester, Duquesne Light Co, Pittsburgh, Pa
E C Stone, Duquesne Light Co, Pittsburgh, Pa
Alexander Maxwell, National Electric Light Association, New York, N Y

Insulated Wires and Cables

D W Roper, Commonwealth Edison Co, Chicago, Ill
Thomas Sproule, Public Service Electric & Gas Co, Newark, N J
Wallace Clark, General Electric Co, Schenectady, N Y
J B Noe, The New York Edison Co, New York, N Y
Alexander Maxwell, National Electric Light Association, New York, N Y

Additional Technical Advisors

W H Cole, The Edison Electric Illuminating Co, Boston, Mass
F M Farmer, Electrical Testing Laboratories, Inc, New York, N Y
W G Kelley, Commonwealth Edison Co, Chicago, Ill
E B Meyer, Public Service Production Co, Newark, N J
L L Elden, The Edison Electric Illuminating Co, Boston, Mass
H S Phelps, The Philadelphia Electric Co, Philadelphia, Pa
C H Shaw, The New York Edison Co, New York, N Y

Lightning, Code on Protection Against

Thomas Sproule, Public Service Electric & Gas Co, Newark, N J
R N Conwell, Public Service Electric & Gas Co, Newark, N J
D W Roper, Commonwealth Edison Co, Chicago, Ill
Alexander Maxwell, National Electric Light Association, New York, N Y
W C Wagner, The Philadelphia Electric Co, Philadelphia, Pa
E C Stone, Duquesne Light Co, Pittsburgh, Pa

Line Insulators for Voltage Not Exceeding 750

T H Haines, The Edison Electric Illuminating Co, Boston, Mass
Thomas Sproule, Public Service Electric & Gas Co, Newark, N J
A B Campbell, National Electric Light Association, New York, N Y
R N Conwell, Public Service Electric & Gas Co, Newark, N J

Manhole Frames and Covers

C H Shaw, The New York Edison Co, New York, N Y
O B Reemelin, The Dayton Power & Light Co, Dayton, Ohio
E S Callahan, Consolidated Telephone & Electrical Subway Co, New York, N Y
A B Campbell, National Electric Light Association, New York, N Y

Additional Technical Advisor

A D Pettee, The New York Edison Co, New York, N Y

Mercury Arc Rectifiers

H D Braley, The New York Edison Co, New York, N Y
R N Conwell, Public Service Electric & Gas Co, Newark, N J
A B Morgan, National Electric Light Association, New York, N Y

Methods of Testing Wood

John S Ware, Jr, Public Service Electric & Gas Co, Newark, N J
Alexander Maxwell, National Electric Light Association, New York, N Y

National Electrical Code

W H Blood, Jr, Stone & Webster, Inc, Boston, Mass
J W Cowles, The Edison Electric Illuminating Co, Boston, Mass
E W Lloyd, Commonwealth Edison Co, Chicago, Ill
W C Wagner, The Philadelphia Electric Co, Philadelphia, Pa
Alexander Maxwell, National Electric Light Association, New York, N Y
A P Good, Commonwealth Edison Co, Chicago, Ill

Additional Technical Advisors

P H Bartlett, The Philadelphia Electric Co, Philadelphia, Pa
A B Campbell, National Electric Light Association, New York, N Y
R S Hale, The Edison Electric Illuminating Co, Boston, Mass
A H Kehoe, The United Electric Light & Power Co, New York, N Y
H T Luscomb, The New York Edison Co, New York, N Y

National Electrical Safety Code, Revisions of Parts 1 and 3 and Section 9

P H Bartlett, The Philadelphia Electric Co, Philadelphia, Pa
L L Elden, The Edison Electric Illuminating Co, Boston, Mass
A H Kehoe, The United Electric Light & Power Co, New York, N Y
A B Campbell, National Electric Light Association, New York, N Y
W T Morrison, The New York Edison Co, New York, N Y

Additional Technical Advisors

H J Burton, Consumers Power Co, Jackson, Mich
J A Cook, The New York Edison Co, New York, N Y
Alexander Maxwell, National Electric Light Association, New York, N Y
J J Ryan, The New York Edison Co, New York, N Y
E C Stone, Duquesne Light Co, Pittsburgh, Pa

National Electrical Safety Code, Revisions of Parts 2 and 4

Thomas Sproule, Public Service Electric & Gas Co, Newark, N J
J C Martin, Middle West Utilities Co, Chicago, Ill
W C Wagner, The Philadelphia Electric Co, Philadelphia, Pa
W T Morrison, The New York Edison Co, New York, N Y
A B Campbell, National Electric Light Association, New York, N Y

Additional Technical Advisors

H C Sutton, The United Gas Improvement Co, Philadelphia, Pa
V F Hammel, Electric Bond & Share Co, New York, N Y
G G Post, The Milwaukee Electric Railway & Light Co, Milwaukee, Wis
John S Ware, Jr, Public Service Electric & Gas Co, Newark, N J
J J Strickland, Jr, Henry L Doherty & Co, New York, N Y
J A Brundige, Electric Bond & Share Co, New York, N Y
H J Burton, Consumers Power Co, Jackson, Mich
J A Cook, The New York Edison Co, New York, N Y
E J Amberg, The Connecticut Light & Power Co, Waterbury, Conn

Joint Crossings Specifications Committee

E J Amberg, The Connecticut Light & Power Co, Waterbury, Conn
E A Holden, Electric Bond & Share Co, New York, N Y
J K Himes, The Dayton Power & Light Co, Dayton, Ohio
A B Campbell, National Electric Light Association, New York, N Y

Petroleum Products and Lubricants, Methods of Testing

N E Funk, The Philadelphia Electric Co, Philadelphia, Pa
A B Morgan, National Electric Light Association, New York, N Y

Pipe Flanges and Fittings

Sabin Crocker, The Detroit Edison Co, Detroit, Mich
W S Morrison, The New York Edison Co, New York, N Y
A L Penniman, Jr, Consolidated Gas, Electric Light & Power Co, Baltimore, Md

Power Line Insulators for Voltages Exceeding 750

J A Brundige, Electric Bond & Share Co, New York, N Y
W G Kelley, Commonwealth Edison Co, Chicago, Ill
R R Cowles, Pacific Gas & Electric Co, San Francisco, Cal
C T Sinclair, The Philadelphia Co, Pittsburgh, Pa
A B Campbell, National Electric Light Association, New York, N Y

Radio

R N Conwell, Public Service Electric & Gas Co, Newark, N J
J O'R Coleman, National Electric Light Association, New York, N Y

Rating of Electrical Machinery

H C Albrecht, The Philadelphia Electric Co, Philadelphia, Pa
L L Elden, The Edison Electric Illuminating Co, Boston, Mass
R H Tapscott, The New York Edison Co, New York, N Y
E C Stone, Duquesne Light Co, Pittsburgh, Pa
Philip Torchio, The New York Edison Co, New York, N Y

Rating of Rivers

O B Caldwell, Portland Electric Power Co, Portland, Ore
H W Dennis, Southern California Edison Co, Los Angeles, Cal
H K Fox, San Joaquin Light & Power Co, Fresno, Cal
N R Gibson, The Niagara Falls Power Co, Niagara Falls, N Y
J W Link, Byllesby Engineering & Management Corp, Chicago, Ill
C A Orrok, The New York Edison Co, New York, N Y
G R Strandberg, Stone & Webster, Inc, Boston, Mass

T R Tetley, Henry L Doherty & Co, New York, N Y
R L Thomas, Pennsylvania Water & Power Co, Baltimore, Md
O G Thurlow, Alabama Power Co, Birmingham, Ala
M O Leighton, Consulting Engineer, Washington, D C
P M Downing, Pacific Gas & Electric Co, San Francisco, Cal
H S Bennion, National Electric Light Association, New York, N Y
Alexander Maxwell, National Electric Light Association, New York, N Y

Refrigerators

C K Nichols, The New York Edison Co, New York, N Y
A B Morgan, National Electric Light Association, New York, N Y

Safety Code for Aeronautics

W F Davidson, Brooklyn Edison Co, Inc, Brooklyn, N Y
A B Morgan, National Electric Light Association, New York, N Y

Safety Code for Cranes, Derricks and Hoists

K M Irwin, The United Gas Improvement Co, Philadelphia, Pa
G M Sutherland, Duquesne Light Co, Pittsburgh, Pa
Alexander Maxwell, National Electric Light Association, New York, N Y

Safety Code for Explosive Dusts

E B Ricketts, The New York Edison Co, New York, N Y

Safety Code for Industrial Sanitation

E W Gorry, The United Electric Light & Power Co, New York, N Y
Alexander Maxwell, National Electric Light Association, New York, N Y

Safety Code for Laundries

C N Lewis, The New York Edison Co, New York, N Y
Alexander Maxwell, National Electric Light Association, New York, N Y

Safety Code for Mechanical Refrigeration

C K Nichols, The New York Edison Co, New York, N Y
Alexander Maxwell, National Electric Light Association, New York, N Y

Safety Code for the Protection of Head and Eyes of Industrial Workers

E J Rutan, The New York Edison Co, New York, N Y
A B Campbell, National Electric Light Association, New York, N Y

Safety Code for Walkway Surfaces

K M Irwin, The United Gas Improvement Co, Philadelphia, Pa
E C Stone, Duquesne Light Co, Pittsburgh, Pa
Alexander Maxwell, National Electric Light Association, New York, N Y

Scientific and Engineering Symbols and Abbreviations

C H Sanderson, The New York Edison Co, New York, N Y
Alexander Maxwell, National Electric Light Association, New York, N Y

Standards for Drawing and Drafting Room Practice

S P Melville, Stone & Webster, Inc, Boston, Mass
Alfred Iddles, Day & Zimmermann Engineering & Construction Co, Philadelphia, Pa
Alexander Maxwell, National Electric Light Association, New York, N Y

Standards for Instrument Transformers

E E Hill, The New York Edison Co, New York, N Y

Symbols for Electrical Equipment of Buildings and Ships

Clarence L Law, The New York Edison Co, New York, N Y
A B Morgan, National Electric Light Association, New York, N Y

Terminal Markings for Electrical Apparatus

R A Hentz, The Philadelphia Electric Co, Philadelphia, Pa
A L Harding, Electric Bond & Share Co, New York, N Y
J D Bowles, Federal Light & Traction Co, New York, N Y
Alexander Maxwell, National Electric Light Association, New York, N Y

Tubular Steel Poles, Specifications for

John S Ware, Jr, Public Service Electric & Gas Co, Newark, N J
W H Warner, New York & Queens Electric Light & Power Co, Long Island City, N Y
A B Campbell, National Electric Light Association, New York, N Y

Wood Poles, Specifications for

John S Ware, Jr, Public Service Electric & Gas Co, Newark, N J
W G Kelley, Commonwealth Edison Co, Chicago, Ill
H C Dean, New York & Queens Electric Light & Power Co, Long Island City, N Y
P P Ashworth, Utah Power & Light Co, Salt Lake City, Utah
A B Campbell, National Electric Light Association, New York, N Y

Additional Technical Advisors

R Ingham, Iowa Electric Co, Cedar Rapids, Iowa
G T McCaskey, Public Service Electric & Gas Co, Newark, N J
H L Wills, Georgia Power Co, Atlanta, Ga
F W L Hill, Electric Bond & Share Co, New York, N Y

Wrought Iron and Wrought Steel Pipe Tubing, Standardization of Dimensions and Material of

A L Penniman, Jr, Consolidated Gas, Electric Light & Power Co, Baltimore, Md
A B Campbell, National Electric Light Association, New York, N Y

Zinc Coating of Iron and Steel, Specifications for

George L Hadden, Henry L Doherty & Co, New York, N Y
V M Hammel, Electric Bond & Share Co, New York, N Y
A B Campbell, National Electric Light Association, New York, N Y

Special Committees

Board of Examination

Alexander, Maxwell, National Electric Light Association, New York, N Y

Enlarged Rules Committee

Subcommittee on Plan of Reorganization

Alexander Maxwell, National Electric Light Association, New York, N Y

Overhead Line Material

Alexander Maxwell, National Electric Light Association, New York, N Y

Standing and Correlating Committees

Electrical Advisory Committee

L L Elden, The Edison Electric Illuminating Co, Boston, Mass
R H Tapscott, The New York Edison Co, New York, N Y
Alexander Maxwell, National Electric Light Association, New York, N Y

Special Committee on Committee Organization

Alexander Maxwell, National Electric Light Association, New York, N Y

Special Committee on Electrical Safety Conferences Standards

Alexander Maxwell, National Electric Light Association, New York, N Y

Subcommittee on Scopes of Projects

Alexander Maxwell, National Electric Light Association, New York, N Y

Safety Code Correlating Committee

W C Wagner, The Philadelphia Electric Co, Philadelphia, Pa
Alexander Maxwell, National Electric Light Association, New York, N Y

AMERICAN UNIFORM BOILER LAW SOCIETY

John Hunter, The Heine Boiler Co, St Louis, Mo

AMERICAN WATER WORKS ASSOCIATION

Advisory and Editing Committee

V M Frost, Public Service Electric & Gas Co, Newark, N J
A L Penniman, Jr, Consolidated Gas, Electric Light & Power Co, Baltimore, Md

CHAMBER OF COMMERCE OF THE UNITED STATES OF AMERICA

National Councillor

John W Lieb, The New York Edison Co, New York, N Y

Alternate National Councillor

George N Tidd, American Gas & Electric Co, New York, N Y

Delegates

P S Arkwright, *ex-officio*, Georgia Power Co, Atlanta, Ga
S Ferguson, The Hartford Electric Light Co, Hartford, Conn
Walter H Johnson, The Philadelphia Electric Co, Philadelphia, Pa
J R Lovejoy, General Electric Co, Schenectady, N Y
Thomas N McCarter, Public Service Electric & Gas Co, Newark, N J
L A Osborne, Westinghouse Electric & Manufacturing Co, East Pittsburgh, Pa
M S Sloan, The New York Edison Co, New York, N Y
Herbert A Wagner, Consolidated Gas, Electric Light & Power Co, Baltimore, Md

COMMITTEE ON THE RELATION OF ELECTRICITY TO AGRICULTURE

(This Committee consists of representatives from the United States Departments of Agriculture, Commerce and Interior, American Farm Bureau Federation, American Society of Agricultural Engineers, Power Farming Association and National Electric Light Association)

ARTHUR HUNTINGTON, Iowa Railway & Light Co, Cedar Rapids, Iowa
G C NEFF, Wisconsin Power & Light Co, Madison, Wis
MARSHALL E SAMPSELL, Central Illinois Public Service Co, Chicago, Ill
CHARLES F STUART, Northern States Power Co, Minneapolis, Minn

Representative of N E L A Accident Prevention Committee to confer on preparation of the Farm Wiring Bulletin
W R LOYD, Alabama Power Co, Birmingham, Ala

INDUSTRY SALES CONFERENCE

J E DAVIDSON, Nebraska Power Co, Omaha, Neb
M C HUSE, The Philadelphia Electric Co, Philadelphia, Pa
E W LLOYD, Commonwealth Edison Co, Chicago, Ill
HARRY MCCONNELL, Electric Bond & Share Co, New York, N Y
R F PACK, Northern States Power Co, Minneapolis, Minn

INTERNATIONAL CHAMBER OF COMMERCE

Chairman, JOHN W LIEB, The New York Edison Co, New York, N Y
P S ARKWRIGHT, *ex-officio,* Georgia Power Co, Atlanta, Ga
S FERGUSON, The Hartford Electric Light Co, Hartford, Conn
WALTER H JOHNSON, The Philadelphia Electric Co, Philadelphia, Pa
J R LOVEJOY, General Electric Co, Schenectady, N Y
THOMAS N MCCARTER, Public Service Electric & Gas Co, Newark, N J
L A OSBORNE, Westinghouse Electric & Manufacturing Co, East Pittsburgh, Pa
M S SLOAN, The New York Edison Co, New York, N Y
GEORGE N TIDD, American Gas & Electric Co, New York, N Y
HERBERT A WAGNER, Consolidated Gas, Electric Light & Power Co, Baltimore, Md

INTERNATIONAL COMMITTEE ON WEIGHTS AND MEASURES

(Conference called by Bureau of Standards to obtain consensus of American opinion on International Aspects of Electrical Units)

CLAYTON H SHARP, Electrical Testing Laboratories, Inc, New York, N Y
A B Morgan, National Electric Light Association, New York, N Y

INTERNATIONAL CONFERENCE ON BITUMINOUS COAL

(To confer on plans for second conference held November, 1928)
A G CHRISTIE, The Johns Hopkins University, Baltimore, Md

JOINT COMMITTEE OF NATIONAL UTILITY ASSOCIATIONS

(This Committee consists of representatives from each of the following Associations: American Electric Railway Association, American Gas Association and National Electric Light Association)

CHARLES L EDGAR, The Edison Electric Illuminating Co, Boston, Mass
W W FREEMAN, Columbia Gas & Electric Corp, New York, N Y
EDWIN GRUHL, The North American Co, New York, N Y
C E GROESBECK, Electric Bond & Share Co, New York, N Y
MARTIN J INSULL, Middle West Utilities Co, Chicago, Ill
JOHN W LIEB, The New York Edison Co, New York, N Y
SIDNEY Z MITCHELL, Electric Bond & Share Co, New York, N Y
J J O'BRIEN, H M Byllesby & Co, Chicago, Ill
R F PACK, Northern States Power Co, Minneapolis, Minn
M S SLOAN, The New York Edison Co, New York, N Y
GEORGE N TIDD, American Gas & Electric Co, New York, N Y
OWEN D YOUNG, General Electric Co, New York, N Y
PAUL S CLAPP, *ex-officio,* National Electric Light Association, New York, N Y

JOINT GENERAL COMMITTEE

of

Bell Telephone System and National Electric Light Association

on

Physical Relations Between Electric Light and Signal Circuits

(The personnel of the Main Committee of the Joint General Committee, immediately following, is complete, i e, the representatives of both the American Telephone & Telegraph Company (Bell Telephone System) and the National Electric Light Association are shown. For the Communications Committee and the various Subcommittees only the representatives of the National Electric Light Association are shown)

Chairman, OWEN D YOUNG, General Electric Co, New York, N Y
Secretary, PAUL S CLAPP, National Electric Light Association, New York, N Y
R H BALLARD, Southern California Edison Co, Los Angeles, Cal
J J CARTY, American Telephone & Telegraph Co, New York, N Y
BANCROFT GHERARDI, American Telephone & Telegraph Co, New York, N Y
E K HALL, American Telephone & Telegraph Co, New York, N Y
MARTIN J INSULL, Middle West Utilities Co, Chicago, Ill
L H KINNARD, The Bell Telephone Co of Pennsylvania, Philadelphia, Pa
ROBERT LINDSAY, The Cleveland Electric Illuminating Co, Cleveland, Ohio
R F PACK, Northern States Power Co, Minneapolis, Minn
BEN S READ, Southern Bell Telephone & Telegraph Co, Atlanta, Ga
CHARLES S RUFFNER, Mohawk Hudson Power Corp, Albany, N Y

Communications Committee

Chairman, R F PACK, Northern States Power Co, Minneapolis, Minn
R H BALLARD, Southern California Edison Co, Los Angeles, Cal
MARTIN J INSULL, Middle West Utilities Co, Chicago, Ill
ROBERT LINDSAY, The Cleveland Electric Illuminating Co, Cleveland, Ohio
CHARLES S RUFFNER, Mohawk Hudson Power Corp, Albany, N Y

Engineering Subcommittee of Communications Committee

Chairman, CHARLES S RUFFNER, Mohawk Hudson Power Corp, Albany, N Y
E C STONE, Duquesne Light Co, Pittsburgh, Pa
R F PACK, Northern States Power Co, Minneapolis, Minn

Special Subcommittees of the Engineering Subcommittee of the Communications Committee

Development and Research
Chairman, H L WILLS, Georgia Power Co, Atlanta, Ga
Secretary, J O'R COLEMAN, National Electric Light Association, New York, N Y
R N CONWELL, Public Service Electric & Gas Co, Newark, N J
R D EVANS, Westinghouse Electric & Manufacturing Co, East Pittsburgh, Pa
J C MARTIN, Middle West Utilities Co, Chicago, Ill
E P PECK, Utica Gas & Electric Co, Utica, N Y
H S PHELPS, The Philadelphia Electric Co, Philadelphia, Pa
L T ROBINSON, General Electric Co, Schenectady, N Y
A E SILVER, Electric Bond & Share Co, New York, N Y

Program Subcommittee—Development and Research
J O'R COLEMAN, National Electric Light Association, New York, N Y

Project Committee No. 1
H E KENT, National Electric Light Association, New York, N Y

Project Committee No. 2
Chairman, R N CONWELL, Public Service Electric & Gas Co, Newark, N J
WM SHULER (Chairman Subcommittee B), Columbia Engineering & Management Corp, Dayton, Ohio
J O'R COLEMAN, National Electric Light Association, New York, N Y
R D EVANS, Westinghouse Electric & Manufacturing Co, East Pittsburgh, Pa
J C MARTIN, Middle West Utilities Co, Chicago, Ill
K B MCEACHRON, General Electric Co, Pittsfield, Mass
S A SMITH, JR, Public Service Electric & Gas Co, Newark, N J

Project Committee No. 3
J O'R COLEMAN, National Electric Light Association, New York, N Y

Project Committee No. 4
J O'R COLEMAN, National Electric Light Association, New York, N Y

Project Committee No. 5
L J GORMAN, The New York Edison Co, New York, N Y

Project Committee No. 6

H S Phelps, The Philadelphia Electric Co, Philadelphia, Pa

Project Committee No. 7

L T Robinson, General Electric Co, Schenectady, N Y

Project Committee No. 8

L T Robinson, General Electric Co, Schenectady, N Y

Project Committee No. 9

Chairman, E P Peck, Utica Gas & Electric Co, Utica, N Y
C A Boddie, Westinghouse Electric & Manufacturing Co, East Pittsburgh, Pa
B R Cumming, General Electric Co, Schenectady, N Y
D A Pierce, Public Service Co of Northern Illinois, Chicago, Ill
H L Wills, Georgia Power Co, Atlanta, Ga

Project Committee No. 10

W F Davidson, Brooklyn Edison Co, Inc, Brooklyn, N Y

Project Committee No. 11

R D Evans, Westinghouse Electric & Manufacturing Co, East Pittsburgh, Pa

Field Problems

Chairman, A E Silver, Electric Bond & Share Co, New York, N Y
J O'R Coleman, National Electric Light Association, New York, N Y
R N Conwell, Public Service Electric & Gas Co, Newark, N J
H S Phelps, The Philadelphia Electric Co, Philadelphia, Pa

JOINT GENERAL COMMITTEE

of

Western Union Telegraph Company and National Electric Light Association

on

Physical Relations Between Electric Light and Telegraph Circuits

(The personnel of the Main Committee of the Joint General Committee immediately following, is complete, i e, the representatives of both the Western Union Telegraph Company and the National Electric Light Association are shown. For the Communications Committee and the Engineering Subcommittee the representatives only of the National Electric Light Association are shown)

Chairman, Owen D Young, General Electric Co, New York, N Y
Secretary, Paul S Clapp, National Electric Light Association, New York, N Y
R H Ballard, Southern California Edison Co, Los Angeles, Cal
Newcomb Carlton, Western Union Telegraph Co, New York, N Y
E Y Gallaher, Western Union Telegraph Co, New York, N Y
Martin J Insull, Middle West Utilities Co, Chicago, Ill
Robert Lindsay, The Cleveland Electric Illuminating Co, Cleveland, Ohio
R F Pack, Northern States Power Co, Minneapolis, Minn
Charles S Ruffner, Mohawk Hudson Power Corp, Albany, N Y
W C Titley, Western Union Telegraph Co, New York, N Y
G M Yorke, Western Union Telegraph Co, New York, N Y

Communications Committee

Chairman, R F Pack, Northern States Power Co, Minneapolis, Minn
R H Ballard, Southern California Edison Co, Los Angeles, Cal
Martin J Insull, Middle West Utilities Co, Chicago, Ill
Robert Lindsay, The Cleveland Electric Illuminating Co, Cleveland, Ohio
Charles S Ruffner, Mohawk Hudson Power Corp, Albany, N Y

Engineering Subcommittee of Communications Committee

Chairman, Charles S Ruffner, Mohawk Hudson Power Corp, Albany, N Y
R F Pack, Northern States Power Co, Minneapolis, Minn
E C Stone, Duquesne Light Co, Pittsburgh, Pa

Subcommittee of Engineers

A Herz, Public Service Co of Northern Illinois, Chicago, Ill
M D Hooven, Public Service Electric & Gas Co, Newark, N J
H S Bennion, National Electric Light Association, New York, N Y

NATIONAL COAL ASSOCIATION

Conference on Coal Research Activities

E B Ricketts, The New York Edison Co, New York, N Y
Alexander Maxwell, National Electric Light Association, New York, N Y

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION

Joint Committee N E M A and N E L A on Oil Circuit Breaker Interrupting Capacity Guarantee

Chairman, G Sutherland, Duquesne Light Co, Pittsburgh, Pa
R A Hentz, The Philadelphia Electric Co, Philadelphia, Pa
C H Sanderson, The New York Edison Co, New York, N Y
Alexander Maxwell, National Electric Light Association, New York, N Y

Joint Committee N E M A and N E L A on Service Entrance Devices

J W Cowles, The Edison Electric Illuminating Co, Boston, Mass
B Currier, The Philadelphia Electric Co, Philadelphia, Pa
C G Durfee, The Rochester Gas & Electric Corp, Rochester, N Y
A P Good, Commonwealth Edison Co, Chicago, Ill
A G Turnbull, Commonwealth Edison Co, Chicago, Ill
E E Hill, The New York Edison Co, New York, N Y

Joint Committee N E M A and N E L A on Standardization of Primary Voltages

A L Harding, Electric Bond & Share Co, New York, N Y
S M Jones, Alabama Power Co, Birmingham, Ala
H C Sutton, The United Gas Improvement Co, Philadelphia, Pa
W F Davidson, Brooklyn Edison Co, Inc, Brooklyn, N Y
Alexander Maxwell, National Electric Light Association, New York, N Y

Joint Committee N E M A and N E L A on Terminal Lugs

A M Garrett, Commonwealth Edison Co, Chicago, Ill
A L Harding, Electric Bond & Share Co, New York, N Y
L F Hickernell, Commonwealth Power Corp, Jackson, Mich
A B Schwenk, The Philadelphia Electric Co, Philadelphia, Pa
R M Stanley, Byllesby Engineering & Management Corp, Chicago, Ill
F D Wyatt, The Cutter Electrical & Manufacturing Co, Philadelphia, Pa

Joint Committee of Engineers on National Electrical Code N E M A and N E L A

A P Good, Commonwealth Edison Co, Chicago, Ill
A H Kehoe, The United Electric Light & Power Co, New York, N Y
J D Noyes, The Detroit Edison Co, Detroit, Mich
W C Wagner, The Philadelphia Electric Co, Philadelphia, Pa

Joint Conference N E M A and N E L A on One-Line Wiring Diagrams

A L Harding, Electric Bond & Share Co, New York, N Y
B R Norton, The Philadelphia Electric Co, Philadelphia, Pa

NATIONAL FIRE PROTECTION ASSOCIATION

Dust Explosion Hazards

E B Ricketts, The New York Edison Co, New York, N Y

Electrical Field Service

W H Blood, Jr, Stone & Webster, Inc, Boston, Mass

Protection of Records

J H Bissell, Stone & Webster, Inc, Boston, Mass

Electric Power Houses

G H Bourne, Allied Power & Light Corp, New York, N Y
F G Boyce, Consumers Power Co, Jackson, Mich
R N Conwell, Public Service Electric & Gas Co, Newark, N J
C M Gilt, Brooklyn Edison Co, Inc, Brooklyn, N Y
Alexander Maxwell, National Electric Light Association, New York, N Y
W F Sims, Commonwealth Edison Co, Chicago, Ill

Additional Technical Advisors

C R Beardsley, Brooklyn Edison Co, Inc, Brooklyn, N Y
F H Deckman, Columbia Engineering & Management Corp, Columbus, Ohio
L L Elden, The Edison Electric Illuminating Co, Boston, Mass
A M Garrett, Commonwealth Edison Co, Chicago, Ill
F R George, Pacific Gas & Electric Co, San Francisco, Cal
E A Hester, Duquesne Light Co, Pittsburgh, Pa
F L Hunt, Western Massachusetts Co, Greenfield, Mass
M J Lowenberg, Stone & Webster, Inc, Boston, Mass
K R MacKinnon, Nebraska Power Co, Omaha, Neb
L W McCullough, The United Electric Light & Power Co, New York, N Y
C H Sanderson, The New York Edison Co, New York, N Y
H J Scholz, Alabama Power Co, Birmingham, Ala
L D Smith, Northern States Power Co, Minneapolis, Minn
R M Stanley, Byllesby Engineering & Management Corp, Chicago, Ill

Electrical Committee

W H Blood, Jr, Stone & Webster, Inc, Boston, Mass
Alexander Maxwell, National Electric Light Association, New York, N Y
J W Cowles, The Edison Electric Illuminating Co, Boston, Mass
W C Wagner, The Philadelphia Electric Co, Philadelphia, Pa
E W Lloyd, Commonwealth Edison Co, Chicago, Ill
A P Good, Commonwealth Edison Co, Chicago, Ill

Technical Subcommittees

Automatic Protection of Circuits
J W Cowles, The Edison Electric Illuminating Co, Boston, Mass

Diversity Factor for Lighting Loads
R S Hale, The Edison Electric Illuminating Co, Boston, Mass

Grounding
W H Blood, Jr, Stone & Webster, Inc, Boston, Mass

Heating Appliances
J W Cowles, The Edison Electric Illuminating Co, Boston, Mass

Installation in Buildings of Bare Conductors as Risers and Feeders
P H Bartlett, The Philadelphia Electric Co, Philadelphia, Pa
R S Hale, The Edison Electric Illuminating Co, Boston, Mass
H T Luscomb, The New York Edison Co, New York, N Y

Outside Work, Pole Lines
J W Cowles, The Edison Electric Illuminating Co, Boston, Mass

Protection of Motors and Motor Circuits
A P Good, Commonwealth Edison Co, Chicago, Ill
A H Kehoe, The United Electric Light & Power Co, New York, N Y

Radio Equipment
A B Campbell, National Electric Light Association, New York, N Y

Services
J W Cowles, The Edison Electric Illuminating Co, Boston, Mass

Storage or Primary Batteries
J W Cowles, The Edison Electric Illuminating Co, Boston, Mass

System and Voltages of Over 600 Volts
J W Cowles, The Edison Electric Illuminating Co, Boston, Mass

Underfloor Raceways
A B Campbell, National Electric Light Association, New York, N Y

Wiring Methods
W H Blood, Jr, Stone & Webster, Inc, Boston, Mass

Wiring of Electric Ranges
A P Good, Commonwealth Edison Co, Chicago, Ill
Alexander Maxwell, National Electric Light Association, New York, N Y

Special Committees

Special Committee on Control of Portable Devices
A P Good, Commonwealth Edison Co, Chicago, Ill

Special Committee on Safety Rules
A P Good, Commonwealth Edison Co, Chicago, Ill

NATIONAL INDUSTRIAL CONFERENCE BOARD

Chairman, John W Lieb, The New York Edison Co, New York, N Y
Charles L Edgar, The Edison Electric Illuminating Co, Boston, Mass
P S Arkwright, *ex-officio,* Georgia Power Co, Atlanta, Ga

NATIONAL RESEARCH COUNCIL

Committee on Insulation

F M Farmer, Electrical Testing Laboratories, Inc, New York, N Y
D W Roper, Commonwealth Edison Co, Chicago, Ill
R H Tapscott, The New York Edison Co, New York, N Y

POWER TRANSMISSION ASSOCIATION

Board of Advisory Engineers
F T Brooks, Philadelphia Suburban-Counties Gas & Electric Co, Philadelphia, Pa
Alexander Maxwell, National Electric Light Association, New York, N Y

SOCIETY FOR ELECTRICAL DEVELOPMENT

Committee on Wiring Development Operations
M C Huse, The Philadelphia Electric Co, Philadelphia, Pa
Alexander Maxwell, National Electric Light Association, New York, N Y

STATE PUBLIC UTILITY INFORMATION BUREAUS

(Follows a list of State Public Utility Information Bureaus, the territory which they cover and their Chairmen and Directors, who are not exclusively representatives of the National Electric Light Association)

Arkansas Public Service Information Bureau
(Arkansas)

Chairman, W E Bann, Southwestern Gas & Electric Co, Texarkana, Ark
Director, Rex I Brown, 320 Boyle Building, Little Rock, Ark

Connecticut Committee on Public Service Information
(Connecticut)

Chairman, Samuel Ferguson, The Hartford Electric Light Co, Hartford, Conn
Executive Secretary, Clarence G Willard, 52 Whitney Avenue, New Haven, Conn

Florida Public Utilities Information Bureau
(Florida)

Chairman, E A Olsen, Florida Power Corp, St Petersburg, Fla
Director, R J Holly, Room 413, First National Bank Building, Sanford, Fla

Utilities Information Committee of Georgia
(Georgia)

Chairman, P S Arkwright, Georgia Power Co, Atlanta, Ga
Executive Secretary, Willard Cope, 302-303 Haas-Howell Building, Atlanta, Ga

Illinois Committee on Public Utility Information
(Illinois)

Chairman, John F Gilchrist, Commonwealth Edison Co, Chicago, Ill
Director, Bernard J Mulaney, Peoples Gas Light & Coke Co, Chicago, Ill
Assistant Director, R R McGregor, 79 West Monroe Street, Chicago, Ill

Indiana Committee on Public Utility Information
(Indiana)

Chairman, (To be appointed)
Manager, William Stokes, 1547 Consolidated Building, Indianapolis, Ind

Iowa Committee on Public Utility Information
(Iowa)

Chairman, F J Hanlon, Peoples Gas & Electric Co, Mason City, Iowa
Director, Joe Carmichael, 310 Crocker Building, Des Moines, Iowa

Information Bureau of Kansas Public Service Companies
(Kansas)

Chairman, L O Ripley, Kansas Gas & Electric Co, Wichita, Kan
Director, H Lee Jones, 820 Kansas Ave, Topeka, Kan

Kentucky Committee on Public Utility Information
(Kentucky)

Chairman, Robert Montgomery, Louisville Gas & Electric Co, Louisville, Ky
Secretary, E F Kelley, Louisville Railway Co, Louisville, Ky

Louisiana-Mississippi Committee on Public Utility Information
(Louisiana-Mississippi)

Chairman, H B Flowers, New Orleans Public Service Inc, New Orleans, La
Director, Hugh M Blain, 1426 Hibernia Building, New Orleans, La

Michigan Committee on Public Utility Information
(Michigan)

Chairman, A C Marshall, The Detroit Edison Co, Detroit, Mich
Director, Arthur W Stace, 202 East Washington Street, Ann Arbor, Mich

Missouri Committee on Public Utility Information
(*Missouri*)

Chairman, Percy Redmund, Southwestern Bell Telephone Co, St Louis, Mo
Acting Secretary, Jesse Blythe, 1017 Olive Street, St Louis, Mo

Nebraska Utilities Information Bureau
(*Nebraska*)

Chairman, K R MacKinnon, Nebraska Power Co, Omaha, Neb
Director, Thorne Browne, 1527 Sharp Building, Lincoln, Neb

New England Bureau of Public Service Information
(*Maine, New Hampshire, Vermont, Massachusetts and Rhode Island*)

Chairman, W A Buttrick, The Twin State Gas & Electric Co, Boston, Mass
Director, Samuel T MacQuarrie, 24 Milk Street, Boston, Mass

New Jersey Public Utility Information Committee
(*New Jersey*)

Chairman, C H Howell, Atlantic City Electric Co, Atlantic City, N J
Director, A G MacKenzie, 313 Market Street, Camden, N J

New York State Committee on Public Utility Information
(*New York*)

Chairman, E H Rosenquest, Westchester Lighting Co, Mt Vernon, N Y
Director, A Von Schrader, Grand Central Terminal Building, New York, N Y

North Central Public Utility Information Bureau
(*Minnesota, North Dakota and South Dakota*)

Chairman, W S Robertson, Minnesota Power & Light Co, Duluth, Minn
Director, Charles F Stuart, 803-4 Plymouth Building, Minneapolis, Minn

North and South Carolina Public Utility Information Bureau
(*North Carolina and South Carolina*)

Chairman, N A Cocke, Duke Power Co, Charlotte, N C
Director, S E Boney, 506 Lawyers Building, Raleigh, N C

Ohio Committee on Public Utility Information
(*Ohio*)

Chairman, Robert Lindsay, The Cleveland Electric Illuminating Co, Cleveland, Ohio
Director, Fred J Bollmeyer, 1308 Ulmer Building, Cleveland, Ohio

Oklahoma Public Utility Information Bureau
(*Oklahoma*)

President, Earl R Ernsberger, Southwestern Light & Power Co, Oklahoma City, Okla
Manager, Edward F McKay, 1020-23 Petroleum Building, Oklahoma City, Okla

Oregon Public Utility Information Bureau
(*Oregon*)

Chairman, Franklin T Griffith, Portland Electric Power Co, Portland, Ore
Manager, H L Walther, 1015 Public Service Building, Portland, Ore

Pennsylvania Public Service Information Committee
(*Pennsylvania*)

Chairman, P H Gadsden, The United Gas Improvement Co, Philadelphia, Pa

Rocky Mountain Committee on Public Utility Information
(*Colorado, New Mexico and Wyoming*)

Chairman, V L Board, Public Service Co of Colorado, Denver, Colo
Executive Manager, George E Lewis, 406 Gas & Electric Building, Denver, Colo

Tennessee Public Service Information Bureau
(*Tennessee*)

Chairman, J P W Brown, Nashville Railway & Light Co, Nashville, Tenn
Director, Guy P Newbern, 502 Cotton States Building, Nashville, Tenn

Texas Public Service Information Bureau
(*Texas*)

Chairman, Charles W Davis, Dallas Power & Light Co, Dallas, Tex
Director, William C Grant, 412 Santa Fe Building, Dallas, Tex

Virginia Committee on Public Utility Information
(*Virginia*)

President, J W Hancock, Appalachian Electric Power Co, Roanoke, Va
Director, A B Tunis, 301 East Grace Street, Richmond, Va

Information Committee Public Utilities Association of West Virginia
(*West Virginia*)

Chairman, Arthur M Hill, Charleston Interurban Railroad Co, Charleston, W Va
Secretary, A Bliss McCrum, P O Box 1483, Charleston, W Va

Wisconsin Public Utility Information Bureau
(*Wisconsin*)

Chairman, J P Pulliam, Wisconsin Public Service Corp, Milwaukee, Wis
Director, A F Herwig, 432 Broadway, Milwaukee, Wis

NATIONAL SAFETY COUNCIL

Engineering Section

Committee on Elimination of Harmful Noises
E W Gorry, The United Electric Light & Power Co, New York, N Y
Alexander Maxwell, National Electric Light Association, New York, N Y

Committee on Low Voltage Electrical Hazard
E W Gorry, The United Electric Light & Power Co, New York, N Y
A B Campbell, National Electric Light Association, New York, N Y

UNION INTERNATIONALE Des PRODUCTEURS et DISTRIBUTEURS D'ENERGIE ELECTRIQUE

Charles L Edgar, The Edison Electric Illuminating Co, Boston, Mass
Samuel Insull, Commonwealth Edison Co, Chicago, Ill
John W Lieb, The New York Edison Co, New York, N Y

UNITED STATES BOARD OF SURVEYS AND MAPS

Advisory Council

I E Moultrop, The Edison Electric Illuminating Co, Boston, Mass

UNITED STATES DEPARTMENT OF COMMERCE

Division of Simplified Practice
Standing Committees

Recommendation No. 58—Carbon Brushes and Brush Shunts
V J F Brain, The New York Edison Co, New York, N Y
Alexander Maxwell, National Electric Light Association, New York, N Y

Recommendation No 73—One Piece Porcelain Insulators
J A Brundige, Electric Bond & Share Co, New York, N Y
Alexander Maxwell, National Electric Light Association, New York, N Y

UNITED STATES DEPARTMENT OF INTERIOR

Eastern Seaboard Power Supply Survey Advisory Board

Charles L Edgar, The Edison Electric Illuminating Co, Boston, Mass
M S Sloan, The New York Edison Co, New York, N Y

UNITED STATES NATIONAL COMMITTEE OF THE INTERNATIONAL COMMISSION ON ILLUMINATION

JOHN W LIEB, The New York Edison Co, New York, N Y
E W LLOYD, Commonwealth Edison Co, Chicago, Ill
R R YOUNG, Public Service Electric & Gas Co, Newark, N J

UNITED STATES NATIONAL COMMITTEE OF THE INTERNATIONAL ELECTROTECHNICAL COMMISSION

Chairman, H W FULLER, Byllesby Engineering & Management Corp, Chicago, Ill
L L ELDEN, The Edison Electric Illuminating Co, Boston, Mass
Alexander Maxwell, National Electric Light Association, New York, N Y

Advisory Committees

Insulating Oils

G SUTHERLAND, Duquesne Light Co, Pittsburgh, Pa

Lampholders and Bases

(Not yet determined)

Prime Movers

V E ALDEN, Stone & Webster, Inc, Boston, Mass
C M ALLEN, Worcester Polytechnic Institute, Worcester, Mass
A D BAILEY, Commonwealth Edison Co, Chicago, Ill

Rating of Electrical Machinery

L L ELDEN, The Edison Electric Illuminating Co, Boston, Mass
J C PARKER, Brooklyn Edison Co, Inc, Brooklyn, N Y
PHILIP TORCHIO, The New York Edison Co, New York, N Y

Rating of Rivers

H S BENNION, National Electric Light Association, New York, N Y
O B CALDWELL, Portland Electric Power Co, Portland, Ore
H W DENNIS, Southern California Edison Co, Los Angeles, Cal
P M DOWNING, Pacific Gas & Electric Co, San Francisco, Cal
H K FOX, San Joaquin Light & Power Corp, Fresno, Cal
N R GIBSON, The Niagara Falls Power Co, Niagara Falls, N Y
M O LEIGHTON, Electric Bond & Share Co, Washington, D C
J W LINK, Byllesby Engineering & Management Corp, Chicago, Ill
ALEXANDER MAXWELL, National Electric Light Association, New York, N Y
G A ORROK, The New York Edison Co, New York, N Y
G R STRANDBERG, Stone & Webster, Inc, Boston, Mass
T R TETLEY, Henry L Doherty & Co, New York, N Y
R L THOMAS, Pennsylvania Water & Power Co, Baltimore, Md
O G THURLOW, Alabama Power Co, Birmingham, Ala

Rules and Regulations for Overhead Transmission Lines

A B CAMPBELL, National Electric Light Association, New York, N Y
W G KELLEY, Commonwealth Edison Co, Chicago, Ill
W C WAGNER, The Philadelphia Electric Co, Philadelphia, Pa

Symbols

A L HARDING, Electric Bond & Share Co, New York, N Y

Terminal Markings

J D BOWLES, Federal Light & Traction Co, New York, N Y
A L HARDING, Electric Bond & Share Co, New York, N Y
R A HENTZ, The Philadelphia Electric Co, Philadelphia, Pa
ALEXANDER MAXWELL, National Electric Light Association, New York, N Y

Voltages

B G JAMIESON, Commonwealth Edison Co, Chicago, Ill
L L ELDEN, The Edison Electric Illuminating Co, Boston, Mass

Watt-Hour Meters

B CURRIER, The Philadelphia Electric Co, Philadelphia, Pa
ALEXANDER MAXWELL, National Electric Light Association, New York, N Y

Outline of National Electric Light Association Organization as Related to Geographic Divisions

This Outline indicates the opportunities for organization relationship between the Geographic Divisions and the National Electric Light Association, and is intended to assist the Geographic Divisions in the early selection of their representatives to serve on the National Executive Committee, General National Committees and the Bureaus and Committees of the Accounting, Commercial, Engineering and Public Relations National Sections.

The Administrative Year of the National Electric Light Association covers the period of July 1 to June 30. Officers take office and Bureaus and Committees function from July 1 to, and including, June 30, following.

In order that the work of an Administrative Year may be started promptly with the active participation of all concerned, it is desirable that the Geographic Divisions select promptly their representatives, who will serve as members of the National Executive Committee, General National Committees and the Bureaus and Committees of the Accounting, Commercial, Engineering and Public Relations National Section. Thus such representatives will be enabled to participate in the formulation of programs of activities for the Year, which plans are usually determined early in July, and thereby be able, not only to serve as members throughout the Year, but also to be of maximum service to their respective Divisions.

National Executive Committee

The personnel of the National Executive Committee consists of the Officers, the Retiring President, the Members-at-Large, the Chairmen of the four (4) National Sections and the Presiding Officers, or other duly accredited representatives, of the Geographic Divisions—one (1) representative from each Division.

Special National Committees

No provision is made on the Special National Committees for Geographic Division representation. In order that these Special National Committees, on which no provision is made for Geographic Division representation, may not be confused with other Committees of the Association on which provision is made for representation, there follows a list of such Special National Committees:

Advertising Committee
Charles A Coffin Prize Committee
Codes and Standards Committee
Constitution and By-Laws Committee
Electrification of Steam Railroads Committee
Exhibition Committee
Finance Committee
Lamp Committee
Prize Awards Committee
Public Policy Committee
Rate Research Committee
Water Power Development Committee
Wiring Policy Committee

General National Committees

The five (5) General National Committees, operating during the Administrative Year, July 1, 1928—June 30, 1929, on which provision is made for Geographic Division representation, are:

Civic Development Committee
Educational Committee
Insurance Committee
Membership Committee
Rural Electric Service Committee

Included in the personnel of these five (5) Committees are two (2) groups of members, namely, Members-at-Large and Geographic Division representatives.

"Members-at-Large" are appointed either by the President or by the Chairmen of the Committees. Such members are selected because of their special qualifications and are located in different sections of the country. They, however, are not regarded, nor do they act, as Geographic Division Representatives—they are, as their title indicates, members-at-large.

Geographic Division representation on the General National Committees is effected in one of two ways:

(a) Where a Geographic Division has a Committee corresponding to a General National Committee, the Chairman of such Division Committee becomes, automatically, a member of the corresponding National Committee.

(b) If a Division does not have a Committee corresponding to a General National Committee, but desires to be represented thereon, the Division may appoint thereto a representative.

Irrespective of the method, (a) or (b) employed, all Geographic Division Representatives members of General National Committees, are *selected* and *appointed* by the Divisions—not, in any case, by the National Association.

Each Geographic Division is entitled to one (1) representative on each General National Committee.

National Sections' Executive Committees

There are four (4) National Sections, namely, Accounting, Commercial, Engineering and Public Relations, each of which has an Executive Committee. Each Geographic Division may have Accounting, Commercial, Engineering and Public Relations Sections, and the Chairmen of such Division Sections become, automatically, members of the Executive Committees of the corresponding National Sections. Example: The Chairman of an Accounting Section of a Geographic Division becomes, automatically, a member of the Executive Committee of the Accounting National Section.

The Chairmen of the Divisions' Sections are *selected* and *appointed* by the Divisions.

National Sections' Bureaus and Committees

The Accounting, Engineering and Public Relations National Sections have Committees, on a number of which provision is made for Geographic Division representation in addition to the members-at-large. The Commercial National Section has both Bureaus and Committees. A Bureau consists of a number of Committees handling kindred subjects. Provision is made for Geographic Division representatives on the Bureaus, but not on the Committees of the Bureaus. There are also Committees, which are not related to the Bureaus, on two of which Committees provision is made for Geographic Division representatives.

"Members-at-Large" are appointed by either the Chairmen of the National Sections embracing such Bureaus and Committees, or by the Chairmen of such Bureaus and Committees. Such members are selected because of their qualifications and are located in different sections of the country. They, however, are not regarded, nor do they act, as Geographic Division representatives—they are, as their title indicates, members-at-large.

Geographic Division representation on the Bureaus and Committees of the four National Sections is effected in one of two ways:

(a) Where a Section of a Geographic Division has a Bureau or a Committee corresponding to a Bureau or Committee of a National Section, on which provision is made for Geographic Division representation, the Chairman of such Division Section Bureau or Committee becomes, automatically, a member of the corresponding National Section Bureau or Committee.

(b) If a Section of a Geographic Division does not have a Bureau or Committee corresponding to a Bureau or a Committee of a National Section, on which provision is made for Geographic Division representation, but desires to be represented on such Bureau or Committee, the Division may appoint thereto a representative.

Irrespective of the method (a) or (b) used, all Division Representatives, members of Bureaus or Committees of the National Sections, are *selected* and *appointed* by the Geographic Divisions—not, in any case, by the Chairmen of the National Bureaus or Committees.

Each Geographic Division is entitled to one (1) representative on each of the following indicated Bureaus and Committees of the four National Sections.

Follows a list of National Sections' Bureaus and Committees, operating during the Administrative Year, July 1, 1928—June 30, 1929, on which provision is made for Geographic Division Representation:

Accounting National Section
- Section's Executive Committee
- Classification of Accounts Committee
- Customers' Records Committee
- Fixed Capital Committee
- General Records Committee
- Purchasing and Storeroom Committee
- Statistics Committee

Commercial National Section
- Section's Executive Committee
- Commercial and Industrial Power and Heating Bureau
- Lighting Bureau
- Merchandising Bureau
- Customer Relations Committee
- Wiring Sales Committee

Engineering National Section
- Section's Executive Committee
- Accident Prevention Committee
- Electric Apparatus Committee
- Hydraulic Power Committee
- Inductive Coordination Committee
- Meter Committee
- Overhead Systems Committee
- Power Systems Committee
- Prime Movers Committee
- Underground Systems Committee

Public Relations National Section
- Section's Executive Committee
- Cooperation with Educational Institutions Committee
- Customer Ownership Committee
- Industrial Relations Committee
- Information Bureau Organizations Committee
- Public Speaking Committee
- Relations with Financial Institutions Committee
- Women's Committee

There are certain Committees of the National Sections on which no provision is made for Geographic Division representation, the personnels of such Committees being entirely of "memberships-at-large." In order that there may be no confusion between these Committees and those on which provision is made for Geographic Division representation, there follows a list of the Committees which do not have Geographic Division representation:

Accounting National Section
- Budget Committee
- Corporate Finance Committee

Commercial National Section
- Commercial Cooking Committee
- Electric Truck Committee
- General Power Committee
- Industrial Heating Committee
- Commercial and Industrial Lighting Committee
- Electrical Advertising Committee
- Home Lighting Committee
- Street Lighting Committee
- Domestic Electric Range Committee
- Merchandise Sales Committee
- Refrigeration Committee
- Water Heating Committee
- Promotional Rates Committee

Engineering National Section
- Engineering Administration Committee
- Special Engineering Research Committee

Public Relations National Section
- Manufacturers' Advertising Committee

PERSONNEL INFORMATION DESIRED

Experience indicates that most satisfactory results are obtained if all personnel information bearing on Sections, Bureaus and Committees of a Geographic Division is cleared through the office of the Secretary of a Division; for example, when a person has accepted appointment as Chairman of a Section, Bureau or Committee of a Division, the name, company affiliation and address of such person should be transmitted to the Secretary of the Division, and not to the Chairman of the corresponding national unit, except in very special cases, in which event copy of such advice should be sent to the Division Secretary and the National Secretary.

When a formal acceptance of an appointment has been received, the Secretary of a Geographic Division should forward the name, company affiliation and address of such individual, together with information as to the National Section, Bureau or Committee on which he is to serve, directly to A. Jackson Marshall, Secretary of the National Electric Light Association, 420 Lexington Avenue, New York. This information immediately upon receipt will be sent by the National Secretary to the Chairman of the National Section, Bureau or Committee concerned, and a copy of this advice will be sent to the person concerned and to the Secretary of the Division.

If, for any reason, a Geographic Division does not desire to be represented on a National Section, Bureau or Committee, advices to this effect should be sent to the National Secretary as soon after July 1 as possible.

APPENDIX 5

LIST OF MEMBER COMPANIES AS OF JUNE 30, 1929

Light and Power Companies

(Class A)

"Class A members shall be regularly incorporated public service companies engaged in producing and supplying electrical energy for light, heat or power for public use."—*Constitution, Art. III, Sec. 2.*

Alabama

Birmingham	Alabama Power Company
	Birmingham Electric Company
River Falls	River Falls Power Company

Arizona

Flagstaff	Flagstaff Electric Light Company
Phoenix	Arizona Edison Company
	Central Arizona Light & Power Company (300 West Washington Street)
Prescott	The Arizona Power Company (Masonic Temple)
Tucson	The Tucson Gas, Electric Light & Power Company
Winslow	Arizona Electric Power Company (Corner 2nd and Williamson Streets)

Arkansas

Blytheville	Arkansas-Missouri Power Company
Fort Smith	Mississippi Valley Power Company
Helena	Arkansas Utilities Company (615 Cherry Street)
Hot Springs National Park	Citizens Electric Company
Pine Bluff	Arkansas Power & Light Company (411 Main Street)
Warren	Arkansas General Utilities Co. (1 No. Market Square, Harrisburg, Pa.)

California

Bay Point	Bay Point Light & Power Company (125 Main Street)
Fresno	San Joaquin Light & Power Corporation
Los Angeles	Los Angeles Gas & Electric Corporation (Box 1100 Station C)
	Southern California Edison Company
Riverside	The Southern Sierras Power Company (771 West 8th Street)
St. Helena	Napa Valley Electric Company (Main Street)
San Diego	San Diego Consolidated Gas & Electric Company (P. O. Box 1374)
San Francisco	Feather River Power Company (530 Bush Street)
	Great Western Power Company of California, 225 Bush Street)
	Pacific Gas & Electric Company (245 Market Street)
	Peoples California Hydro-Electric Corporation (212 Fitzpatrick Bldg., Portland, Ore.)
Santa Cruz	Coast Counties Gas & Electric Company (2500 Russ Bldg.), San Francisco, Cal.
Vallejo	Vallejo Electric Light & Power Company (Bin "R")

Colorado

Denver	Arvada Electric Company (1066 Gas & Electric Bldg.)
	Public Service Company of Colorado
Durango	Western Colorado Power Company
Evergreen	Evergreen Public Service Company
Glenwood Springs	The Glenwood Light & Water Company
Golden	Colorado Central Power Company
Greeley	The Home Gas & Electric Company
Pueblo	Southern Colorado Power Company
Silverton	The Silverton Electric Light Company
Springfield	Highland Utilities Company
Trinidad	The Trinidad Electric Transmission Railway & Gas Company

Connecticut

Danbury	Danbury & Bethel Gas & Electric Light Company
Derby	The Derby Gas & Electric Company
East Hampton	Central Connecticut Power & Light Company
Hartford	The Hartford Electric Light Company
Litchfield	The Litchfield Electric Light & Power Company
Mystic	Mystic Power Company
New London	Connecticut Power Company (33 Union Street)
Norwich	The Eastern Connecticut Power Company
South Manchester	Manchester Electric Company
Stamford	The Stamford Gas & Electric Company (429 Atlantic Street)
Thompsonville	The Northern Connecticut Power Company
Unionville	The Union Electric Light & Power Company (Perry Street)
Waterbury	The Connecticut Light & Power Company
Willimantic	Rockville-Willimantic Lighting Company (850 Main Street)

Delaware

Wilmington	Delaware Power & Light Company (834 Market Street)

District of Columbia

Washington	Potomac Electric Power Company

Florida

Auburndale	Auburndale Power Company
Fernandina	Southern States Power Company
Hastings	Hastings Power & Ice Company
Key West	The Key West Electric Company
Madison	Madison County Power Company
Miami	Florida Power & Light Company (Box 875)
Monticello	The Jefferson County Power Company
Pensacola	Gulf Power Company (42 South Palatox Street)
Perry	Taylor County Power Company
St. Petersburg	Florida Power Corporation (P. O. Box 2261)
Tampa	Tampa Electric Company

Georgia

Albany	South Georgia Power Company (Columbus)
Atlanta	Georgia Power Company (Electric & Gas Bldg.)
Blue Ridge	Toccoa Electric Power Company (Tenn. Elec. Power Bldg., Chattanooga, Tenn.)
Columbus	Columbus Electric & Power Company
Griffin	Georgia Hydro-Electric Company
Savannah	Savannah Electric & Power Company
Valdosta	Georgia Power & Light Company

Idaho

Boise	Idaho Power Company
Cœur D'Alene	Kootenai Power Company, Limited
Salmon	Salmon River Power & Light Company

Illinois

Alton	Alton Light & Power Company (122 East Broadway)
Aurora	Western United Gas & Electric Company
Chicago	Bayfield Utilities Company (105 West Adams Street) Byllesby Engineering & Management Corporation (231 South LaSalle Street) Central Public Service Corporation (105 West Adams Street) Commonwealth Edison Company (72 West Adams Street) Illinois Power & Light Corporation (231 South LaSalle Street) Inland Power & Light Company (79 West Monroe Street) Middle West Utilities Company (72 West Adams Street) Midland Utilities Company (2025-122 South Michigan Avenue) National Public Utilities Company (39 South La Salle Street, Room 402) North American Light & Power Company (231 South La Salle Street) North Continent Utilities Corp. (2311 South La Salle Street, Room 1833) Public Service Company of Northern Illinois (72 West Adams Street) The United Light & Power Company (2200 Bankers Bldg.) United Public Service Company (100 West Monroe Street) Utilities Management Company (29 South LaSalle Street) Utilities Power & Light Corporation (327 South LaSalle Street)
Dixon	Illinois Northern Utilities Company
East St. Louis	East St. Louis Light & Power Company
Galena	Interstate Light & Power Company (103 Main Street)
Lincoln	Illinois Public Utility Company
Moline	Peoples' Power Company
Mt. Carmel	Mt. Carmel Public Utility & Service Company
Peoria	Central Illinois Light Company
Rockford	Rockford Electric Company
Springfield	Central Illinois Public Service Company Illinois Power Company

Indiana

Attica	Attica Electric Company (117 N. Brady St.)
Clinton	Wabash Valley Electric Company
Evansville	Southern Indiana Gas & Electric Company
Fort Wayne	Indiana Service Corp. (122 E. Wayne St.)
Greensburg	Hoosier Public Utility Company
Hammond	Northern Indiana Public Service Company (649 Hohman St.)
Indianapolis	Central Indiana Power Company (606 Guaranty Bldg.) Indianapolis Power & Light Company (48 Monument Circle) Interstate Public Service Company (Wild Bldg., 129 E. Market)
Kokomo	Northern Indiana Power Company
La Porte	La Porte Gas & Electric Company
Madison	Madison Light & Power Company
Marengo	General Utilities Company
Marion	Indiana General Service Company
Richmond	The Liberty Light & Power Company
South Bend	Indiana & Michigan Electric Company
Terre Haute	Terre Haute, Indianapolis & Eastern Traction Company (Terre Haute Division, 301 Tribune Bldg.)
Union City	Union City Electric Company
Winchester	Citizens Heat, Light & Power Company

Iowa

Cedar Rapids	Iowa Electric Company Iowa Railway & Light Corp.
Centerville	Iowa Southern Utilities
Council Bluffs	Citizens Power & Light Company
Davenport	Peoples' Light Company
Des Moines	Iowa Power & Light Company
Dubuque	Central States Power & Light Corp. (First National Bank Bldg.) Eastern Iowa Electric Company Interstate Power Company
Fort Dodge	Fort Dodge Gas & Electric Company
Fort Madison	Fort Madison Electric Company
Glenwood	Mills County Power Company
Iowa City	Iowa City Light & Power Company
Keokuk	Keokuk Electric Company Mississippi River Power Company
Mason City	Peoples Gas & Electric Company
Northwood	Northwood-Kensett Electric Company
Sioux City	Iowa Public Service Company (Box 766) McGraw Electric Company (120 S. La Salle St., Chicago, Ill.) Sioux City Gas & Electric Company

Kansas

Abilene ....The United Power & Light Corporation of Kansas
Caney ....The Caney Electric Company
Concordia ....The Kansas Power Company
Cottonwood Falls .Inter-County Electric Company
Fort Scott ....Kansas Utilities Company (10 East Wall Street)
Lawrence ....Kansas Electric Power Company
Salina ....The Western Light & Power Corp. (The Public Utilities Investment Company Bldg.)
Topeka ....The Kansas Power & Light Company
Wichita ....Kansas Gas & Electric Company (Sedgwick Bldg., 201 No. Market Street)

Kentucky

Bloomfield ......Kentucky Service Company
Bowling Green....Kentucky-Tennessee Light & Power Company (910 State Street)
Covington ....Union Light, Heat & Power Company
Hazard ....Kentucky & West Virginia Power Company
Lexington ....Lexington Utilities Company
Louisville ....Kentucky Utilities Company (Starks Building)
Louisville Gas & Electric Company
Maysville ....Kentucky Power & Light Company

Louisiana

Alexandria ....Louisiana Ice & Utilities, Inc. (2034 Hill Street)
Algiers ....Louisiana Power & Light Company (142 Delaronde Street)
Baton Rouge ....Baton Rouge Electric Company
New Iberia ......Gulf Public Service Company
New Orleans .....New Orleans Public Service, Inc. (Box 340)
Shreveport ....Southwestern Gas & Electric Company

Maine

Augusta ....Central Maine Power Company
New England Public Service Company
Bangor ....Bangor Hydro-Electric Company
Biddeford ....Clark Power Company
Calais ....St. Croix Gas Light Company
Caribou ....Caribou Water, Light & Power Company
Kezar Falls ......Cornish & Kezar Falls Light & Power Company
Lewiston ....Androscoggin Electric Company (Main Street)
Portland ....Cumberland County Power & Light Company
Presque Isle .....Gould Electric Company
Rumford ....Rumford Falls Light & Water Company
South Berwick ...Berwick & Salmon Falls Electric Company (131 State Street, Boston, Mass.)

Maryland

Annapolis ....Annapolis & Chesapeake Bay Power Company
Baltimore ....Consolidated Gas, Electric Light & Power Company (Lexington Bldg., Lexington and Liberty Streets)
General Utilities & Operating Company (1310 Standard Oil Building)
Hagerstown ......The Potomac Edison Company
Salisbury ....Eastern Shore Public Service Company (107 Main Street)

Massachusetts

Agawam ....Agawam Electric Company (73 State Street, Springfield)
Amesbury ....Amesbury Electric Light Company
Amherst ....Amherst Gas Company
Athol ....Athol Gas & Electric Company (426 Main Street)
Attleboro ....Attleboro Steam & Electric Company
Ayer ....Ayer Electric Light Company
Beverly ....Beverly Gas & Electric Company
Boston ....Adams Gas Light Company (77 Franklin Street)
Atlantic Public Utilities, Inc. (Park Square Bldg., 31 St. James Ave.)
Eastern Massachusetts Electric Company (200 Devonshire Street)
Edison Electric Illuminating Company of Boston (70 State Street)
New England Power Co. (89 Broad Street)
Stone & Webster, Inc. (49 Federal Street)
Charles H. Tenney & Company (200 Devonshire Street)
Brockton ....Edison Electric Illuminating Company of Brockton
Cambridge ....Cambridge Electric Light Company
Charlestown .....Charlestown Gas & Electric Company (27 Main Street)
Clinton ....Clinton Gas Light Company
Easthampton .....Easthampton Gas Company
East Pepperell ...Middlesex County Electric Company
East Weymouth ..Weymouth Light & Power Company
Fall River ....Fall River Electric Light Company
Montaup Electric Company (85 North Main Street)
Fitchburg ....Fitchburg Gas & Electric Light Company (655 Main Street)
Franklin ....Union Light & Power Company
Gardner ....Gardner Electric Light Company
Gloucester ....Gloucester Electric Company
Greenfield ....Greenfield Electric Light & Power Company
Haverhill ....Haverhill Electric Company
Holyoke ....Holyoke Water Power Company
Hyannis ....Cape & Vineyard Electric Company
Lawrence ....Lawrence Gas & Electric Company
Lee ....Lee Electric Company
Leominster ....Leominster Electric Light & Power Company (46 Main Street)
Lowell ....The Lowell Electric Light Corporation
Ludlow ....Ludlow Electric Light Company (73 State Street, Springfield)
Lynn ....Lynn Gas & Electric Company
Malden ....Malden Electric Company
Manchester ......Manchester Electric Company (21 Summer Street)
Marlborough .....Marlborough Electric Company
Milford ....Milford Electric Light & Power Company (241 Main Street)

Massachusetts (*Continued*)

New Bedford	New Bedford Gas & Edison Light Company
North Abington	Electric Light & Power Company of Abington and Rockland
North Adams	North Adams Gas Light Company
Northampton	Northampton Electric Lighting Company (212 Main Street)
Norton	Norton Power & Electric Company
Palmer	Central Massachusetts Electric Company
Pittsfield	Pittsfield Electric Company
Plymouth	Plymouth Electric Light Company
Provincetown	Provincetown Light & Power Company (127 Commercial Street)
Quincy	Quincy Electric Light & Power Company (1535 Hancock Street)
Randolph	Randolph & Holbrook Power & Electric Company (150 Congress Street, Boston)
Revere	Suburban Gas & Electric Company
Salem	Salem Electric Lighting Company
Spencer	Spencer Gas Company (77 Franklin Street, Boston)
Springfield	United Electric Light Company
Stockbridge	Southern Berkshire Power & Electric Company
Turners Falls	Turners Falls Power & Electric Company
Uxbridge	Worcester Suburban Electric Company
Ware	Ware Electric Company
Wareham	Southeastern Massachusetts Power & Electric Company
Webster	Webster & Southbridge Gas & Electric Company
Westboro	Westboro Gas & Electric Company (150 Congress Street, Boston)
Williamsburg	Mill River Electric Light Company (77 Franklin Street, Boston)
Williamstown	Williamstown Gas Company (77 Franklin Street, Boston)
Winchenden	Winchenden Electric Light & Power Company
Worcester	Worcester Electric Light Company (11 Foster Street)

Michigan

Adrian	Citizens Light & Power Company
Alpena	Alpena Power Company
Benton Harbor	Benton Harbor & St. Joe Railway & Light Company
Detroit	The Detroit Edison Company
Frankfort	Lower Peninsula Power Company
Hammond	Berrien Gas & Electric Company
Houghton	Houghton County Electric Light Company
Hudson	Southern Michigan Light & Power Company
Iron River	Iron Range Light & Power Company
Jackson	Commonwealth Power Corporation Consumers Power Company
Lapeer	Michigan Electric Power Company
Menominee	Menominee & Marinette Light & Traction Company
Rogers City	Rogers City Electric Light & Power Company
Sault Ste. Marie	The Chippewa Edison Company (113 Ashman Street) Edison Sault Electric Company
Tecumseh	Lenawee County Light & Power Company (Adrian)
Three Rivers	Michigan Gas & Electric Company
Traverse City	Michigan Public Service Company (General Office, Box 365)

Minnesota

Arlington	Peoples Minnesota Gas & Electric Corp. (Amery)
Canby	Union Public Service Co. (Pioneer Bldg., St. Paul, Minn.)
Dodge Center	Iowa Minnesota Light & Power Company
Duluth	Minnesota Power & Light Company
Elk River	Elk River Power & Light Companay
Fergus Falls	Otter Tail Power Company
Jasper	Home Light & Power Company
Jordan	Jordan Electric Light & Heating Company
Kenyon	Gunderson Electric Company
Minneapolis	The Minneapolis General Electric Company Montana Dakota Power Company (831 Second Avenue South) Northern States Power Company (15 South Fifth Street) Northwestern Public Utilities, Inc. (22 West Monroe Street, Chicago, Ill.)
Pine City	Eastern Minnesota Power Company
Preston	Root River Power & Light Company
Proctor	Proctor Water & Light Company (Lock Drawer 1028)
Redwood Falls	Redwood Falls Light & Power Company
Twin Valley	Crosswell Power Company
Waconia	Western Power & Light Company
Wheaton	Wheaton Electric Light Company
Winona	Mississippi Valley Public Service Company

Mississippi

Gulfport	Mississippi Power Company
Jackson	The Mississippi Power & Light Company (326 Lampton Bldg.)

Missouri

Joplin	Empire District Electric Company
Kansas City	Kansas City Power & Light Company (1330 Grand Avenue)
Lexington	Missouri Gas & Electric Service Company (1108 Main Street)
Louisiana	Missouri Edison Company
Maryville	Maryville Electric Light & Power Company
Mexico	Missouri Power & Light Company (740 Board of Trade Bldg., Kansas City)
Pleasant Hill	Missouri Public Service Company (Warrensburg)
Ste. Genevieve	Missouri General Utilities Company
St. Joseph	St. Joseph Railway, Light, Heat & Power Company

Missouri (*Continued*)

St. Louis	Commonwealth Utilities Corp. (911 Liberty Central Trust Bldg., 506 Olive Street)
	Community Power & Light Company (205 Planters Building, Fourth and Pine Streets)
	General Public Utilities Company (205 Planters Bldg.)
	The Laclede Power & Light Company (1017 Olive Street)
	Union Electric Light & Power Company
Sedalia	The City Light & Traction Company
Sikeston	Missouri Utilities Company
Springfield	Springfield Gas & Electric Company
Troy	East Missouri Power Company

Montana

Butte	The Montana Power Company
Dillon	Union Electric Company
Great Falls	Great Northern Utilities Company (110 Central Avenue)
Helena	Helena Gas & Electric Company
Missoula	Missoula Public Service Company
Plains	Plains Light & Water Company

Nebraska

Gothenburg	Gothenburg Light & Power Company
Grand Island	Central Power Company
Lincoln	Iowa-Nebraska Light & Power Company (Gas & Electric Bldg.)
Loup City	Nebraska Electric Power Company
McCook	Nebraska Light & Power Company
Omaha	Central West Public Service Company Room 1900, 120 South La Salle Street, Chicago)
	Central West Public Service Company of Nebraska (117-123 North 13th Street)
	Nebraska Power Company
O'Neill	Interstate Power Company of Nebraska (1000 Main Street, Dubuque)
Palisade	F. C. Krotter
Scottsbluff	Missouri Service Company (Box C)
	Western Public Service Company (P. O. Box C)
Superior	Southern Nebraska Power Company

Nevada

East Ely	Ely Light & Power Company (229 Eleventh Street)
Elko	Elko Lamoille Power Company
Goldfield	Nevada-California Power Company
Lovelock	Nevada Valleys Power Company
Reno	Sierra Pacific Power Company
Winnemucca	Western States Utilities Company

New Hampshire

Concord	Concord Electric Company
Derry	Derry Electric Company (P. O. Box 210, Portsmouth)
Exeter	Exeter & Hampton Electric Company (81 Water Street)
Lebanon	Grafton County Electric Light & Power Company
Manchester	Public Service Company of New Hampshire
Newport	New Hampshire Power Company
North Conway	Goodrich Falls Electric Company
Portsmouth	New Hampshire Gas & Electric Company

New Jersey

Asbury Park	Eastern New Jersey Power Company
	Jersey Central Power & Light Company
Atlantic City	Atlantic City Electric Company
Closter	Rockland Electric Company
Dover	The New Jersey Power & Light Company)
Millville	Millville Electric Light Company
Newark	Public Service Electric & Gas Company

New Mexico

Albuquerque	Albuquerque Gas & Electric Company
Clovis	New Mexico Utilities Company
Deming	Deming Ice & Electric Company
Las Cruces	Mesilla Valley Electric Company
Las Vegas	The Las Vegas Light & Power Company
Sante Fe	New Mexico Power Company
Socorro	New Mexico Public Service Company

New York

Albany	Mohawk-Hudson Power Corporation (126 State Street)
	New York Power & Light Corporation (126 State Street)
Binghamton	Binghamton Light, Heat & Power Company
Buffalo	Buffalo General Electric Company (Electric Bldg.)
	Buffalo, Niagara and Eastern Power Corporation (Electric Bldg.)
	Niagara, Lockport & Ontario Power Company (400 Electric Bldg.)
Canajoharie	Montgomery Electric Light & Power Company (94 Church Street)
Cazenovia	Cazenovia Electric Company
Cold Spring	Cold Spring Light, Heat & Power Company
Corinth	Corinth Electric Light & Power Company
Cortland	Cortland County Traction Company
Ellenville	Ellenville Electric Company
Elmira	Elmira Water, Light & Railroad Company
Fulton	Fulton Light, Heat & Power Company
Gouverneur	Oswegatchie Light & Power Company
Granville	Granville Electric Company (27 West Main Street)
Lancaster	Western New York Gas & Electric Corp. (Central and Brady Aves.)
Lockport	Lockport Light, Heat & Power Company
Malone	Malone Light & Power Company
Monroe	Orange & Rockland Electric Company
Mount Vernon	Westchester Lighting Company
New York City:	
Bronx	Bronx Gas & Electric Company (P. O. Box 50)
Brooklyn	Brooklyn Edison Company, Inc. (380 Pearl Street)

New York (*Continued*)

New York City:	
Manhattan	Allied Power & Light Corp. (20 Pine Street)
	American Commonwealth Power Corp. (Suite 1029, 120 Broadway)
	American Electric Power Company (20 Pine Street)
	American Gas & Electric Company (30 Church Street)
	American Water Works & Electric Company, Inc. (50 Broad Street)
	Associated Gas & Electric Company (33 Liberty Street)
	W. S. Barstow & Company (50 Pine Street)
	Cities Service Company (60 Wall Street)
	Cities Service Power & Light Company (60 Wall Street)
	Henry L. Doherty & Company (60 Wall Street)
	Electric Bond & Share Company (2 Rector Street)
	Electric Management & Engineering Corporation (57 William Street, 14th Floor)
	Electrical Securities Corporation (31 Nassau Street)
	Engineers Public Service Company (120 Broadway)
	Federal Light & Traction Company (52 William Street, 21st Floor)
	Long Island Lighting Company (50 Church Street)
	National Electric Power Company (57 William Street)
	National Public Service Company (57 William Street)
	The New York Edison Company (4 Irving Place)
	North American Gas & Electric Company (57 William Street)
	Peoples Light & Power Corporation (27 William Street, Suite 914-922)
	United Electric Light & Power Company (4 Irving Place)
	The J. G. White Management Corporation (33 Liberty Street)
Queens	Queens Borough Gas & Electric Company (Far Rockaway, N. Y.)
	New York & Queens Electric Light & Power Company (28-19 Bridge Plaza, North, Long Island City, N. Y.)
Richmond	Staten Island Edison Corporation (Lock Box "C," St. George, Staten Island)
Niagara Falls	Niagara Electric Service Corporation (109 Main Street)
	Niagara Falls Power Company
North Tonawanda	Tonawanda Power Company
Nyack	Rockland Light & Power Company
Oneonta	New York State Electric Corporation.
Ossining	Northern Westchester Lighting Company
Oswego	Peoples Gas & Electric Company of Oswego
Patchogue	Patchogue Electric Light Company
Peekskill	Peekskill Lighting & Railroad Company
Plattsburgh	Eastern New York Electric & Gas Company, Inc.
Potsdam	St. Lawrence County Utilities, Inc.
Poughkeepsie	Central Hudson Gas & Electric Corporation (50 Market Street)
Rochester	Rochester Gas & Electric Corporation
Sherrill	Kenwood Electric Light Company
Syracuse	The Syracuse Lighting Company, Inc.
Ticonderoga	The Ticonderoga Electric Light & Power Company (East Exchange Street)
Utica	Utica Gas & Electric Company (258 Genesee Street)
Watertown	Northern New York Utilities, Inc.
Yonkers	Yonkers Electric Light & Power Company (45 South Broadway)

North Carolina

Chapel Hill	University Consolidated Service Plant (Elec. & Water Division)
Durham	Durham Public Service Company
Greensboro	North Carolina Public Service Company
Raleigh	Carolina Power & Light Company
Wilmington	Tide Water Power Company

North Dakota

Amenia	Amenia Power Company
Arthur	Hunter Power Company (Box 44)
Bismarck	North Dakota Power & Light Company
Devil's Lake	Dakota Public Service Company
Fargo	Union Light, Heat & Power Company
Grand Forks	Red River Power Company
Harvey	Central Light & Power Company
Pembina	Interstate Power Company of North Dakota (Dubuque, Iowa)

Ohio

Akron	Northern Ohio Power & Light Company
Alliance	The Suburban Power Company (Alliance First Nat'l Bank Bldg.)
Ansonia	The Ansonia Lighting Company
Athens	The Southern Ohio Electric Company (29 So. Court Street)
Bowling Green	The Ohio Northern Public Service Company (131 W. Wooster Street)
Canton	The Ohio Power Company
Cincinnati	Columbia Engineering & Management Corporation (314 West Fourth Street)
	The Union Gas & Electric Company
Cleveland	The Buckeye Public Service Company (1803 Terminal Tower Bldg.)
	Cleveland Electric Illuminating Company (Box 392)
	The Cleveland Light & Power Company (8 St. Clair Avenue, N. W.)
	The Lake Erie Power & Light Company (Union Trust Bldg.)
	The Ohio Public Service Company (1800 Keith Bldg.)
	The Western Reserve Power & Light Company (1670 Union Trust Bldg.)
Columbus	Columbus Railway Power & Light Company (215 North Front Street)
	The Ohio Utilities Company (150 East Broad Street)
	The Scioto Valley Railway & Power Company (Third & Rich Streets)
Covington	The Buckeye Light & Power Company
Dayton	The Dayton Power & Light Company
Eaton	The Eaton Lighting Company (101 East Main Street)
Findlay	The Toledo, Bowling Green & Southern Traction Company

Ohio (*Continued*)

Greenville	The Brookville & Lewisburg Lighting Company (112 West Fourth Street) Greenville Electric Light & Power Company (112 West Fourth Street)
London	London Light & Power Company (108 So. Main Street)
Marion	Columbus, Delaware & Marion Electric Company (Room No. 8-100 F. Bldg.)
North Baltimore	The North Baltimore Service Company (29 South La Salle Street, Chicago, Ill.)
Rudolph	Rudolph Light & Power Company (29 South La Salle Street, Chicago, Ill.)
Sidney	Ohio Electric Power Company (Bryan Bldg.)
Springfield	Ohio Edison Company (121 E. High Street)
Toledo	The Lake Shore Power Company (c/o Toledo Edison Company, Edison Bldg.) The Toledo Edison Company
Wooster	The Wooster Electric Company (29 Beall Avenue)
Youngstown	The Pennsylvania-Ohio Power & Light Company (Box 58)
Zanesville	Southern Ohio Public Service Company (Richards Bldg.)

Oklahoma

Fairfax	Oklahoma Utilities Company
Lawton	Southwestern Light & Power Company (517-522 Braniff Bldg., Oklahoma City)
Oklahoma City	Oklahoma Gas & Electric Company
Sand Springs	Oklahoma Power & Water Company (11 West 2nd Street)
Tulsa	Public Service Company of Oklahoma

Oregon

Albany	Mountain States Power Company
Athena	Preston-Shaffer Milling Company
Aurora	Molalla Electric Company
Baker	Eastern Oregon Light & Power Company
Hermiston	Hermiston Light & Power Company
Medford	The California Oregon Power Company
Newberg	Yamhill Electric Company (600 First Street)
Portland	Northwestern Electric Company (Public Service Bldg., 6th Street—Taylor to Salmon) Pacific Power & Light Company (Gasco Bldg.) Peoples West Coast Hydro-Electric Corporation (212 Fitzpatrick Bldg.) Portland Electric Power Company

Pennsylvania

Allentown	Pennsylvania Power & Light Company (Ninth and Hamilton Streets)
Altoona	Penn Central Light & Power Company
Bradford	Bradford Electric Company (68 Chestnut Street)
Carlisle	The Carlisle Gas & Water Company
Chester	Delaware County Electric Company (16-18 East Fifth Street)
Coatesville	Chester Valley Electric Company
Colver	Colver Electric Company (123 South Broad Street, Philadelphia)
Cresson	Cresson Electric Light Company
Dushore	Sullivan County Electric Company
Erie	Erie County Electric Company (N. W. 12th and French) Erie Lighting Company
Forty Fort-Kingston	Harvey's Lake Light Company (45 Owen Street)
Glen Rock	Glen Rock Electric Light & Power Company
Greencastle	Greencastle Light, Heat, Fuel & Power Company (Coatesville, Pa.)
Greenville	Pennsylvania Power Company
Holtwood	Pennsylvania Water & Power Company (Lexington Building, Baltimore, Md.)
Johnstown	Pennsylvania Electric Company (Post Office Drawer "G")
Kennett Square	Chester County Light & Power Company
Kingston	Luzerne County Gas & Electric Corporation
Lancaster	Edison Electric Company
La Plume	Abington Electric Company
Mauch Chunk	Mauch Chunk Heat, Power & Electric Light Company
Meadville	Harley D. Carpenter (Box 406)
Mercersburg	Mercersburg, Lehmasters & Markes Electric Company
Milford	Pike County Light & Power Company (Nyack, N. Y.)
Natrona	Natrona Light & Power Company
Norristown	Philadelphia Suburban-Counties Gas & Electric Co. (208-214 De Kalb Street)
Oil City	Keystone Public Service Company (Drake Theater Bldg., Seneca Street)
Oxford	Southern Pennsylvania Power Company (119 South Third Street)
Palmerton	Palmerton Lighting Company (340 Delaware Avenue)
Philadelphia	E. W. Clark Engineering Corporation (321 Chestnut Street) Day & Zimmermann, Inc. (112 North Broad Street) The Philadelphia Electric Company (1000 Chestnut Street) United Gas Improvement Company (Broad and Arch Streets)
Pittsburgh	The Duquesne Light Company The West Penn Electric Company (14 Wood Street) The West Penn Power Company (West Penn Bldg.)
Reading	Metropolitan Edison Company
Renovo	Renovo Edison Light, Heat & Power Company
Scranton	Scranton Electric Company
Tyrone	Home Electric Light & Steam Heating Company
Waterford	Waterford Electric Light Company (East Third Street)
Waynesboro	South Penn Power Company
Wellsboro	Wellsboro Electric Company
Windber	Windber Electric Corporation.
York	Edison Light & Power Company

Rhode Island

Newport	Newport Electric Corporation (204 Thames Street)
Pawtucket	Blackstone Valley Gas & Electric Company
Providence	Narragansett Electric Company
Westerly	South County Public Service Company

South Carolina

Belton	Belton Light & Power Company
Charleston	South Carolina Power Company (141 Meeting Street)
Conway	Quattlebaum Light & Ice Company

South Dakota

Deadwood	Consolidated Power & Light Company
Huron	Northwestern Public Service Company (National Bank Bldg.)
Mobridge	Northern Power & Light Company
Rapid City	The Dakota Power Company
Watertown	Watertown Public Service Company (11 No. Broadway)

Tennessee

Bristol	Bristol Gas & Electric Company
Chattanooga	Southern Cities Power Company (Provident Bldg.) The Tennessee Electric Power Company
Jackson	West Tennessee Power & Light Company (110 Baltimore Street)
Johnson City	Tennessee Eastern Electric Company
Kingsport	Kingsport Utilities, Inc.
Knoxville	Knoxville Power & Light Company (626 South Gay Street)
Memphis	Memphis Power & Light Company
Nashville	Nashville Railway & Light Company
Shelbyville	South Kentucky Power Company (Citizens Bank)
Springfield	Tennessee Light & Power Company

Texas

Abilene	West Texas Utilities Company (Box 127)
Amarillo	Southwestern Public Service Company (526 Taylor Street)
Beaumont	Gulf States Utilities Company (366 Liberty Street)
Borger	Panhandle Power & Light Company (Drawer "I")
Dalhart	Dalhart Public Service Company
Dallas	Central and South West Utilities Company (1100 Allen Bldg.) Dallas Power & Light Company (Interurban Bldg.) Texas Power & Light Company (728 Interurban Bldg.)
El Paso	El Paso Electric Company
Fort Worth	Fort Worth Power & Light Company (Box 647) Northern Texas Traction Company (400 Main Street) Texas-Louisiana Power Company (622 Fort Worth Club Bldg.)
Freeport	Freeport Sulphur Company (P. O. Box 68)
Galveston	Galveston Electric Company
Girvin	Pecos Valley Power & Light Company (Fort Worth National Bank Bldg., Fort Worth)
Houston	Houston Lighting & Power Company
Hubbard	Union Central Light & Power Company
Plainview	Texas Utilities Company
San Antonio	Central Power & Light Company (1020 Frost National Bank Bldg.) San Antonio Public Service Company

Utah

Cedar City	Dixie Power Company (Box 448)
Moroni	Big Springs Power Company
Salt Lake City	Telluride Power Company (1309 Walker Bank Bldg.) Utah Power & Light Company

Vermont

Bellows Falls	Fall Mountain Electric Company
Brattleboro	Twin State Gas & Electric Company (Boston, Mass.)
Chester	Chester Power & Light Company, Inc.
Middlebury	Middlebury Electric Company (131 State Street, Boston)
Montpelier	Green Mountain Power Corp.
Pittsford	Allied Vermont Utilities, Inc.
Rutland	Public Service Corporation of Vermont 131 State Street, Boston) Rutland Railway, Light & Power Company (131 State Street, Boston) Vermont Hydro Electric Corp. (131 State Street, Boston)
St. Albans	Public Electric Light Company (161 Devonshire Street, Room 805, Boston)
Windsor	Windsor Electric Light Company (131 State Street, Boston)
Woodstock	Woodstock Electric Company

Virginia

Charlottesville	Virginia Public Service Company
Harrisonburg	Shenandoah River Power Company (National Bank Bldg.)
Purcellville	Loudoun Light & Power Company
Richmond	Virginia Electric & Power Company
Winchester	Northern Virginia Power Company

Washington

Aberdeen	Grays Harbor Railway & Light Company
Cheney	Cheney Light & Power Company
Colville	Stevens County Power & Light Company
Port Angeles	Northwestern Power & Light Company
Raymond	Willapa Electric Company
Seattle	Puget Sound Power & Light Company Washington Irrigation & Development Company (905 White Bldg.)
Spokane	The Washington Water Power Company
Tacoma	Washington Gas & Electric Company (101 South Tenth Street)

West Virginia

Charleston	Appalachian Electric Power Company Columbia Gas & Electric Corporation (61 Broadway, New York, N. Y.)
Fairmont	Monongahela West Penn Public Service Company
Iaeger	United Light & Power Company
Martinsburg	Potomac Light & Power Company
Mullens	Union Power Company (c/o W. Va. Engineering Co., Kanawha National Bank Bldg., Charles)
Petersburg	Community Power Company Potomac Valley Power Corporation
Piedmont	Piedmont Electric Light & Power Company
War	War Light & Water Company
Wheeling	Wheeling Electric Company

Wisconsin

Abbotsford	Midland Public Service Company
Amery	Wisconsin Hydro Electric Company
Ashland	Lake Superior District Power Company
Eau Claire	Northern States Power Company of Wisconsin
Green Bay	Wisconsin Public Service Corporation
Lake Geneva	Southern Wisconsin Electric Company (260 Broad Street)
Madison	Madison Gas & Electric Company Wisconsin Power & Light Company (Suite 900, Gay Bldg., 16 Carroll Street)
Milwaukee	Milwaukee Electric Railway & Light Company
Prairie du Chien	Interstate Power Company of Wisconsin (1000 Main Street, Dubuque)
Racine	Wisconsin Gas & Electric Company (305 Sixth Street)
Superior	Superior Water, Light & Power Company
Waupaca	Waupaca Electric Service & Railway Company
Wausau	Wisconsin Valley Electric Company
West Bend	Wisconsin Public Utility Company

Wyoming

Casper	Mountain States Power Company (Wyoming Division)
Cheyenne	The Cheyenne Light, Fuel & Power Company (1704-06 Capitol Avenue)
Lander	Lander Electric Light & Power Company
Rawlins	The Rawlins Electric Light & Fuel Company (Box 527)
Sheridan	The Sheridan County Electric Company

UNITED STATES POSSESSIONS

Alaska

Cordova	Alaska Public Utilities
Juneau	Alaska Electric Light & Power Company
Ketchikan	Citizens Light, Power & Water Company
Valdez	Prince William Sound Water Power, Light & Telephone Company

Hawaii

Hilo	Hilo Electric Light Company, Limited
Honolulu	The Hawaiian Electric Company, Ltd. (900 Richards Street)

Philippine Islands

Manila	The Manila Electric Company

Porto Rico

Ponce	Ponce Electric Company
San Juan	Porto Rico Railway, Light & Power Company

CANADA

Alberta

Calgary	Calgary Power Company, Limited (164 St. James Street, Montreal, Quebec) Canadian Utilities, Limited (215 Sixth Avenue, West)
Vulcan	Vulcan Light & Power Company, Limited

British Columbia

Fernie	East Kootenay Power Company, Limited
Rossland	West Kootenay Power & Light Company, Limited
Vancouver	British Columbia Electric Railway Company, Limited

Manitoba

Great Falls	Manitoba Power Company, Limited
Winnipeg	Winnipeg Electric Company (Electric Railway Chambers)

New Brunswick

Aroostook	Maine & New Brunswick Elec'l Power Company, Limited (Presque Isle, Maine)
Bathurst	Bathurst Electric & Water Power Company, Limited
Fredericton	The Maritime Electric Company, Limited
Grant Falls	St. John River Power Company (Box 219)
Moncton	Moncton Tramways, Electricity & Gas Company, Limited
St. John	New Brunswick Power Company
St. Stephen	The Maritime Electric Company, Limited
Woodstock	Woodstock Electric Railway, Light & Power Company

Nova Scotia

Amherst	Canada Electric Company, Limited (26 Church Street)
Halifax	Nova Scotia Tramways & Power Company, Limited
New Waterford	Dominion Utilities Company, Limited
Sydney	Cape Breton Electric Company
Windsor	The Avon River Power Company, Limited
Yarmouth	Western Nova Scotia Electric Company, Limited.

Ontario

Arnprior	The Galletta Electric Power & Milling Company
Cornwall	Stormont Electric Light & Power Company
Erin	Caledon Electric Company, Limited
Fort William	Kaministiquia Power Company, Limited
Gananoque	The Gananoque Electric Light & Water Supply Company, Limited
Hamilton	Dominion Power & Transmission Company, Limited
Iroquois Falls	Abitibi Electric Development Company, Limited
Massey	Lloyd Deagle & Company
Mattawa	The Mattawa Electric Light & Power Company, Limited
Merrickville	Rideau Power Company
New Liskeard	Canada Northern Power Corporation, Limited Northern Ontario Light & Power Company, Limited Northern Quebec Power Company, Limited
Niagara Falls	Canadian Niagara Power Company, Limited
Ottawa	Gatineau Electric Light Companv, Limited (140 Wellington Street) Gatineau Power Company The Ottawa Electric Company
Pembroke	The Pembroke Electric Light Company, Limited
Renfrew	Calabogie Light & Power Company
Sault Ste. Marie	Algoma Steel Corporation, Limited Great Lakes Power Company

Prince Edward Island

Charlottetown	The Maritime Electric Company, Limited

Quebec

Arvida	Duke-Price Power Company, Limited Saguenay Electric Company
Buckingham	The James Maclaren Company, Limited
Chambly, Canton	Chambly Power Corp.
Huntingdon	Beauharnois Electric Company, Limited
Montreal	Continental Heat & Light Company (611 (Power Bldg.) Great Northern Power Company (614 Dominion Express Bldg.) Laurentide Power Company, Limited (Power Bldg.) Montreal Light, Heat & Power, Consolidated Southern Canada Power Company, Limited (132 St. James Street) Southern Canada Power Company, Limited (330 Coristine Bldg.)
Quebec	Quebec Power Company Quebec Railway, Light, Heat & Power Company
Rimouski	Lower St. Lawrence Power Company
St. Joseph, Beauce County	St. Francis Light & Power Company
St. Timothee	The Canadian Light & Power Company
Shawinigan Falls	Electric Service Corporation The Shawinigan Water & Power Company (Montreal)
Sorel	Sorel Light & Power Company
Thetford Mines	St. Francis Water Power Company
Three Rivers	North Shore Power Company

Saskatchewan

Regina	Arcola Light & Power Company (36-38 Western Trust Bldg.) Dominion Electric Power, Limited (1770 Scarth Street)

MEXICO

Guanajuato	Central Mexico Light & Power Company (2 Rector Street, New York, N. Y.)
Mexico City	The Mexican Light & Power Company, Limited (Apartado 490)
Monterrey	Monterrey Railway, Light & Power Company (Apartado 58)

NEWFOUNDLAND

St. Johns	Newfoundland Light & Power Company, Limited (P. O. Box 823) United Towns Electric Company, Limited

Manufacturer Companies

(Class D)

"Class D members shall be companies or firms engaged in the manufacture of apparatus, machinery, equipment, supplies or material for the production or use of Electrical energy."—*Constitution, Art. III, Sec.* 5.

Alabama

Birmingham .....Bessemer Galvanizing Works (205 Phoenix Bldg.)

California

Alhambra ....C. F. Braun & Company

Los Angeles .....Diamond Electrical Manufacturing Company (1320 East Sixteenth Street)
Kelman Electric & Mfg. Company (1650 Naud Street)

San Francisco ....General Appliance Corp. (44 Whitehall Street, New York, N. Y.)
Majestic Electric Appliance Company, Inc. (590 Folsom Street)
Pacific Coast Steel Company (Hunter-Dulin Bldg.)
Pacific Electric Manufacturing Company (5815 Third Street)
The Pelton Water Wheel Company (19th and Harrison Streets)

Connecticut

Ansonia ....The Ansonia Electrical Company (63 Main Street)

Branford ....Malleable Iron Fittings Company (Pole Hardware Department)

Bridgeport ....Bridgeport Brass Company (475 Fifth Avenue, New York, N. Y.)
Bryant Electric Company
Harvey Hubbell, Inc.

Hartford ....Colt's Patent Fire Arms Mfg. Co. (Electrical Division)
The Hart Manufacturing Company (Hamilton Street)
The States Company (19 New Park Avenue)

Meriden ....Manning, Bowman & Company
The Miller Company (99 Center Street)

New Britain .....Landers, Frary & Clark

New Haven ......The Bigelow Company (P. O. Drawer 706)
The National Electric Condenser Company (P. O. Box 1820)
Products Protection Corporation (P. O. Box 904)
Rockbestos Products Corporation (P. O. Box 1102)
Whirldry Corporation (c/o Winchester Repeating Arms Co.)

Plainville ....The Trumbull Electric Manufacturing Company

Torrington ......The Fitzgerald Mfg. Company (Main Street)

Waterbury ....The American Brass Company (c/o Anaconda Copper Mining Co., 25 Broadway, New York, N. Y.)
The Beardsley & Wolcott Mfg. Company (125 Maple Street)
The Bristol Company
Scovill Manufacturing Company

Delaware

Edge Moor ......Edge Moor Iron Company

Florida

Jacksonville ....American Cross Arms Company, Inc. (P. O. Box 82)

Illinois

Bloomington .....Williams Oil-O-Matic Heating Corp.

Chicago ....American Concrete Marbelite Company (232 East Erie Street)
American Insulated Wire Div. of General Cable Corporation (954 West 21st Street)
American Ironing Machine Company (100 East Ohio Street)
Anaconda Wire and Cable Company Rolling Mills Department (25 Broadway, Room 1870, New York, N. Y.)
Automatic Burner Corp. (312 North May Street)
Beardslee Chandelier Manufacturing Company (216-20 South Jefferson Street)
Benjamin Electric Manufacturing Company (128 South Sangamon Street)
Chicago Flexible Shaft Company (5600 West Roosevelt Road)
The Conover Company (140 South Dearborn Street)
Continental Valve & Equipment Company (82 Herbert Street, Framingham, Mass.)
Crane Company (836 South Michigan Avenue)
Crane Packing Company (1800 Cuyler Avenue)
Curtis Lighting, Inc. (1119 West Jackson Boulevard)
Delta Star Electric Company (2433-2443 Fulton Street)
Economy Fuse & Manufacturing Company (Greenview Avenue at Diversey Parkway)
Edison Electric Appliance Company, Inc. (5660 West Taylor Street)
Federal Electric Company (8700 South State Street)
G. & W. Electric Specialty Company (7780 Dante Avenue, Grand Crossing Station)
Hurley Machine Company (Division of Electric Household Utilities Corporation, West 22d Street and 54th Avenue)
Paul E. Johnson, Inc. (1824 South Albert Street)
Mathias Klein & Sons (3200 Belmont Avenue)
Kulp Theft Proof Lamp Company (330 South Wells Street)
Max Marquiz (4821 Sheridan Road)
The Mercoid Corp. (25 Church Street, Room 307, New York, N. Y.)

Illinois (*Continued*)

Chicago (***Continued***) .... Minerallac Electric Company (25 North Peoria Street)
Naugle Pole & Tie Company (5 South Wabash Avenue)
Reynolds Electric Company (2650 West Congress Street)
Royal Electric Manufacturing Company (619-621 East 40th Street)
W. H. Salisbury & Company, Inc. (308 West Madison Street)
Schweitzer & Conrad, Inc. (4431-4439 Ravenswood Avenue)
Standard Oil Company of Indiana, Tech. Div., Lubg. Dept. (910 South Michigan Avenue)
Taylor Forge & Pipe Works (Box 485)
Triplex Washing Machine Corp. (644 West Lake Street)
Victor X-Ray Corporation (2012 Jackson Boulevard)
Walker Vehicle Company (87th and State Streets, Chesterfield Station)

Harvey .... The Buda Company

Macomb .... Illinois Electric Porcelain Company (512 North Pearl Street)

Peoria .... Altorfer Brothers Company

Rockford .... George D. Roper Corporation

Rock Island ..... Rock Island Manufacturing Company (First Street at Fifteenth Avenue)

Springfield .... Sangamo Electric Company
Springfield Boiler Company (1901 East Capitol Avenue)

Sycamore .... Inland Wire & Cable Company

Indiana

Brazil .... The Clay Products Company

East Chicago ..... Edward Valve & Manufacturing Company (1200 W. 145th Street)

Evansville .... Servel, Inc.

Gary .... Walter Bates Steel Corporation (East Fifth Avenue)

Indianapolis ..... Transelectric Company (518 Traction Terminal Building)

Lafayette .... Duncan Electric Manufacturing Company

Marion .... Rutenber Electric Company

South Bend ...... South Bend Current Controller Company (P. O. Box 245)

Iowa

Council Bluffs .... Giant Manufacturing Company

Newton .... Automatic Washer Company, Inc.
One Minute Manufacturing Company

Kentucky

Covington .... The Wadsworth Electric Manufacturing Company, Inc. (22-30 West Eleventh Street)

Maine

Portland .... Brown Company (Fibre Conduit Dept.)

Maryland

Baltimore .... Locke Insulator Corporation (Maryland Trust Company Bldg.)
May Oil Burner Corp. (3500 East Biddle Street)
Standard Gas Equipment Corp., Acorn Div. (Bayard and Hamburg Streets)

Massachusetts

Ashland .... Warren Telechron Company

Boston .... Albert & J. M. Anderson Manufacturing Company (289-305 A Street, Boston 9,)
Bernitz Furnace Appliance Company (Public Service Bldg., 89 Broad Street)
Condit Electrical Manufacturing Corporation (838 Summer Street)
The Dampney Company of America (50-60 Business Street, Hyde Park)
Holtzer-Cabot Electric Company (125 Amory Street, Roxbury)
Simplex Wire & Cable Company (201 Devonshire Street)
Stets Company (141 Milk Street)
B. F. Sturtevant Company (Hyde Park)
Tower Manufacturing Company (122 Brookline Avenue)
Walker & Pratt Manufacturing Company (31-35 Union Street)
Walworth Company (Statler Bldg.)
Wheeler Reflector Company (275 Congress Street)

Medford Hillside . Doble Engineering Company

Springfield .... American Electric Service & Maintenance Company (P. O. Box 1231)

Waltham .... The Palmer Electric & Mfg. Co. (corner of Pond and Exchange Streets)

Watertown ...... Hood Rubber Company (Nichols Avenue)

Worcester .... American Steel & Wire Company (94 Grove Street)
Devon Manufacturing Company (677 Cambridge Street)
Riley Stoker Corporation (9 Neponset Street)
M. S. Wright Company (164 Fremont Street)

Michigan

Battle Creek ...... H. B. Sherman Manufacturing Company (9 Barney Street)

Bay City .... Kuhlman Electric Company

Detroit .... American Electrical Heater Company
Bartlett Manufacturing Company (743 Beaubien Street)
Burroughs Adding Machine Company (6071 Second Boulevard)
Copeland Products, Inc. (630 Lycaste Avenue)
Diamond Power Specialty Corporation (10340 Oakland Avenue)
Electrovent Corp. (5057 Woodward Avenue)
Eureka Vacuum Cleaner Company (Hamilton and Dewey Avenues)
General Utilities Manufacturing Company (2587 East Grand Boulevard)
Ironrite Ironer Company (38 Piquette Avenue)
Kelvinator Corporation (14250 Plymouth Road)
Knott & Garllus Company (3945-3951 "A" Street)
The Peninsular Stove Company (1417 Fort Street West)
Square D Company (6060 Rivard Street)
Whitehead Refrigeration Company (3730 Woodward Avenue)

Grand Rapids .... Leonard Div. of Kelvinator Corp., Clyde Park Avenue)

Michigan (*Continued*)

Jackson ....Reynolds Spring Company (North East Avenue)
St. Joseph ....Upton Machine Company
Wayne ....Deceleco, Inc.

Minnesota

Minneapolis ......B. J. Carney & Company (100 N. 7th Street)
Electric Machinery Manufacturing Company (1331 N. E. Tyler Street)
National Pole & Treating Company (1100 Builders Exchange Building)
The Valentine-Clark Company (P. O. Box 1797)
Waters-Genter Company (213 N. Second)
St. Paul ....Bohn Refrigerator Company (1350 University Avenue)
Seeger Refrigerator Company (Arcade-Wells-Whitehall Streets)

Missouri

Centralia ....Chance Company (Allen at Wilson)
St. Louis ....Century Electric Company (1827 Pine Street)
Electrol, Incorporated (170 Dorcas Street)
Emerson Electric Manufacturing Company (2018 Washington Avenue)
The Edwin F. Guth Company (2615 Washington Avenue)
Jas. R. Kearney Corporation (4224 Clayton Avenue)
W. N. Matthews Corporation (3722 Forest Park)
Moloney Electric Company (5390 Kingshighway, N. W.)
St. Louis Malleable Casting Company (7701 N. Conduit Avenue)
Wagner Electric Corporation (6400 Plymouth Avenue)

Nebraska

Omaha ....Clark Electric Water Heater, Division of McGraw Electric Company (13th and Capitol Avenue)

New Hampshire

Laconia ....Laconia Car Company

New Jersey

Garwood ....Diamond Expansion Bolt Company
Gloucester City ..Welsbach Company (Essex and Ellis)
Harrison ....Driver-Harris Company
Edison Lamp Works of General Electric Company
Hoboken ....Cooper Hewitt Electric Company (410 Eighth Street)
Newark ....American Transformer Company (178-182 Emmet Street)
Baker & Company, Inc. (54 Austin Street)
Hanovia Chemical & Manufacturing Company (Chestnut Street and N. J. R. R. Avenue)
Weston Electrical Instrument Corporation (614 Frelinghuysen Avenue)
Orange ....Edison Storage Battery Company
Thomas A. Edison, Inc., Edicraft Division (P. O. Box 543)
Passaic ....The Okonite Company (501 Fifth Avenue, New York, N. Y.)
The Okonite-Callender Cable Company, Inc. (501 Fifth Avenue, New York, N. Y.)
Trenton ....Circle F Manufacturing Company (720 Monmouth Street)
De Laval Steam Turbine Company
Imperial Porcelain Works
Panelyte Corp. (Enterprise Avenue)
John A. Roebling's Sons Company (640 South Broad Street)

New York

Albany ....Hynes & Cox Electric Corp. (406 No. Pearl Street)
Beacon ....The Green Fuel Economizer Company
Binghamton ......Nineteen Hundred Corp. (255 Clinton Street)
Buffalo ....The Flexlume Corp. (1100 Military Road)
Remington Rand Business Service, Inc. (465 Washington Street)
Savory, Inc. (90 Alabama Street)
Corning ....Corning Glass Works
Jamestown ....Blackstone Manufacturing Company (56-58 Blackstone Avenue)
Johnson City ....Central Flatiron Manufacturing Company
LeRoy ....Lapp Insulator Company, Inc.
Lima ....The Porcelain Insulator Corp.
Mount Vernon ...Ward Motor Vehicle Company (South Fulton Avenue)

New York City:

Brooklyn ......Gleason-Tiebout Glass Company (99 Commercial Street)
Lackner Products Corp. (135 Luqueer Street)
Metropolitan Device Corporation (1250 Atlantic Avenue)
Albert Wahle Company, Inc. (Metropolitan and Morgan Avenues)
Manhattan .....Alberene Stone Company (153 West 23rd Street)
American Brown Boveri Electric Corporation (Graybar Building, 420 Lexington Avenue)
American Flexible Shaft Manufacturing Corp. (331 Madison Avenue)
The Babcock & Wilcox Company (85 Liberty Street)
Bakelite Corporation (247 Park Avenue)
Bishop Wire & Cable Corporation (420 East 25th Street)
Borne Scrymser Company (Whitehall Building, 17 Battery Place)
Bullard-Davis, Inc. (67 Wall Street)
Burndy Engineering Company, Inc. (10 East 43rd Street)
Claude Neon Lights, Inc. (41 East 42nd Street)
Coal Conversion Corp. (285 Madison Avenue, Room 1214)
Combustion Engineering Corporation (200 Madison Avenue)
Consolidated Ashcroft Hancock Company, Inc. (100 East 42nd Street)
Curtin-Howe Corporation (11 Park Place)
The De Laval Separator Company (165 Broadway)

New York (*Continued*)

New York City:

Manhattan (*Continued*) ..... Dexter Rubber Corp. (2 West 45th Street)
Dossert & Company (242 West 41st Street)
Dubilier Condenser Corp. (342 Madison Avenue)
Electrical Research Products, Inc. (250 West 57th Street)
The Engineer Company (17 Battery Place)
The Engineering Products Corporation, Inc. (25 Church Street, Room 309)
Foster Wheeler Corporation (165 Broadway)
General Office Equipment Corp. (342 Madison Avenue)
General Outdoor Advertising Company, Inc. (1 Park Avenue)
Gould Storage Battery Company, Inc. (250 Park Avenue)
The Griscom-Russell Company (285 Madison Avenue)
Habirshaw Cable & Wire Corp. (233 Broadway—Room 2636)
Holophane Company, Inc. (342 Madison Avenue)
Ingersoll-Rand Company (A. S. Cameron Steam Pump Works, 11 Broadway)
International Business Machines Corp. (50 Broad Street)
The International Nickel Company (67 Wall Street)
Johns-Manville, Corp. (Madison Avenue and 41st Street)
Kellems Products, Inc. (6 Varick Street)
The Kempton Manufacturing Corp. (148 West 23rd Street.
Kerite Insulated Wire & Cable Company (Hudson Terminal Building, 30 Church Street)
Walter Kidde & Co., Inc. (140 Cedar Street)
Lightolier Company (569 Broadway)
Luckenbach & Hallberg, Inc. (29 West 57th Street)
Mica Insulator Company (200 Varick Street)
National Electric Products Corp. (233 Broadway)
Noma Electric Corporation (340 Hudson Street)
Otis Elevator Company (Otis Building, 260 Eleventh Avenue)
Peerless Insulated Wire & Cable Company (30 Church Street)
The Permutit Company (440 Fourth Avenue)
Portable Light Company, Inc. (12 Warren Street)
Radio Corporation of America (233 Broadway)
The Rawlplug Company, Inc. (66 West Broadway)
Research Corporation (25 West 43rd Street)
Safety Cable Company (420 Lexington Avenue)
Serelco, Inc. (420 Lexington Avenue)
Silvray Company, Inc. (53 West 14th Street)
Smoot Engineering Corporation (136 Liberty Street)
Standard Oil Company of New Jersey (26 Broadway)

New York City:

Manhattan (*Continued*) ..... The Superheater Company (17 East 42nd Street)
The R. Thomas & Sons Company (30 Church Street)
Seth Thomas Clock Company (19 West 44th Street)
Tork Clocks, Inc. (12 East 41st Street)
Vacuum Oil Company (61 Broadway)
Waterbury Cable Service, Inc. (342 Madison Avenue)
Western Electric Company, Inc. (195 Broadway)
Westinghouse Commercial Investment Company (150 Broadway)
Westinghouse Electric International Company (150 Broadway)
Westinghouse Lamp Company (150 Broadway)
Worthington Pump & Machinery Corp. (2 Park Avenue)

Queens .... The Frink Corp. (23-10 Bridge Plaza, South, Long Island City)
Memco Engineering & Manufacturing Company, Inc. (381 Hamilton Street, Long Island City)
Morganite Brush Company, Inc. (3302-3320 Anable Avenue, Long Island City)

Niagara Falls ... Globar Corporation (P. O. Box 618)

Orchard Park.... Park Metalware Company, Inc. (Thorne Avenue and Bank Street)

Port Jervis .... Gillinder Brothers (Erie & Liberty Streets)

Poughkeepsie .... Hoe Corporation (Cottage Street)

Rochester .... North East Electric Company (379 Lyell Avenue)
Rainbow Appliance Corporation (11-27 Hand Street)
Robeson-Rochester Corporation (176 Anderson Avenue)
Vacuumizer Manufacturing Corp. (77 St. Paul Street)

Rome .... Rome Wire Company

Schenectady ...... General Electric Company (Equitable Building, 120 Broadway, New York, N. Y.)
International General Electric Company, Inc. (Att: Commercial Engineer)
York Insulated Wire Dorks of General Electric Company (1737 Broadway, New York, N. Y.)

Solvay .... Pass & Seymour, Inc.

Syracuse .... Archbold-Brady Company (Greenway Avenue)
Syracuse Washing Machine Corp.

Utica .... American LaFrance and Foamite Ind., Inc. (Turner Street)
Savage Arms Corporation (100 East 42nd Street, New York, N. Y.)

Wellsville .... The Air Preheater Corp.

Ohio

Alliance .... The Buckeye Twist Drill Company (496-544 West Ely Street)

Canton .... Nelson & Kuemmerling (718 Brant Building, Cleveland Avenue, N. W.)
Superior Iceless Refrigerator, Inc.
The Superior Switchboard & Devices Company (420 Schroyer Avenue)
The Union Metal Manufacturing Company (Maple Avenue)
The Wilson Rubber Company (1200 Garfield Avenue)

Ohio (*Continued*)

Cincinnati .... Logan County Coal Corp. (2111 Union Central Bldg.)
The Lunkenheimer Company

Cleveland .... The Apex Electrical Manufacturing Company
Bailey Meter Company (1050 Ivanhoe Road)
The Cinderella Washing Machine Company (4300 Euclid Avenue)
Electric Vacuum Cleaner Company, Inc. (Euclid Avenue and Ivanhoe Road)
The P. A. Geier Company (540 East 105th Street)
Hi-Voltage Equipment Company (3305 Croton Avenue)
The Kayline Company (600 Huron Rd.)
National Carbon Company, Inc. (W. 117th Street and Madison Avenue)
National Lamp Works of General Electric Company (Nela Park)
The Proctor & Schwartz Electric Company (6612 Euclid Avenue)
Wellington J. Smith Company (501 Davis Farley Bldg.)

Columbus .... The International Derrick & Equipment Company (875 Michigan Avenue)

Dayton .... Dayton Pump & Manufacturing Company (500 North Webster Street)
Delco Light Company (421 East First Street)
Fridigaire Corporation (Third National Bank Building)
The Master Electric Company

Dover .... The Dover Manufacturing Company

Findlay .... Porcelain Products, Inc.

Gettysburg .... Ira M. Petersime & Son

Hamilton .... The Estate Stove Company

Mansfield .... Ohio Brass Company
Westinghouse Electric & Manufacturing Co. (Mansfield Works)

North Canton .... The Hoover Company

Sidney .... Prima Manufacturing Company (Park Street)

Toledo .... The Swartzbaugh Manufacturing Company

Vermilion .... The F. W. Wakefield Brass Company

Pennsylvania

Ambler .... Asbestos Shingle Slate & Sheathing Company

Beaver Falls ...... Keystone Refrigerating Corp. (Fifteenth Street and Tenth Avenue)

Charleroi .... Macbeth-Evans Glass Company

East Pittsburgh ... Westinghouse Electric & Manufacturing Company

Erie .... Erie City Iron Works (Fifteenth and East Avenue)

Fullerton .... Fuller-Lehigh Company

Glassport .... Copperweld Steel Company

Greensburg ...... Railway & Industrial Engineering Company

Jeannette .... Elliott Company

Norristown ...... Franklin Air Compressor Corp. (Main Street and School Lane)

Philadelphia ..... The Allen-Sherman-Hoff Company (225 South 15th Street)
American Engineering Company
Andale Company (1600 Arch St.)
Atwater Kent Manufacturing Company (4700 Wissahickon Avenue)

Philadelphia (*Continued*)
R. H. Beaumont Company (319 Arch Street)
James G. Biddle (1211-13 Arch Street)
Decorative Lamp & Shade Company (1217-33 Spring Garden Street)
Electric Power Equipment Corporation (412-20 North 18th Street)
Electric Service Supplies Company (17th and Cambria Streets)
The Electric Storage Battery Company (19th Street and Allegheny Avenue)
Hall Electric Heating Company, Inc. (1429 Walnut Street)
I-T-E Circuit Breaker Company (501 N. 19th Street)
Kingsbury Machine Works, Inc. (4320 Tackawanna Street, Frankford)
Leeds & Northrup Company (4901 Stenton Avenue)
I. P. Morris & De La Vergne, Inc. (Richmond & Norris Streets)
Murlin Manufacturing Co. (5420 Paschall Avenue)
Philadelphia Electrical & Manufacturing Company (1228 North 31st Street)
Philadelphia Storage Battery Company (Ontario and C Streets)
Roberts & Mander Stove Company (Eleventh Street, and Washington Avenue)
The Sharples Specialty Company (23rd and Westmoreland Streets)
C. H. Wheeler Manufacturing Company (Lehigh and Sedgley Avenues)
Wright Appliance Company (2109 Market Street)

Pittsburgh .... Aluminum Company of America (2400 Oliver Building)
Blaw-Knox Company (P. O. Box 915)
Gainaday Electric Company (P. O. Box 1236)
Hubbard & Company (Granite Building)
Mine Safety Appliances Company (Braddock, Thomas and Meade)
National Valve & Manufacturing Company (Arsenal Station)
R. D. Nuttall Company (McCandless Avenue and Harrison Street)
Oliver Iron & Steel Corporation (South Tenth and Muriel Streets)
The Phoenix Glass Company (230 Fifth Avenue, New York, N. Y.)
Pittsburgh Reflector Company (Bowman Building, Third Avenue and Ross Street)
Riter Conley Company (318 Oliver Building)
Seyler Manufacturing Company (Sharpsburg Post Office)
Standard Sanitary Manufacturing Company (Bessemer Bldg.)
Standard Underground Cable Company (S. W. Corner 17th & Pike Streets)
P. Wall Manufacturing Supply Company (30 Church Street, New York, N. Y.)

Pottstown .... Automatic Electric Heater Company (Cross and Kelm Streets)

Reading .... Reading Sheet Metal Products Company (385 Yonge Street)
(Front and Chestnut Street)

Wilkes-Barre ..... Hazard Insulated Wire Works (Division of The Okonite Co.)

Rhode Island

Pawtucket .... Tubular Woven Fabric Company

Providence .... American Electrical Works

South Carolina

Spartanburg	Taylor-Colquitt Company (Montgomery Bldg.)

Texas

Orange	Texas Creosoting Company

Virginia

Newport News	Newport News Shipbuilding & Dry Dock Company
Waynesboro	W. J. Loth Stove Company, Inc.

West Virginia

Follansbee	The Jefferson Glass Company
Huntington	The Armstrong Electric & Manufacturing Corp. (Seventh Avenue and First Street)
Kenova	Champion Switch Company
	Jeffery-Dewitt Insulator Company

Wisconsin

Beaver Dam	Malleable Iron Range Company
Clintonville	Four Wheel Drive Auto Company
Madison	Hankscraft Company (121 North Dickinson Street)
Milwaukee	Allen-Bradley Company (494 Reed Street)
	Allis-Chalmers Manufacturing Company
	Cutler-Hammer Manufacturing Company (P. O. Box 1564)
	A. J. Lindemann & Hoverson Company (First and Cleveland Avenues)
	The MacGillis & Gibbs Company (1201 Wells Building)
	Nordberg Manufacturing Company
South Milwaukee	Line Material Company (Railroad Tr. and Michigan Avenue)
Two Rivers	Metal Ware Corporation

CANADA

Ontario

Galt	Babcock-Wilcox & Goldie-McCulloch, Limited
Hamilton	Boston Insulated Wire & Cable Company, Limited
	Canadian Porcelain Company, Limited
	Canadian Westinghouse Company, Limited
	The Coffield Washer Company of Canada, Limited (80 Park Street, North)
	The Hoover Company, Limited
	N. Slater Company, Limited
	Standard Underground Cable Company of Canada, Limited (Sherman Avenue North)
London	Kelvinator of Canada, Limited
Niagara Falls	Canadian Ohio Brass Company, Limited
Pembroke	Superior Electrics, Limited
Renfrew	Renfrew Electric Products, Limited
St. Catharines	Packard Electric Company (c/o Packard Company, Limited)
Scarborough Junction	Canadian Line Materials, Limited
Toronto	The Aluminum Company of Canada (1307 Bank of Hamilton Building)
	The British Aluminum Company, Limited (380-382 Adelaide Street, West)
	Canada Wire & Cable Company (Box 518)
	Canadian General Electric Company (212 King Street, West)
	Canadian National Carbon Company, Limited (805 Davenport Road)
	Dominion Cutout Company (250 Richmond Street, West)
	Eastern Power Devices, Limited (171 John Street)
	English Electric Company of Canada, Limited (Northern Ontario Building)
	Ferranti Electric, Limited (26 Noble Street)
	The Holophane Company, Limited (385 Yonge Street)
	Lincoln Meter Company, Inc. (72 Stafford Street)
	Moloney Electric Company of Canada
	Sangamo Electric Company of Canada, Limited (183 George Street)
	Square D Company of Canada, Limited (146 King Street, West)
	Thor-Canadian Company, Limited (371 Yonge Street)
Weston	Moffats, Limited (Electrical Division)

Quebec

Montreal	Canadian Laco Lamps, Limited (1511 St. James Street)
	The Devoe Electric Switch Co. (872 Notre Dame Street, West)
	Dominion Engineering Works, Limited
	Economy Fuse & Mfg. Co. of Canada (Unity Building)
	Elpeco of Canada, Limited (2589 Notre Dame Street, East)
	Frigidaire Corporation (966 St. Catherine, West)
	General Steel Wares, Limited (23 Wellington Street)
	Northern Electric Company, Limited (637 Craig Street, West)
	Eugene F. Phillips Electrical Works, Limited (P. O. Box 729)
	The Premier Vacuum Cleaner Company, Limited (Keefer Bldg.)
St. Johns	Hart Battery Company, Limited

Associate Companies

(Class F)

"Class F members shall be companies or firms of electrical jobbers, contractors, dealers, electrical or mechanical engineers, publishers and associations—corporations or individuals—who are interested in advancing the use of electrical energy and are not engaged in its production or distribution."—*Constitution, Art. III, Sec. 7.*

Alabama

Birmingham	E. P. Ingram (City Hall, Room 200)

California

Cassel	Frank G. Baum
Emeryville	Gardner Electric Manufacturing Co. (4227 Hollis Street)
Los Angeles	Bent Concrete Pipe Company (542 South Broadway, Room 615)
	R. G. Campbell Electric Company (114 East Fourth Street)
	Clapp & LaMoree (1325 San Julian St.)
	Leon E. Clark (218 East Third Street)
	Detrick-Joslyn Company (110 N. Alameda Street)
	Electrical Products Claude Neon, Inc. (1122 Venice Boulevard)
	Everhot Elec. & Mfg. Co. (116 Llewellyn Street)
	Farnham & Cunningham (307 South Hill Street)
	Philip H. Gough (819 East First Street)
	Graham-Reynolds Electric Company (300 East Third Street)
	Illinois Electric Company of California (313 South San Pedro Street)
	Jones-Lyman & Company, Inc. (401 Bartlett Bldg.)
	Newbery Electric Corporation (726 South Olive Street)
	Pacific States Electric Company (385 East Second Street)
	Pinson's Electric Service (308 East Fourth Street)
	Thor Pacific Company (1017 South Grand Avenue)
	H. H. Walker, Electragist (1323 Venice Boulevard)
	Western Light & Fixture Company (301 South Los Angeles Street)
Oakland	Pacific Electric Motor Company (88 East Tenth Street)
Redlands	Barry Dibble
San Francisco	Alexander & Lavenson (926 Howard Street)
	Associated Oil Company (Sales Dept. Industrial Lubricant Division, 79 New Montgomery Street)
	Constant Angle Arch Dam Company (1202 Hobart Building)
	The Electric Material Company, Inc. (589 Howard Street)
	Fobes Supply Company (260 Fifth Street)
	Garland-Affolter Engineering Corporation (Rialto Building)
	Joshua Hendy Iron Works (200 Pine Street)
	W. Wesley Hicks (215 Rialto Building)
	Hot-N-Kold Corporation (417 Sutter Street)
San Francisco *(Continued)*	K. P. F. Electric Company (855-859 Howard Street)
	Kortick Manufacturing Co. (333 First Street)
	Louis F. Leurey, Consulting Electrical Engineer (58 Sutter Street)
	Maydwell & Hartzell, Inc. (158 Eleventh Street)
	Charles C. Moore & Company, Engineers, Inc. (Sheldon Building, First and Market Streets)
	Pacific States Electric Company (1201 Bryant Street)
	Preferred Electric Company (681 Market Street)
	Sandoval Sales Company (115 Jessie Street)
	G. M. Simonson, Consulting Engineer (74 New Montgomery Street)
	Taper Tube Pole Co. of California (479-81 Monadnock Bldg.)
	Thebo, Starr & Anderton, Inc. (523 Sharron Bldg.)
	Fred H. Tibbetts, Civil Engineer (310 South Sansome Street)
	Utilities Equipment Corp. (1644-A Russ Bldg.)

Colorado

Denver	Mountain States Telephone & Telegraph Company (Administration Building, 800 14th Street, P. O. Box 960)
	Herbert S. Sands, Consulting Engineer (1115 First National Bank Building)

Connecticut

Hartford	The Hartford Steam Boiler Inspection & Insurance Company (56 Prospect Street)
	Putnam & Company (6 Central Row)
New Haven	The Hessel & Hoppen Company (30-36 Crown Street)
	Sidney Withington, Electrical Engineer (N. Y., N. H. & H. R. R. Co.)
Stamford	The F. A. Bartlett Tree Expert Company (P. O. Box 852, 45 Stage St.)
Waterbury	Tracy Smith (c/o Hugh L. Thompson, Consulting Engineer, P. O. Box 1033)

Delaware

Wilmington	J. C. Allen, Electrical Engineer, c/o Atlas Powder Company
	E. I. du Pont de Nemours & Company (Du Pont Building, Room 3113 Technical Library)
	Willis A. Naudain, Electrical Engineer (P. O. Box 846)

District of Columbia

Washington ...... A. R. Cheyney, Consulting Engineer (P. O. Box 275, 12th & Penna. Avenue Station)
Charles B. Hawley Engineering Corporation (1132 Munsey Building)
Public Utilities Reports, Inc. (1038 Munsey Bldg.)

Florida

Jacksonville ..... General Electric Supply Corp. (Union Terminal Warehouse)
Tampa .... Pierce Electric Company (710 Bell Street)

Georgia

Atlanta .... Charles G. Adsit (516 Grant Bldg.)
Electrical South (1020 Grant Building)
General Electric Supply Corp. (172 Haynes Street, S. W.)
Southern Power Journal (1021 Grant Building)

Illinois

Chicago .... Bennett-Watts-Haywood Company (publishers, *Electric Light & Power*, 360 N. Michigan Avenue, Room 1722)
S. Morgan Bushnell (Suite 2062 Builders Bldg., 228 North La Salle Street)
Central States General Electric Supply Company (228 South Wells Street)
Electrical Trade Publishing Company, (520 North Michigan Avenue)
Frank F. Fowle & Company (53 West Jackson Boulevard)
Freyn Engineering Company (310 South Michigan Avenue)
L. F. Harza, Consulting Hydro-Electric Engineer (2122 Engineering Building, 205 West Wacker Drive)
Hoosier Engineering Company (100 West Monroe Street)
Illinois Electric Company of Illinois (113-125 North May Street)
Industrial Power (608 South Dearborn Street)
Clarence G. Johnson, Consulting Engineer (39 South La Salle Street)
G. H. Knutson, Financial Engineer (Harris Trust Building, 111 West Monroe Street)
Lucas & Luick, Engineers (1554, 231 South La Salle Street)
James S. Mahan (222 West Adams Street, Room 900, P. O. Box 1089)
C. W. McGuire (39 South La Salle Street)
McJunkin Advertising Company (228 North La Salle Street)
Neiler, Rich & Company (431 South Dearborn Street)
Langdon Pearse (910 South Michigan Avenue)
Pettengill, Inc. (1700 Prairie Avenue)
Power Plant Engineering (53 West Jackson Boulevard)
Sargent & Lundy (1412 Edison Building, 72 West Adams Street)
Burke Smith (212 West Washington Street)
Spooner & Merrill, Inc. (111 West Monroe Street)

Chicago *(Continued)* .... Utilities Publication Company (35 East Wacker Drive)
William E. Vogelback (100 West Monroe St.)
James Walker, Consulting Engineer (105 West Adams Street)
Arthur Young Company (105 South La Salle Street)
Evanston .... Bishop Publishing Company (833 Dobson Street)
Peoria .... American Water Utilities Corporation (207-11 Peoria Life Building)
Sycamore .... A. B. Gochenour (724 West State Street)

Indiana

Indianapolis ..... Lake States General Electric Supply Company, Inc. (326 West Georgia Street)
Varney Electrical Supply Company (539 Madison Avenue)

Kentucky

Paducah .... Southern Pine Mfg. Co. (City National Bank Building)

Louisiana

Hammond .... Henry A. Mentz, Consulting Engineer
New Orleans .... General Electric Supply Corp. (800 Constance Street)

Maryland

Baltimore ...... Commercial Credit Company (First National Bank Bldg.)
General Electric Supply Corp. (5-7-9 South Gay Street)

Massachusetts

Boston .... Arthur H. Abbott, Inc. (88 Broad Street)
George N. Bailey, Engineer (c/o New England Power Construction Company, 89 Broad Street)
H. K. Barrows, Consulting Engineer (6 Beacon Street)
Edward C. Brown Company (220 Devonshire Street)
George H. Buckminster Company (59 Oliver Street)
Coffin & Burr, Inc. (60 State Street)
Doremus & Company (20 Kilby Street)
George W. Ellis Company, Inc. (Statler Building, 20 Providence Street)
General Electric Supply Corporation (378 Stuart Street)
Edward A. Graustein, Engineer (6 Beacon Street)
Hixon Electric Company (22 Elkins Street)
Jackson & Moreland (31 St. James Avenue)
J. W. Johnston (19 Pearl Street)
Arthur S. Knight, Consultant (84 State Street, Room 401)
John Livor, Inc. (1105 Statler Bldg.)
Charles T. Main, Inc. (201 Devonshire Street)
Milhender Electric Supply Company (617 Atlantic Avenue)
New England Telephone & Telegraph Company (50 Oliver Street, Room 808)

Massachusetts (*Continued*)

Boston (*Continued*) .... Franklin A. Snow Company (Rooms 808-809, 216 Tremont Street)
Howard M. Turner, Consulting Engineer (12 Pearl Street)
Vaughan Engineers (The Waterman Building, 44 School Street)
George H. Wahn Company (69 High Street)
Wetmore-Savage Electric Supply Company (76 Pearl Street)

Lowell .... John A. Stevens (16 Shattuck Street)
Springfield .... M. J. Daley & Company, Inc. (1654 Main Street)
Fred T. Ley & Company, Inc. (1215 Main Street)

Woburn .... W. G. Stretton (12 Montvale Avenue)

Michigan

Detroit .... Business News Publishing Company (550 Maccabees Building)
Campbell-Ewald Company (General Motors Building)
Commercial Electric Supply Company (138 East Congress Street)
Investment Research Corp. (2646 Penobscot Building)
Lake States General Electric Supply Company, Inc. (415-419 East Congress Street)
Highland Park .. A. L. Drum & Company (14401 Third Avenue)
Jackson .... Fargo Engineering Company (147 South Mechanic Street)

Minnesota

Minneapolis ..... Jos. L. Barnard Company (1727 LaGoon Avenue)
The Belmont Corp. (316 South Third Street)
John A. Clark Electric Company (624 Baker Building)
Howard & Geeseka Company (1008 Marquette Avenue)
P. E. Loye, Consulting Engineer (602 Baker Bldg.)
Northern White Cedar Association (702 Lumber Exchange)
Northwest General Electric Supply Company (227 South Fifth Street)
Page & Hill Company (814 Plymouth Building)
T. M. Partridge Lumber Company (731 Lumber Exchange)
Western Red Cedar Association (707 Metropolitan Bank Bldg.)
St. Paul .... Great Northern Electric Appliance Co. (145-147 East Fifth Street)
Jobbers Supply Company (731 North Prior Avenue)
Northwest General Electric Supply Co. (174 East Sixth Street)
Robert P. Payne (296 MacAlester Avenue)
White Bear Lake. B. O. Horton (219 Seventh Street)

Missouri

Kansas City ..... Black & Veatch, Consulting Engineer (Mutual Building)
Burns & McDonnell Engineering Company (402 Interstate Bldg.)
Kansas City (*Continued*) ..... Mid-West General Electric Supply Company (1411 Walnut Street)
Arthur L. Mullergren, Consulting Engineer (770 Board of Trade Building)
The Chas. L. Ward Company (701 Midland Building, 1229-31 Baltimore Avenue)
St. Louis .... Commercial Electrical Supply Company (320 South Broadway)
General Electric Supply Corp. (200 South Seventh Street)
H. C. Heink, Mechanical Engineer (c/o Grinnel Company, Inc., 1140 Central Industrial Avenue)
John Hunter, Mechanical Engineer (805 Merchants Laclede Bldg.)

Montana

Butte .... Butte Electric Supply Company (900 East Front Street)

Nebraska

Omaha .... Mid-West General Electric Supply Company (114 South 14th Street)

New Jersey

Atlantic City ..... John W. Armitage (2927 Atlantic Avenue)
Frank Shinnen, Chief, Electrical Bureau of Atlantic City (City Hall)
Belleville .... Frabur Engineering Company (Cortlandt Street)
Camden .... Charles S. Wright (2182 Federal Street)
East Orange ...... Charles A. Stanwick (33 Beach Street)
Jersey City .... The M. W. Kellogg Company (Foot of Danforth Avenue)
Maplewood ...... V. C. Kylberg (103 Baker Street)
Newark .... Ellsworth Francisco (City Hall)
General Electric Supply Corp. (52 Lafayette Street)
Newark Electrical Supply Company (152 Mulberry Street)
The Prudential Insurance Company of America
Trenton .... M. M. Fleron & Son, Inc. (113 North Broad Street)
Ventnor City .... H. A. Davis Company (6409 Ventnor Avenue)

New York

Albany .... Charles J. Barrow, Consulting Engineer (50 State Street)
Buffalo .... Seneca Vocational School (666 East Delavan Avenue)
Deferiet .... John E. A. Warner (P. O. Box 5)
New York City:
Brooklyn ...... W. B. McVicker Company (295 Douglass Street)
Marvin Shiebler (181 Joralemon Street)
Manhattan ..... Harry Alexander, Inc. (330 Fifth Avenue)
George Allen & Son (205 East 85th Street)
Alpha Electric Company, Inc. (45 West 45th Street)
Ambursen Construction Company, Inc. (Grand Central Terminal)
American Telephone & Telegraph Company (195 Broadway)
G. O. Apikian (24 East 21st Street)
Edward E. Ashley, Jr. (393 Seventh Avenue)

New York (*Continued*)

New York City:

Manhattan ..... Harry Barker, Consulting Engineer (11 Park Place)
(*Continued*)
Robert T. Battle, Electrical Engineer (254-6 West 31st Street)
Robert Cameron Beadle, Inc. (551 Fifth Avenue)
Henry D. Behr, Electrical Engineer (Publix Theatres Corporation, Paramount Building)
James H. Betts, Electrical Engineer (International Neon Corp., 41 East 42nd Street)
Boiler & Engineering Insurance Service Bureau (One Park Avenue)
Bonbright & Company, Inc. (25 Nassau Street)
Bowser Service Corporation (225 Fifth Avenue)
W. H. Braun (115 Broadway)
H. W. Brooks, Consulting Engineer (Metropolitan Tower, Room 316, 1 Madison Avenue)
Brown, Crosby & Company, Inc. (96 Wall Street)
Lilian Cassels (47 West 42nd Street)
The Central Station (15 West 55th Street)
E. J. Cheney (61 Broadway)
Cinderella Appliances Corp. (280 Madison Avenue)
Columbia Casualty Company (1 Park Avenue)
Consolidated Telegraph & Electrical Subway Company (54 Lafayette Street)
Hugh L. Cooper & Company (101 Park Avenue)
R. W. Cramer & Company, Inc. (136 Liberty Street)
Dela Croix & Monroe (225 Fifth Avenue)
Duparquet Huot & Moneuse Company (108 West 22nd Street)
Electric Meter Corporation (116 East 19th Street)
Electrical Goods (239 West 39th Street)
Electrical Record (461 Eighth Avenue)
Electrical Testing Laboratories (80th Street and East End Avenue)
Electrical World (10th Avenue and 36th Street)
Electricity on the Farm (225 West 34th Street)
The Financial World (53 Park Place)
B. C. Forbes Publishing Company, Inc. (120 Fifth Avenue)
Ford, Bacon & Davis, Inc. (39 Broadway)
The Foundation Company (120 Liberty Street)
K. G. Frank (75 West Street)
General Contract Purchase Corp. (420 Lexington Avenue)
General Electric Supply Corp. 585-591 Hudson Street)
G. M. Gest (1336 Woolworth Building)
Goodwin, Morton & Badrian, Inc. (522 Fifth Avenue)
Graybar Electric Company, Inc. (Graybar Bldg., Lexington Avenue and 43rd Street)
Guaranty Company of New York (140 Broadway)
Louis Harding, Secretary (Central Traction & Lighting Bureau, 1 Liberty Street)

New York City:

Manhattan ..... Harris, Forbes & Company (Pine and William Streets)
(*Continued*)
W. J. Henderson, Public Utility Accounting (150 Broadway)
Warren Hilleary (Royal Indemnity Company, 150 William Street)
Paul James Howe (c-o. Western Union Telegraph Company, 195 Broadway)
Lee P. Hynes, Electrical Engineer (30 Church Street)
Industrial Engineering (10th Avenue and 36th Street)
International Standard Electric Corp. (67 Broad Street)
Ives & Davidson (15 Park Row)
Franz Joerger, Sales Agent (40 Rector Street)
The Joslyn Company (233 Broadway)
Kaiser, Muller & Davies (101 Park Avenue)
Jeremiah J. Kennedy (52 Broadway)
Harry Alvin Kidder, Supt. of Motive Power (Interborough Rapid Transit Company, 600 West 59th Street)
William S. Leffler, Consulting Engineer (Salmon Towers, 11 West 42nd Street, 24th Floor)
Charles O. Lenz, Consulting Engineer, (33 Rector Street, 12th Floor)
Lighting Fixtures & Lighting (215 Fourth Avenue)
Ray D. Lillibridge, Inc. (8 West 40th Street)
MacNutt-Watts, Tankard, Inc. (9 Great Jones Street)
McGraw-Hill Publishing Company, Inc. (10th Avenue and 36th Street)
Meter Service Corp. (122 East 42nd Street)
Harvey E. Mole (90 West Street)
Murray & Flood (369 Lexington Ave.)
Thomas E. Murray, Inc. (88 Lexington Avenue)
David Moffat Myers, Consulting Engineer (1 Madison Avenue)
New York Journal of Commerce (46 Barclay Street)
The New York Service Company (141 East 29th Street)
Norton, Bird & Whitman (15 Broad Street)
The Ocean Accident & Guarantee Corporation, Limited (1 Park Avenue)
Geo. A. Orrok, Consulting Engineer (52 Vanderbilt Avenue)
Farley Osgood, Consulting Engineer (31 Nassau Street)
Ernest V. Pannell (c-o. British Aluminum Company, Limited, Chanin Bldg., 122 East 42nd Street)
Parsons, Klapp, Brinckerhoff & Douglas (84 Pine Street)
E. L. Phillips & Company (50 Church Street)
William Porter (30 Church Street)
Pubutility Publishing Company, Inc. (53 Park Place)
Quaw & Foley (30 Broad Street)
Charles S. Reed, Consulting Engineer (74 Trinity Place)
Herbert B. Reynolds (600 West 59th Street)
E. H. Rollins & Sons (44 Wall Street)
Sales Engineering Service Corporation (42 Broadway)
Sanderson & Porter (52 William Street)

New York (*Continued*)

New York City:

Manhattan (*Continued*) ..... E. Y. Sayer Engineering Corporation (Knickerbocker Building, Broadway & 42nd Street)
Semet-Solvay Engineering Corp. (40 Rector Street)
Sparklets, Inc. (19 W. 44th Street)
Stevens & Wood, Inc. (20 Pine Street)
Stone & Webster Engineering Corp. (120 Broadway)
Trojan Engineering Corp. (40 Exchange Place)
Frederick A. Waldron, Consulting Engineer (40 Exchange Place)
Don M. Welsh (Room 202, I. R. T. Company, Administration Building, (2545 Seventh Avenue)
P. H. Whiting & Co., Inc. (72 Wall Street)
W. S. Wilson Corp. (155 Chambers Street)
Julian E. Woodwell (501 Fifth Avenue)

Queens .... Austin & Moore, Inc. (87 Wilbur Street, Long Island City)

Niagara Falls .... Charles C. Egbert (Gluck Building)

North Tonawanda. American District Steam Company

Rochester .... Kelly-Read & Company, Inc. (508 St. Paul Street)

Syracuse .... H. C. Roberts Electrical Supply Company, Inc. (241 West Water Street)

North Carolina

Charlotte .... Mees & Mees, Inc., Engineers (616 Johnston Bldg.)

Ohio

Cincinnati .... The Beltzhoover Electric Company (N. E. Corner Fourth and Plum Streets)
Lake States General Electrical Supply Company, Inc. (215 West Third Street)

Cleveland .... Lawrence D. Bale (733 Hanna Building)
The Cleveland Railway Company
The Collier Construction Company (500 E. 102nd Street)
Continental Shares, Inc. (520 Cuyahoga Building)
Erner Electric Company (1430 West 9th Street)
A. D. Fishel Company (942 Engineers Building)
Fuller & Smith (1501 Euclid Avenue)
Lake States General Electrical Supply Company, Inc. (Chester Avenue at 18th Street)
Line Equipment Sales Company (1241 East 45th Street)
The Rae Advertising Company (Rockefeller Building)
The Richardson-Briggs Company (231 Superior Avenue)

Columbus .... Lake States General Electrical Supply Company, Inc. (146-148 North Third Street)
Snook, Martin & Company, Consulting Engineers (40 West Gay Street)
Samuel S. Wyer (1116 Beggs Bldg.)

Kent .... The Davey Tree Expert Company (South Water Street)

Oxford .... O. E. Kumler, Electrical Contractor (210 West Collins Street)

Toledo .... The Froelich & Emery Engineering Company (410 Second National Bank Building)
Lake States General Electrical Supply Company, Inc. (28-32 St. Clair Street)

Oklahoma

Oklahoma City ... Southwest General Electric Supply Company (127-129 East California Street)

Tulsa .... Taylor-Easterling & Company, Inc. (329 Kennedy Bldg.)

Oregon

Hood River ...... Frank O. Berry

Portland .... Fobes Supply Company (8th and Davis Streets)
Pacific States Electric Company (61-67 5th Street, North)

Pennsylvania

Brookville .... Peter F. Loftus, Consulting Electrical Engineer

Harrisburg .... David C. Ainey, Engineer (212 Locust Street)

Kennett Square .. Russell P. Brewer, Maintenance Engineer (Longwood Farms)

Philadelphia ..... The Bell Telephone Company of Pennsylvania (1835 Arch Street)
F. G. Corbus (2409 West Westmoreland Street)
Electric Time Corporation (133 So. 12th Street)
C. H. Geist, Securities Corporation (1622 Packard Building)
General Electric Supply Corp. (37-39 North 7th Street)
Harrison & Company (1824 Land Title Building)
E. E. Hedler (250 North 11th Street)
Wm. B. Herbst (6904 Sherman Street, Mt. Airy)
Larner Engineering Company (Atlantic Building)
Mellon, Taylor, Hendrickson, Inc. (225 South 15th Street)
Newburger, Henderson & Loeb (1512 Walnut Street)
Arthur Perry & Company (1500 Walnut Street Building)
H. C. Roberts Electrical Supply Company (1101 Race Street)
The Rumsey Electric Company (1007 Arch Street)
Scofield Engineering Company (1324 Commercial Trust Building)
United Engineers & Constructors, Inc. (112 North Broad Street)
Welsbach Electric Street Lighting Company (261 North Broad Street, Fourth Floor)

Phoenixville ..... Raymond C. Kern

Pittsburgh ...... David Boyd-Smith (800 Union Trust Building)
The Electric Journal (1205 Keenan Trust Building)
Electric League of Pittsburgh (318 Westinghouse Building)

Pennsylvania (*Continued*)

Pittsburgh (*Continued*) .... B. Floerscheim & Company, Inc. (622 Farmers Bank Bldg.)
General Electric Supply Corp. (420-422 Duquesne Way)
J. A. Malady, Electrical Engineer (2307 First National Bank Bldg.)
The L. B. Michaels Company (529 Fulton Building)
Henry N. Muller Company (2213 First National Bank Building)
National Fireproofing Company (Fulton Building)
Pittsburgh Testing Laboratory (P. O. Box 1115)
Maurice R. Scharff, Consulting Engineer (19th Floor, First National Bank Bldg.)
E. S. Stickle Company (934 Union Trust Building)
H. O. Swoboda, Inc. (3400 Forbes Street)

Reading .... W. O. Miller (104 North Main Street)

Rhode Island

Providence .... Jenks & Ballou (2600 Industrial Trust Bldg.)
Union Electric Supply Company (60 Pine Street)

South Carolina

Greenville .... J. E. Sirrine & Company

Tennessee

Chattanooga ..... General Electric Supply Corp. (429 Broad Street)

Memphis .... General Electric Supply Corp. (16 South Lauderdale)

Texas

Dallas .... Electric Appliance Company, Inc. (409 Browder Street)
Southwest General Electric Supply Company (1801 North Lamar Street)

Fort Worth ...... Southwestern Laboratories (Box 1008)

Houston .... Southwest General Electric Supply Company (5 North Milam Street)

San Antonio ..... M. L. Diver, Consulting Engineer (P. O. Box 1073)

Utah

Salt Lake City .. Capital Electric Company (P. O. Box 1877)

Virginia

Clifton Forge .... A. H. Grimsley (425 Alleghany Street)

Colemans Falls... Spottswood C. Foster

Norfolk .... Woodhouse Electric Company, Inc. (238 Court Street)

Richmond .... General Electric Supply Corp. (4th and Canal Streets)
Marsden C. Smith, Engineer, Department of Public Utilities (Room 317, City Hall)

Washington

Seattle .... Eicher & Bratt (Colman Building)
Fobes Supply Company (560 First Avenue, South)
Pacific States Electric Company (570 First Avenue, South)
Washington Surveying and Rating Bureau (1100 Alaska Building, P. O. Box 1818)

Spokane .... Fobes Supply Company (152 South Monroe Street)

Wisconsin

Madison .... Fred R. Cutcheon, Engineer (c/o Service Bldg., University of Wisconsin)

Milwaukee .... The American Appraisal Company, 165 East Michigan Street
Julius Andrae & Sons Company (Broadway & Michigan Streets)
The Electric Meter Engineering Company (3712 Vliet Street)
Ed Schuster & Company, Inc. (Third and Garfield (Servel Department)

CANADA

Alberta

Calgary .... Robert MacKay, Esq. (718 Boulevard, N. W.)

British Columbia

Powell River..... Powell River Company, Limited

Manitoba

Winnipeg .... James Veitch, Esq. (C-27, Riverview Mansions)

Nova Scotia

Liverpool .... Mersey Paper Company, Limited

Sydney .... Dominion Iron & Steel Company, Limited (National Trust Company Receiver and Manager)

Ontario

Hamilton .... Allen Engineering Company, Limited (P. O. Box 311)
The Jas. Moncur Electric Co., Limited
Sawyer-Massey, Limited

Kapuskasing ..... Spruce Falls Power & Paper Company

Niagara Falls ..... R. L. Hearn (875 Robert Street)

Ottawa .... Canadian Engineering Standards Association (Bryson Building, 178 Queen Street)
Canadian Hoosier Engineering Company, Limited (Birks Bldg.)
Electrical Standards Laboratory (Department Trade and Commerce, West Block)
General Supply Company of Canada, Limited (356-60 Sparks Street)
John B. McRae, Esq., Consulting Engineer (323 Jackson Building)

Sault Ste. Marie... Abitibi Power & Paper Company, Limited
Geo. H. Kohl, Esq. (Royal Bank Bldg.)

Ontario (*Continued*)

Toronto .... Harry H. Angus, Esq. (Bloor and Balmuto Streets)
F. Jno. Bell (Royal Bank Bldg.)
Canadian & General Finance Company, Limited (357 Bay Street)
Kerry & Chace, Limited (Confederation Life Building)
Wills Maclachlan, Esq. (Room 41B, 2 Bloor Street, East)
Hugh C. MacLean Publications, Limited (347 Adelaide Street, West)
Powerlite Devices, Limited (171 John Street)
University of Toronto

Walkerville ...... The Canadian Bridge Company, Limited

Quebec

Beaupre .... Ste. Anne Paper Company, Limited

Cap de la Madeleine .... Canadian Power & Paper Corp., St. Maurice Division

Grand Mere ..... Canada Power & Paper Corp., Laurentide Division

Kenogami .... Price Bros. & Company, Limited

Montreal .... Babcock, Wilcox & Goldie McCulloch, Limited (P. O. Box 6, St. Henry)
De Gaspe Beaubien & Company (2 Place D'Armes)
Bell Telephone Company of Canada (P. O. Box 150)
Busfield, McLeod, Limited (1440 St. Catherine Street West)
Callard & Company, Limited (890 St. Antoine Street)
Century Electric Company (691 St. Paul Street, West)
Department of Electrical Engineering, McGill University
Ecole Polytechnique (1430 St. Denis Street)
The Engineering Institute of Canada (2050 Mansfield Street)
G. M. Gest, Limited (Power Bldg.)
Griswold & Company, Limited (1111 Beaver Hall Hill)
Inventions, Limited (1070 Bleury Street)
R. S. Kelsch, Esq. (Apt. 43, 1227 Sherbrooke Street, West)
Lake St. John Power & Paper Company, Limited (522 Drummond Building)
R. S. & W. S. Lea, Consulting Engineers (1226 University Street)

Montreal .... Lyman Tube & Supply Company, Limited (10 St. Sophie Lane)
(*Continued*)
George K. McDougall (85 Osborne Street)
A. J. F. Montabone (Room 2-1430 Bleury Street)
Montreal Engineering Company, Limited (164 St. James Street)
Nesbitt, Thomson & Company, Limited (215 St. James Street, West)
G. D. Peters & Company, Ltd. (10 Cathcart Street)
Everard W. Playford (1131 University Street)
Port Alfred Pulp & Paper Corp. (224 Canada Cement Building)
A. E. Sargent, Chief Electrical Engineer, National Breweries, Limited (36 Chaboillez Square)
Arthur Surveyer, Consulting Engineer (1117 St. Catherine Street, West)
George E. Templeman, Esq. (Electrical Comm. of the City of Montreal, 717 Terminal Bldg., 159 Craig Street, West)
Fred Thomson Company, Limited (915 St. Genevieve Street)
Alexander Wilson, Esq. Room 715, New Birks Building)

Quebec .... Anglo-Canadian Pulp and Paper Mills, Limited
Alexander Lariviere, Chief Engineer (Quebec Public Service Comm., Court House)
Mechanics Supply Company, Limited (80-90 St. Paul Street)

Shawinigan Falls . Canada Power & Paper Corp., Belgo Division
Shawinigan Chemicals, Limited

Three Rivers .... Canadian International Paper Company (P. O. Box 510)
The Wabasso Cotton Company, Limited
Wayagamack Pulp & Paper Company, Limited

Westmount .... J. A. Shaw, Esq. (448 Lansdowne Avenue)

Porto Rico

San Juan .... Antillas Electric Corp. (P. O. Box 1009)

Brazil

Rio de Janeiro .. Burton E. Anderson, Electrical Engineer (Emprezas Electricas Brasilerias, S. A., Caixa Postal 883, c/o Mr. P. B. McKee)

FOREIGN MEMBERS

(Class H)

"Class H members shall be individuals or corporations, not residents of the United States or of Canada, engaged in the central station industry, or interested in advancing the use of electrical energy, who shall ally themselves with this association."—*Constitution, Art III, Sec.* 9.

ASIA

China

Canton ....Kwang Tung Electric Supply Company, Limited

Macao ....Macao Electric Lighting Company, Limited (Rua Central, F. J. Gellion, manager)

Federated Malay States

Taiping, Perak....Ernest F. Stephenson (Electrical Inspector's Office)

India

Bombay ....The Tata Hydro-Electric Power Supply Company, Limited (Bombay House, Bruce Street, Fort)

Calcutta ....Calcutta Tramways Company, Limited (7 Church Lane)

Japan

Dairen ....S. Haraguchi, The South Manchuria Electric Company, Limited (Manchuria)

Oiso Yoshiwo, Power Engineer (58 Kushunokicho, South Manchuria)

Kobe ....Mitsubishi Electrical Engineering Company, Limited (Wadasaki-Cho)

Kyoto City....... Kyoto Electric Light Company

Osaka ....Nippon Electric Power Company, Limited (Osaka Bldg., Soze-Cho, Kitaku)

Sanyo Chuo Hydro Electric Company (No. 48 4-chome Kitahama Higashi-Ku)

Ujigawa Electric Company, Limited (Sonezaki Kita-Ku)

Tokyo ....Daido Denryoku Kabushiki Kaisha, (Tokyo Kaijo Building, Marunouchi)

The Electric Association of Japan (1 chome 5 Yuraku-cho Marunouchi)

Electrical Exploitation, Bureau D of Communication (Teishinsho Denkikyoku Gyomuka)

The English Electric Company, Limited (Yuraku Building, Marunouchi)

S. Hirota (22 Denyen-Chofu-Ebara-Gori, near Tokyo)

Keiji Ito (Marunouchi Bldg., Room 682)

Tokiwo Kobayakawa (c-o. Kyosan & Company, 4th Floor, Japan Industrial Bank Building, Marunouchi)

Ryotaro Mitsuda, Doctor of Engineering (Electro-Technical Laboratory)

Hide Mori (Bureau of Electric Power, Ministry of Communications)

Shibaura Engineering Works (Shibaura)

Kozo Tada (Shinyetsu Electric Power Company (c/o Osaka Bldg., Marunouchi)

Tokyo ....Toho Denryoku Kabushiki Kaisha (Kaijo Bldg.)
(*Continued*)

Tokyo Electric Light Company (Sakurada-Hongo-cho, Shibaku)

Yokohama ....The Furukawa Electric Company, Limited (Nishi-Hiranuma)

Java

Bandoeng ....Dienst voor Waterkracht en Electriciteit

Siam

Bangkok ....Siam Electric Corporation, Limited

AUSTRALIA

New South Wales

Sydney ....Australian Commonwealth Engineering Standards Association (Macleay House, 16 College Street)

George Alfred Julius (Culwalla Chambers, Casltereagh Street)

Queensland

Brisbane ....City Electric Light Company, Limited (P. O. Box 403 F. G. P. O.)

John Stephens Just (Box 1067N, G. P. O.)

South Australia

Adelaide ....The Adelaide Electric Supply Company F. W. Wheadon, Engr. and Mgr. (Grenfell Street E.)

Mechanical Supplies, Limited (69 Grenfell Street)

Port Pirie ....The Broken Hill Associated Smelters Property, Limited

Victoria

Melbourne ....Australian General Electric Company (P. O. Box 538)

The Edison Swan Electric Co., Limited (368 Little Collins Street)

Melbourne Electric Supply Company, Limited (19 Queen Street, F. W. Clements, Manager)

NEW ZEALAND

Ashburton ....Herbert George Kemp (P. O. Box 40)

Christchurch .....J. R. Templin (Box 420) C. E. Engineer

Dunedin ....Messrs. Turnbull & Jones, Limited, Electrical Engineers (78-80 Stuart Street, P. O. Box 362, Otago)

Lower Hutt ......Ernest Bickerstaff (P. O. Box 13)

Wellington ......The National Electrical and Engineering Company, Limited (P. O. Box 1055)

TASMANIA

Hobart ....Electrolytic Zinc Company of Australasia, Limited (Box AA-B)

CENTRAL AMERICA

Costa Rica

San Jose ....Compania Nacional de Electricidad (Apartado No. 499)

Guatemala

Guatemala City ..Empresa Guatemalteca de Electricidad 6a, Avenida Eur y 8a, Calle Poniente

Salvador

San Salvador ....Cia de Alumbrado Elec de San Salvador (Apartado No. 186)

EUROPE

Czecho-Slovakia

Prerov ....Stredomoravska Elektrarny Akciova Spolecnost

England

Birmingham .....Belliss and Morcom, Limited (Ledsam Street Works)
Robert Orsettich, General Electric Company, Limited, Witton Works

County Durham ..Synthetic Ammonia & Nitrates, Limited (Billingham Nr Stockton-on-Tees)

Kent ....W. T. Henley Telegraph Works Company, Limited, Research Department, Gravesend

Lancashire ....British Insulated Cables, Limited (Prescot)

Leeds ....William Bradley Woodhouse (36 Park Place)

London ....British Electrical & Allied Manufacturers Association (36 and 38 Kingsway, W. C.)
British Electrical Development Association, Inc. (15 Savoy Street, Strand, W. C. 2)
David Brownlie (46 Grange Road, Ealing W. 5)
Central Electricity Board (1 Charing Cross, W. C. 2)
Dewrance & Company (165 Great Dover Street, S. E. 1)
Electricity Commission (Savoy Court, Strand, W. C. 2)
The Foundation Company, Limited (Aldwych House, Aldwych W. C. 2)
Imperial Chemical Industries, Limited (Imperial Chemical House, Millbank, S. W. 1)
International Combustion Limited (Africa House, Kingsway)
Kennedy & Donkin (Broadway Court, Westminster, S. W.)
The London Electric Supply Corporation, Limited (25 A Cockspur Street, S. W. 1)
London Power Company, Limited (Engineering Department, Horseferry Road, Westminister, S. W. 1)
Merz & McLellan (32 Victoria Street, S. W. 1)
The Metropolitan Electric Supply Company, Limited (16 Stratford Place, W. 1)
The North Metropolitan Electric Power Supply Company (Broadway Building, Broadway, Westminster, S. W. 1)

London .... *(Continued)* Dr. H. F. Parshall (502A Salisbury House, London Wall, E. C. 2)
Standen Leonard Pearce (c/o The London Power Company, Limited—Engineering Department, Horseferry Road, Westminster, S. W. 1)
W. M. Selvey, Consulting Engineer (64 Victoria Street)
West Gloucestershire Power Company, Limited (Stafford House, 14-20 King St., E. C. 4)
J. G. White & Company, Limited (9 Cloak Lane, Cannon Street, E. C. 4)
W. R. Wood, Esq. (c/o Combustion Steam Generator, Limited, Aldwych House, Aldwych, W. C. 2, Underfeed Stoker Company, Limited)
Worthington-Simpson, Limited (Queen's House, Kingsway, W. C. 2)

Manchester ......Metropolitan Vickers Electrical Co., Ltd., (Manager, Research and Education Departments, Trafford Park)

Newcastle - Upon - Tyne ....Newcastle-Upon-Tyne Electric Supply Company Limited (Carliol House)

Worcestershire ...The Shropshire, Worcestershire & Staffordshire Electric Power Company, (Mucklow's Hill, Halesowen)

France

Belfort ....Societe Alsacienne de Constructions Mecaniques

Paris ....Cie Continentale pour la Fabrication des Compteurs et Autres Appareils (Rue d'Astorg 17)
Ernest F. H. Mercier (3 Rue de Messine)

Strasbourg ....Electricite de Strasbourg (1 Rue de 22 Novembre)

Germany

Berlin ....Allgemeine Elektricitats - Gesellschaft, (Fabriken Oberleitung Abt AI, Alexander Ufer, 2/4, N. W. 4)
A. Borsig, G. m. b. H. (Berlin-Tegel, Berlinerstr.)
Gesellschaft fur elektrische Unternehmungen (Dorotheenstrasse 36, N. W. 7)
Osram G m b H Kommanditgesellschaft Abteilungfuer Lichtwirt-schaft (Ehrenbergstrasse 11-14, Prussia)

Holland

Amsterdam ....Algemeene Nederlandsch-Indische, Electriciteit Maatschappij (17 Nieuwe Spiegelstraat)

Italy

Milano ....Carlo Moriondi, Consulting Engineer (Via Pergolesi 19)

Turin ....Societa Idroelettrica Piemonte, Via Arsenale (Gian Giacomo Ponti, Managing Director)

Norway

Oslo ....Nissen & Von Krogh, Kronprinsensgade
Norske Elektricitetsverkers Forening, Kronprinsensgade, 19

Sunndalsora ......A/S Aura

Spain

Barcelona .... Ebro Irrigation Company (Plaza Cataluna 2)
Madrid .... Jose Pla Armero, Consulting Engineer (Goya 34, 3 dr.)
Valencia .... Sociedad Anonima de Fuerzas Electricas (P. O. Box, Apartado 174)

Sweden

Stockholm .... Kungl Vattenfallsstyrelsen Kraftverksbyran (Karduansmakaregatan 8)
Svenska Elektricitetsverksforeningen (Tulegatan 13, Stockholm 6)

Switzerland

Bern .... Bernische Kraftwerke A-G (Viktoriaplatz 2, Dr. E. Moll, Commercial Manager)
Zug .... Landis & Gyr, S. A.

Turkey

Constantinople .. Turkish Anonyme Electrical Society of Constantinople

SOUTH AMERICA

Argentine Republic

Buenos Aires .... Compania Anglo-Argentina de Electricidad (188 Esmeralda)
Compania Argentina de Electricidad (Calle Balcarce 184)
Cia Hispano-Americana de Electricidad Balcarce 184)
Cordoba .... Compania Luz Y Fuerza Motriz de Cordoba (Calle Rivera Indarte 155)
Rios .... Compania Luz Y Fuerza de Parana (Parana Entra)
Rosario .... Sociedad de Electricidad de Rosario (Maipu No. 835)
Santa Fe .... Compania Argentina de Tramways Y Tuerza, Limited

Bolivia

La Paz .... The Bolivian Power Company, Limited (56 Sucre Street)

Brazil

Bahia .... Cia Linha Circular De Carris Da Bahia Largo do Plano Inclinado (Goncalves No. 30)
Para .... Para Electric Railway & Lighting Company, Limited (Caixa 29)
Parana .... Companhia Forca E Luz Do Parana (Caixa Postal 236, Curityba)
Pernambuco ..... Pernambuco Tramways & Power Company, Limited (Caixa 282)
Porto Alegre ..... Companhia Energia Electrica Rio Grandense (Caixa Postal 256) Rio Grande do Sul
Rio de Janeiro ... Cia Brasileira De Energia Electrica (Avenida Rio Branco No. 9)
Emperzas Electricas Brasileiras, S. A. (Caixa Postal No. 883)
The Rio de Janeiro Ty., Lt. & Pr. Co., Limited (c/o Canadian Shipping Agency, Inc., 25 S. William Street, New York, N. Y.)
Sao Paulo .... Cia de Forca e luz de Jaboticabal (Travessa do Commercio No. 9)
Cia Paulista De Forca E Luz (Caixa Postal No. 6, Bauru)
Empreza de Electricidade de Araraquara (Caixa Postal n 70, Araraquara)
Empreza Forca E Luz De Ribeirao Preto (Caixa Postal No. 55, Ribeirao Preto)
Empreza Forca e Luz do Jahu (Caixa Postal No. 47, Jahu)
Sao Paulo Tramway, Light & Power Co. (c/o Canadian Shipping Agency, Inc., 25 S. William Street, New York, N. Y.)
Victoria, Esperito Santo .... Cia Central Brasileira De Forca Elec. (P. O. Box 3838)

Chile

Antafogasta ...... Cia Sud Americana de Servicios Publicos, S. A. (Casilla No. 98)
Santiago .... Compania Chilena de Electricidad, Limitada (Casilla 1557)
Compania General de Electricidad Industrial (Casilla Correo No. 1824)

Colombia

Barranquilla ..... Compania Colombiana de Electricidad (Apartado 58)

Ecuador

Guayaquil .... H. S. Foley, General Manager, Empresa Electrica del Ecuador, Inc.
Quito .... The Quito Electric Light & Power Company (Apartado No. 82)

Uruguay

Montevideo ...... S. Masson. Ing. Jefe de las Usinas Electricas Del Estado

Venezuela

Maracaibo .... Venezuela Power Company, Limited (Avenida Industria)

WEST INDIES

Jamaica

Kingston .... Jamaica Public Service Company, Limited

Cuba

Havana .... Cia Cubana De Electricidad (Monte No. 1)

BERMUDA

Hamilton .... The Bermuda Electric Light, Power & Traction Company (Serpentine Road)

CANAL ZONE

Ancon .... Compania Panamena de Fuerza Y Luz (P. O. Box 2023)

MEXICO

Mexico City ..... Carlos Macias (3a Calle Zarco 59)
Rodolfo C. Rodriquez, Chief Electrical Engineer, National Railways of Mexico (Colonia Station)

APPENDIX 6

PRESIDENTS OF THE ASSOCIATION

*James F. Morrison of Baltimore
*Samuel A. Duncan of Pittsburgh
Edwin R. Weeks of Kansas City
Marsden J. Perry of Providence
*Charles R. Huntley of Buffalo
*James I. Ayer of St. Louis
Edward A. Armstrong of Camden
*M. Judson Francisco of Rutland
*C. H. Wilmerding of Chicago
*Frederic Nicholls of Toronto
Samuel Insull of Chicago
*Alden M. Young of Waterbury
Samuel T. Carnes of Memphis
*James Blake Cahoon of New York
Henry L. Doherty of Denver
Louis A. Ferguson of Chicago
Charles L. Edgar of Boston
Ernest H. Davis of Williamsport
William H. Blood, Jr., of Boston
Arthur Williams of New York
*Dudley Farrand of Newark
*William C. L. Eglin of Philadelphia
*Frank W. Frueauff of Denver
W. W. Freeman of Brooklyn
John F. Gilchrist of Chicago
Frank M. Tait of Dayton
*Joseph B. McCall of Philadelphia
Holton H. Scott of New York
Edward W. Lloyd of Chicago
Herbert A. Wagner of Baltimore
John W. Lieb of New York
Walter F. Wells of Brooklyn
R. H. Ballard of Los Angeles
Martin J. Insull of Chicago
*Milan R. Bump of New York
Frank W. Smith of New York
Walter H. Johnson of Philadelphia
Franklin T. Griffith of Portland
James E. Davidson of Omaha
R. F. Pack of Minneapolis
H. T. Sands of New York
P. S. Arkwright of Atlanta

HONORARY MEMBERS

E. R. Crompton	London, England
Marcel Deprez	Paris, France
George D. Forbes	London, England
*Prof. I. Fujioka	Tokyo, Japan
*Z. T. Gramme	Paris, France
*Dr. John Hopkinson	London, England
*Edouard Hospitalier	Paris, France
Dr. E. L. Nichols	Cornell University, Ithaca, New York
*Baron Alphonse de Rothschild	Paris, France
John T. Sprague	Birmingham, England
*Joseph W. Swan	Lauriston, Bromley, Kent, England
*Prof. Silvanus P. Thompson	Technical College, Finsbury, London, England
*Professor Yashima	Tokyo, Japan
*Lord Kelvin	Glasgow, Scotland
*Prof. Henry A. Rowland	Johns Hopkins University, Baltimore, Maryland
*Charles F. Brush	Cleveland, Ohio
Thomas A. Edison	Orange, New Jersey
Prof. Elihu Thomson	Lynn, Massachusetts
Frank J. Sprague	New York City
*George S. Bowen	Elgin, Illinois
Dr. Edward Weston	Newark, New Jersey
*Sir William Dawson	Montreal, Canada
Frank R. Redpath	Montreal, Canada
Dr. Henry T. Bovey	London, England
Thomas D. Lockwood	Boston, Massachusetts
Nikola Tesla	New York City
*James I. Ayer	Boston, Massachusetts
*Cyrus Osborne Baker	New York City
*Frederic Nicholls	Toronto, Canada
*T. Commerford Martin	New York City
*Dr. Charles Proteus Steinmetz	Schenectady, New York
*George Westinghouse	Pittsburgh, Pennsylvania
Dr. Arthur E. Kennelly	Harvard University, Cambridge, Massachusetts
*Charles A. Coffin	New York City
*A. C. Dunham	Hartford, Connecticut

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*Deceased.

APPENDIX 7

CONVENTIONS OF THE ASSOCIATION

No.	Place and Date	President
1st	Chicago, Feb. 25-26, 1885	James F. Morrison
2nd	New York, Aug. 18-20, 1885	James F. Morrison
3rd	Baltimore, Feb. 10-12, 1886	James F. Morrison
4th	Detroit, Aug. 31-Sept. 2, 1886	James F. Morrison
5th	Philadelphia, Feb. 15-17, 1887	James F. Morrison
6th	Boston, Aug. 9-11, 1887	James F. Morrison
7th	Pittsburgh, Feb. 2-23, 1888	James F. Morrison
8th	New York, Aug. 29-31, 1888	Samuel A. Duncan
9th	Chicago, Feb. 19-21, 1889	Samuel A. Duncan
10th	Niagara Falls, Aug. 6-8, 1889	Edwin R. Weeks
11th	Kansas City, Feb. 11-14, 1890	Edwin R. Weeks
12th	Cape May, Aug. 19-21, 1890	Marsden J. Perry
13th	Providence, Feb. 17-19, 1891	Marsden J. Perry
14th	Montreal, Sept. 7-10, 1891	Charles R. Huntley
15th	Buffalo, Feb. 23-25, 1892	Charles R. Huntley
16th	St. Louis, Feb. 28-March 2, 1893	James I. Ayer
17th	Washington, Feb. 27-March 2, 1894	Edward A. Armstrong
18th	Cleveland, Feb. 19-21, 1895	M. Judson Francisco
19th	New York, May 5-9, 1896	C. H. Wilmerding
20th	Niagara Falls, June 8-10, 1897	Frederic Nicholls
21st	Chicago, June 7-9, 1898	Samuel Insull
22nd	New York, May 23-25, 1899	Alden M. Young
23rd	Chicago, May 22-24, 1900	Samuel T. Carnes
24th	Niagara Falls, May 21-23, 1901	James Blake Cahoon
25th	Cincinnati, May 20-22, 1902	Henry L. Doherty
26th	Chicago, May 26-28, 1903	Louis A. Ferguson
27th	Boston, May 24-26, 1904	Charles L. Edgar
28th	Denver-Colorado Springs, June 6-11, 1905	Ernest H. Davis
29th	Atlantic City, June 5-8, 1906	William H. Blood, Jr.
30th	Washington, June 4-8, 1907	Arthur Williams
31st	Chicago, May 19-22, 1908	Dudley Farrand
32nd	Atlantic City, June 1-4, 1909	William C. L. Eglin
33rd	St. Louis, May 23-27, 1910	Frank W. Frueauff
34th	New York, May 29-June 2, 1911	W. W. Freeman
35th	Seattle, June 10-14, 1912	John F. Gilchrist
36th	Chicago, June 2-6, 1913	Frank M. Tait
37th	Philadelphia, June 1-5, 1914	Joseph B. McCall
38th	San Francisco, June 7-11, 1915	Holton H. Scott
39th	Chicago, May 22-26, 1916	Edward W. Lloyd
40th	New York City, May 9-10, 1917	Herbert A. Wagner
41st	Atlantic City, June 13-14, 1918	John W. Lieb
42nd	Atlantic City, May 19-22, 1919	Walter F. Wells
43rd	Pasadena, May 18-22, 1920	R. H. Ballard
44th	Chicago, May 31-June 3, 1921	Martin J. Insull
45th	Atlantic City, May 15-19, 1922	Milan R. Bump
46th	New York, June 4-8, 1923	Frank W. Smith
47th	Atlantic City, May 19-23, 1924	Walter H. Johnson
48th	San Francisco, June 15-19, 1925	Franklin T. Griffith
49th	Atlantic City, May 17-21, 1926	James E. Davidson
50th	Atlantic City, June 6-10, 1927	R. F. Pack
51st	Atlantic City, June 4-8, 1928	H. T. Sands
52nd	Atlantic City, June 3-7, 1929	P. S. Arkwright

APPENDIX 8

NUMBERING OF PROCEEDINGS

To facilitate the filing of sets of the Proceedings of the Association, numbers have been assigned to all volumes issued since the inception of the Association in 1885. This will also greatly facilitate reference and citation to the various volumes. Future indexes will refer to the volumes by these numbers

In addition to the PROCEEDINGS there are the following:
Index to PROCEEDINGS, Conventions 1-32, 1885-1909, 243 pages.
Index to PROCEEDINGS, Conventions 32-36, 1909-1913, 272 pages.

New Number	Convention	Year	New Number	Convention	Year
Vol. 1	1st, 2nd and 3rd	1885-86	Vol. 44	35th—Vol. 3	1912
2	4th and 5th	1886-87	45	35th—Vol. 4	1912
3	6th and 7th	1887-88	46	36th—General	1913
4	8th	1888	47	36th—Accounting	1913
5	9th	1889	48	36th—Commercial	1913
6	10th	1889	49	36th—Technical	1913
7	11th	1890	50	37th—General	1914
8	12th	1890	51	37th—Accounting	1914
9	13th	1891	52	37th—Commercial	1914
10	14th	1891	53	37th—Technical	1914
11	15th	1892	54	38th—General	1915
12	16th	1893	55	38th—Accounting	1915
13	17th	1894	56	38th—Commercial	1915
14	18th	1895	57	38th—Technical	1915
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